Connectivity Models for Mobile Networking

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Agenda

- Motivation
- Derivation of the connectivity model
- Connectivity Trace Generator
- Extraction of the input parameters from real traces
- Current research directions

Motivation

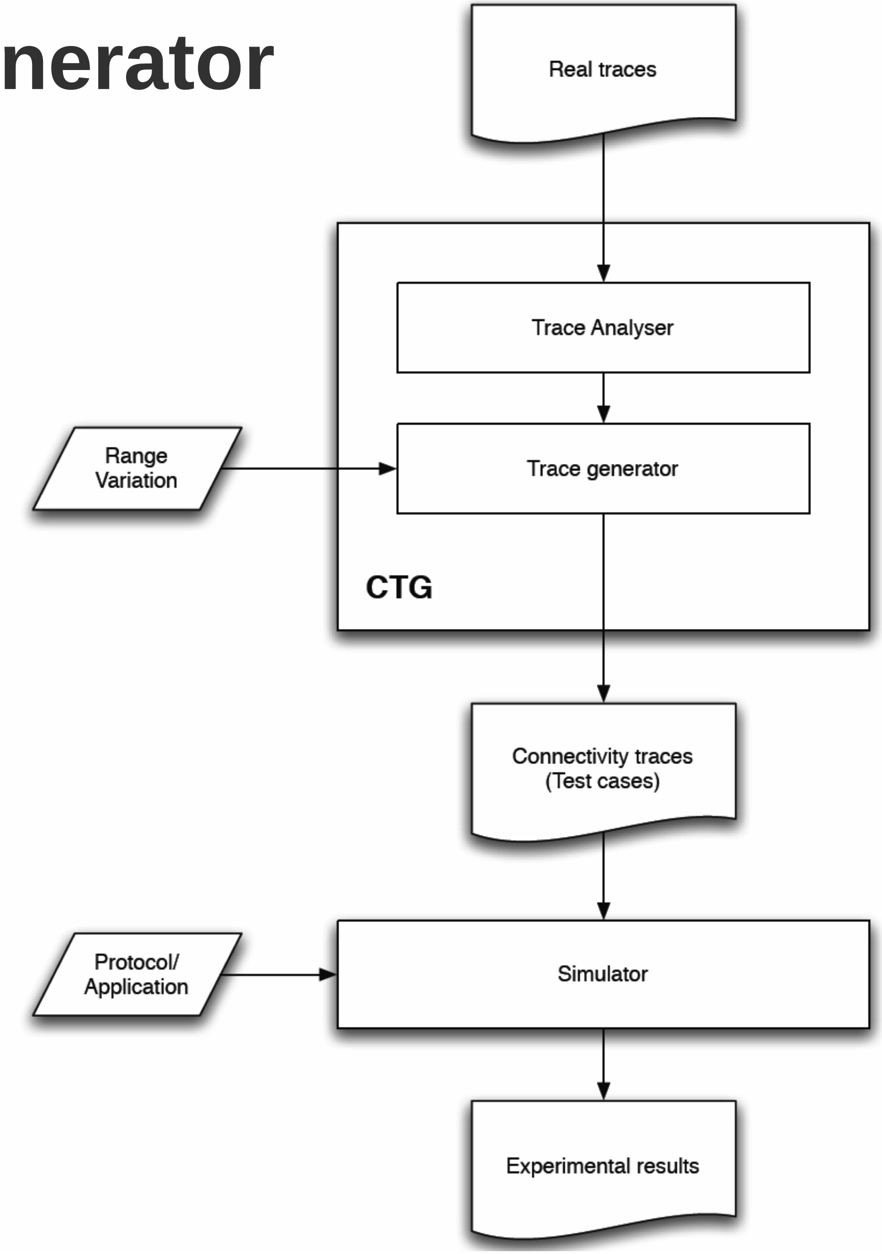
- Spatial models are important for many applications, but for studying connectivity models can be extremely useful
- Understanding connectivity patterns between humans is important for:
  - Design and testing of opportunistic communication protocols
  - Design and testing of peer-to-peer applications (file sharing, etc.) among mobile devices
  - Bandwidth provisioning
  - …

