Reproducing Opportunistic Connectivity Traces Using Connectivity Models

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Opportunistic networking is a new communication paradigm which explores the potential of inter-device contacts due to human mobility [3,5]. Intermittent connectivity, non existence of an end-to-end path between nodes and extreme dynamism in topological structure are inherent characteristics of opportunistic networking [2, 5]. In opportunistic networking devices make control and management decisions by themselves with locally available information. The unique differences that draw the line between opportunistic networking and other legacy networking environments call for newer approaches for systems development.

Distributing content in opportunistic networks is still at the level of experiments and case studies [4, 7]. Numerous opportunistic networking applications, such as Pocket Switched Networks (PSN) [3], are being developed, and it is necessary to develop frameworks for efficient content distribution. In order to do content distribution, we need to be able to evaluate the impact of the pattern of and the duration of radio contacts on the overall performance of the proposed system. Due to the cost and technical complexity involved in conducting large scale real world experiments, MANET community has been using mobility models to model node mobility in simulation based studies. Research studies have revealed that device inter-contact time distributions exhibited in opportunistic networking contacts are very much different from what is generated by popular mobility models [2]. To test and validate any proposed new protocols and applications, tests have to be repeated by varying parameters to explore the behavioral changes of protocols and applications. As the network becomes larger with thousands of nodes, overheads in simulation based studies using mobility models become excessive.

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Our main objective is to reproduce opportunistic connectivity traces for the testing and validating of the large scale opportunistic content distribution systems. This not only includes analyzing the connectivity information among nodes but also includes analyzing the network for the repetitiveness of contacts. In one of our previous works we have defined connectivity models to model relationships among mobile nodes in a simulated opportunistic communication environment [6]. Please refer [6] for complete details of this model proposal. By running simulation based studies using connectivity models, we can extract the contact time and inter contact time values. These values enable us to investigate the capability of the considered opportunistic network in supporting content distribution.

In our model we have included a parameter called K to represent the number of clusters. If we take typical opportunistic contact traces from field tests and analyze them for contact patterns, we can observe that there exist contacts that are more frequent than others. The nodes that make the most frequent contacts establish their contacts in the form of clusters. When we start including contacts in decreasing order of frequency of contacts we can see that the shape of clusters changing and there are more and more intra-cluster and inter-cluster contacts. The concept of clusters of contacts enable us to look at the strength of contacts between nodes and analyze the network's capability in future innovative large scale content distribution applications.

In this paper we present some of the preliminary results in reproducing opportunistic connectivity traces using the proposed connectivity models. In accordance to our proposed model from [6], the reproduction of synthetic connectivity traces using the connectivity model is done in two stages: In the first stage, decisions on the establishments of connections between any two nodes is made using a poisson distribution. This step determines the social relatedness P_R between any two nodes in the proposed model. In the second stage, connection duration between each pair of connected nodes is determined. That is, to determine whether two socially related nodes are connected at any given point of time by an edge e. This relates to P_C in the proposed model.

We have obtained the imote connectivity trace files (UC-Traces) from a field test conducted at the University of Cambridge [7]. The anonymized version of these traces could be downloaded from the CRAWDAD [1] web site. Identifying the exact distribution of node connectivity for establishing synthetic connectivity is the crucial part of this work. By means of statistical analysis we find appropriate parameters and values for PR and PC from the UC-traces. In this preliminary study we assume the value of 1 for the parameter K in our connectivity model. We also consider a node population N of 54 and run simulations for a period of 15 days to resemble the experiments in [7].

We extract the contact time and inter-contact time values from log files. In order to validate the reproduced traces (Synth-traces) against the field test traces [7], we do a comparative study mainly on the inter-contact time distributions. The complementary cumulative distributions graph of the inter-contact time values for both traces are plotted in Figure 1, and we can observe that both traces show a close match. We also see that both taces exhibit a power law based behavior as Chaintreau et al pointed out in [2]. In addition, we observe that the heavy tail starts decaying faster after a certain period of time. This could be an effect of the testing process. This effect has also been observed in other opportunistic connectivity traces [2].