Related Work

- Study of WLAN connectivity (measurements) [Baker 2000, Balachandran et alii 2002, Balazinska 2003, Henderson et alii 2004]
- Human connectivity & Pocket Switched Networks [Chaintreau et alii 2006]
- Software engineering testing community [Rutherford et alii 2006, Wang et alii 2007]
- Emergence of power laws [Karagiannis et alii 2007]

Connectivity Trace Generator

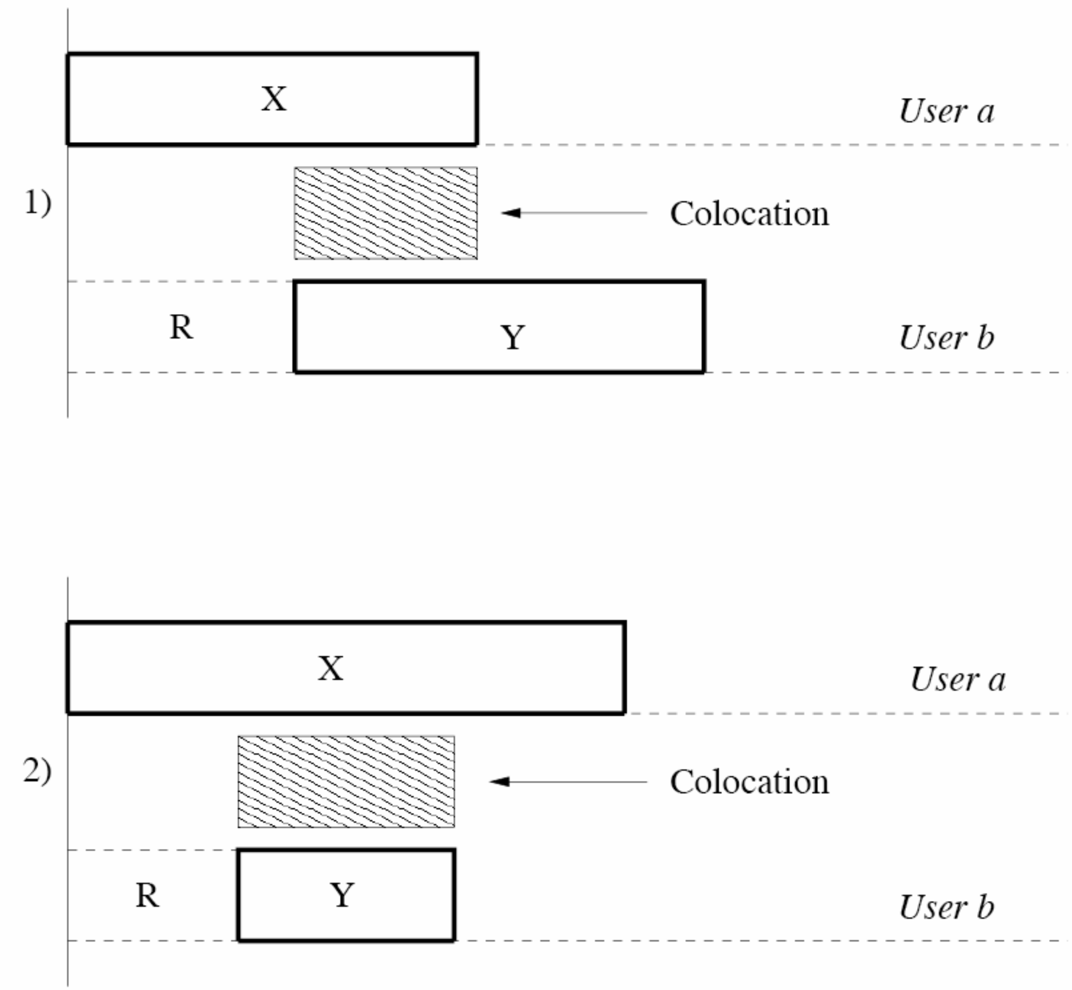
- Tool for generating connectivity traces starting from real traces
- Generates input for (any) simulators



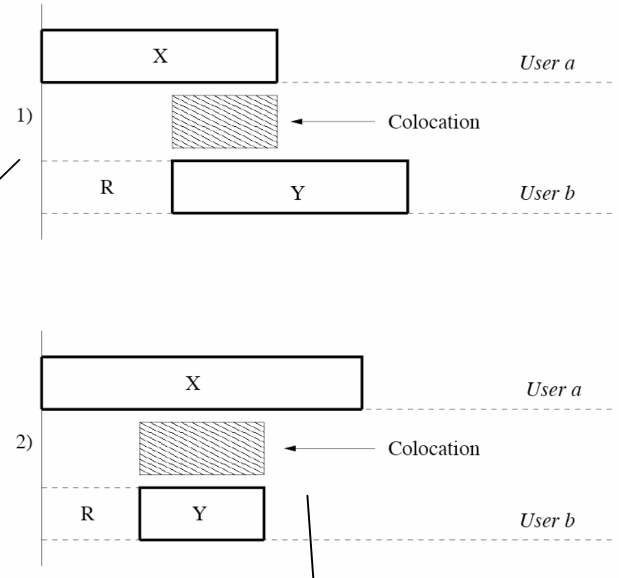
First Step: Deriving a Colocation Model

- Derivation of colocation patterns given residence time in a particular colocation of an individual
- Two assumptions to simplify the mathematical treatment of the problem in first instance:
  - Users’ behaviours are independent: the behaviours of a user does not depend on other users’ behaviours
  - Users’ behaviours are uniform: all users have the same behaviours

Understanding Connectivity



The Connectivity Model



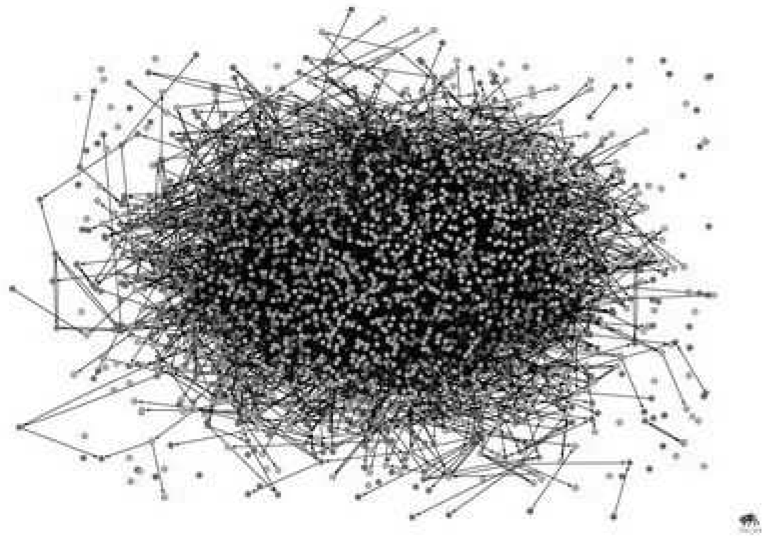
$$p_C(t) = p(Y > X - R)p_{X-R}(t) + p(Y \leq X - R)p_Y(t)$$

Generation of the Synthetic Connectivity Traces

- From the mathematical model of location we can extract the colocation distribution
- Either residence time or colocation patterns can be used
- Inputs of the tool are
  - Number of nodes
  - Graph of the potential contacts
  - Distribution of contacts time ($p_C(t)$)
  - Distribution of inter-contacts time ($p_{IC}(t)$)

Graph of the Potential Contacts (aka the underlying Social Network)

- Synthetic network characterised by a structure extracted from measurements
  - Reality Mining Data (MIT) -> Normal Distribution
  - Dartmouth College Campus -> Scale free
- …or a real one can be directly used
- Model allows for the variation of the structure of the network



Credit: Marta Gonzales

Contact Graphs

- The **Graph of the Potential Contacts** is the graph representing **all** the contacts that take place during the simulated interval
- From this graph we extract **the Instant Snapshot Contact Graph**, a time-varying graph of the links that are active at a certain time *t:*
  - A link is activated according to the distribution of the contacts time and the inter-contacts time
    - $p_C(t)$) is used to assign a duration to the ON time of each edge
    - $p_{IC}(t)$) is used to assign a duration to the OFF time of each edge

QuickTime™ and a
Animation decompressor
are needed to see this picture.