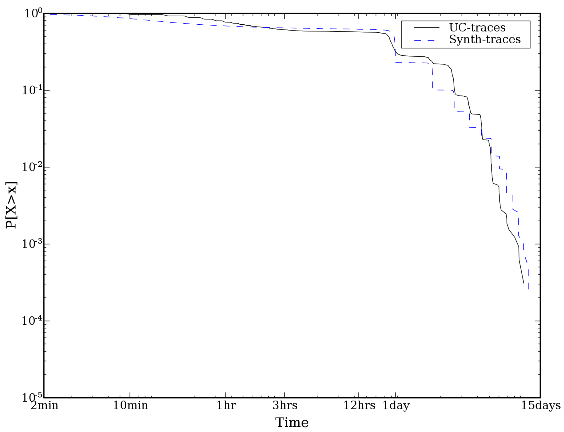

Figure 1: Inter-Contact time distributions of UC-traces and synthetically generated traces.

Calegari et al. [1], have recently proposed a tool called Connectivity Trace Generator for the automatic generation of the connectivity traces. Even though the proposed tool of [1] is also based on probabilistic distributions of contacts between node pairs, there are significant differences and advancements in reproducing traces in our approach. Our approach considers the whole network as a collection of clusters based on the repetitiveness of contacts between nodes. By varying the view at which we look at the network by means of repetitiveness of contacts, we will be able to look at the properties of the network such as which of the potential nodes could be used as backbone nodes, which of the nodes could be used as data carriers etc. In addition, we will also be able to reproduce traces at different levels of clustering and analyze the capability of the network in delivering content.

We plan to explore the properties of clusters in our continuing work. This will enable us to explore many potential research questions in opportunistic content distribution. One such question we like to explore is estimating the feasibility of treating a large scale opportunistic network as a persistent data store. In such a system the content of interest could persist in mobile devices and be shared opportunistically with other devices. Intermittent connectivity, high node mobility and frequent topological changes have a high impact on data survival in these networks. Data persistence will enable future development of applications that rely on opportunistic connections among devices, and will open up new avenues for novel content distribution technologies.

[1]Community Resource for Archiving Wireless Data At Dartmouth (CRAWDAD) http://crawdad.cs.dartmouth.edu

1. REFERENCES

[1] R. Calegari, M. Musolesi, F. Raimondi, and C. Mascolo. Ctg: A connectivity trace generator for testing the performance of opportunistic mobile systems. In *Proceedings of the ESEC and ACM SIGSOFT FSE07*, Dubrovnik, Croatia, September 2007. ACM Press.

[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 the IEEE INFOCOM 2006*, Barcelona, Spain, April 23-29 2006.

[3] P. Hui, A. Chaintreau, J. Scott, R. Gass, J. Crowcroft, and C. Diot. Pocket switched networks and human mobility in conference environments. In *Proceedings of the 2005 ACM SIGCOMM Workshop on Delay-Tolerant Networking (WDTN 05)*, pages 244–251, Philadelphia, USA, August 2005.

[4] P. Hui, J. Leguay, J. Crowcroft, J. Scott, T. Friedman, and V. Conan. Osmosis in pocket switched networks. In *Proceedings of the First International Conference on Communications and Networking*, Beijing, China, Oct 25-27 2006.

[5] T. Kathiravelu and A. Pears. What & when : Distributing content in opportunistic networks. In *Proceedings of the International Conference on Wireless and Mobile Computing (ICWMC 2006)*, Bucharest, Romania, July 2006.

[6] T. Kathiravelu, A. Pears, and N. Ranasinghe. Connectivity models : A new approach to modeling connectivity in opportunistic networks. In *Proceedings of the 8th international information technology Conference IITC2006*, Colombo, Sri Lanka, October 12-13 2006.

[7] J. Leguay, A. Lindgren, J. Scott, T. Friedman, and J. Crowcroft. Opportunistic content distribution in an urban setting. In *Proceedings of the ACM SIGCOMM 2006 - Workshop on Challenged Networks (CHANTS)*, Pisa, Italy, September 2006.