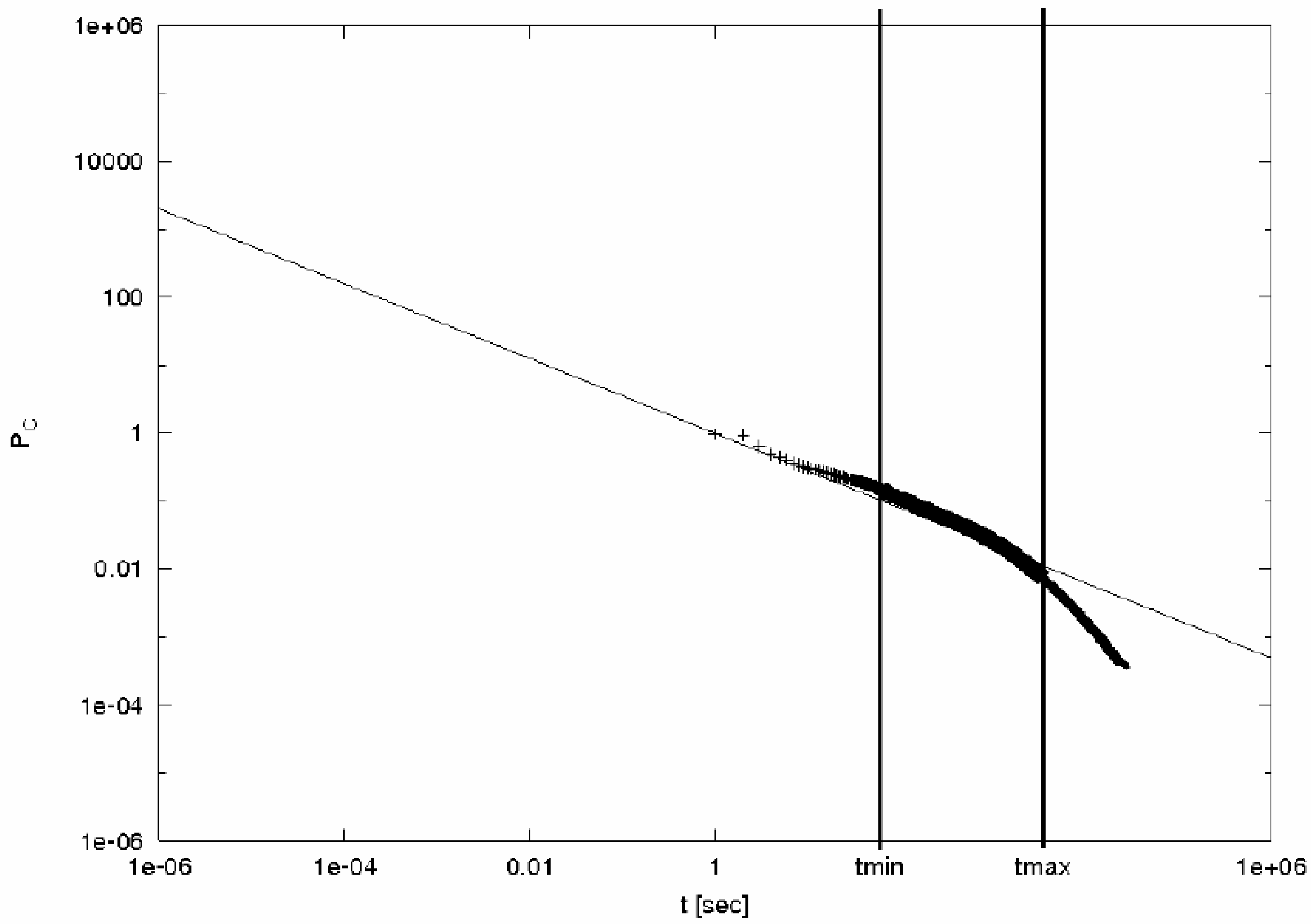
Synthetic traces from Reality Mining data

Credit: Dimitrios Moustakas

Case study: Parameters from the Dartmouth Traces

- Dataset from 01/04/2004 to 30/06/2004
- Measurements from APs in the Dartmouth College campus
- 13889 users
- 178 different locations
- Subset considered 19/04/2004 to 19/05/2004 (academic term) from 9am to 5pm

Distribution of Colocation Time in Academic Building 22

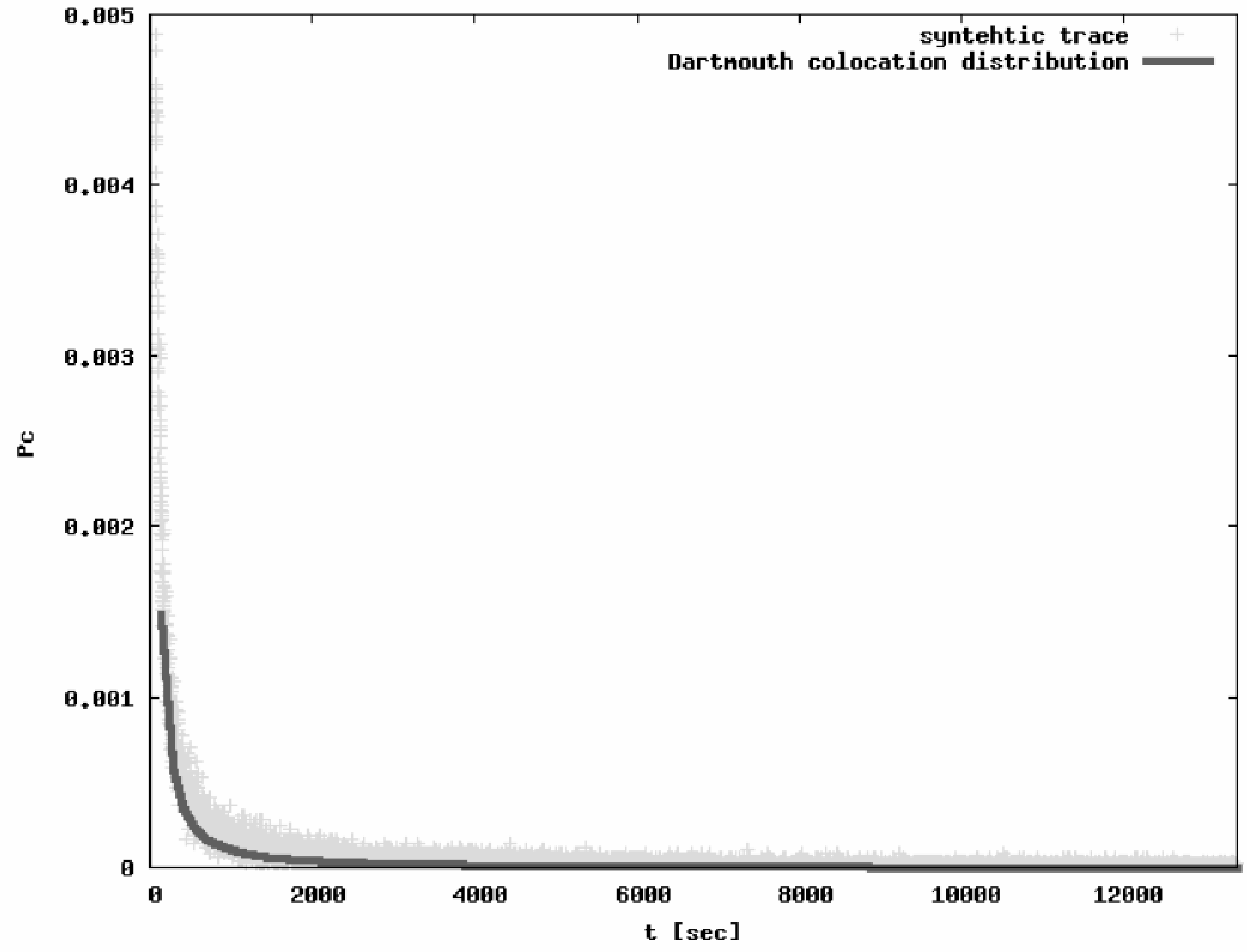


Distribution are Power Laws (in a Certain Range)

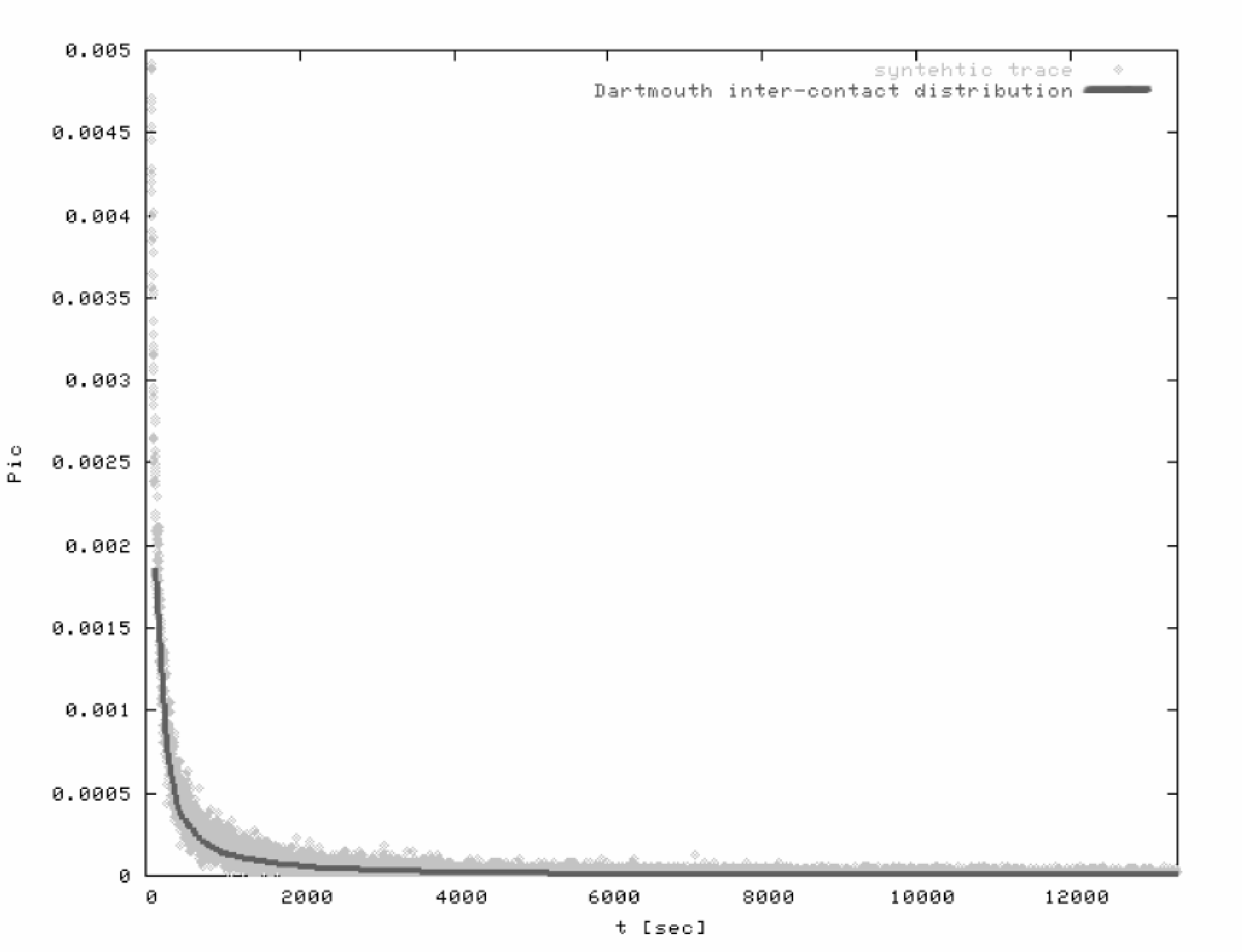
$$F(x)=x^{-K}$$

Location	$-k_X$	$-k_{IC}$	$-k_R$
Academic Building 22	-1.448	-1.745	-1.062
Residential Building 20	-1.303	-1.909	-1.047
All campus (averaged)	-1.281	-1.553	-1.064

Synthetic vs Real Traces: Contact Time



Synthetic vs Real Traces: Inter-contacts Time



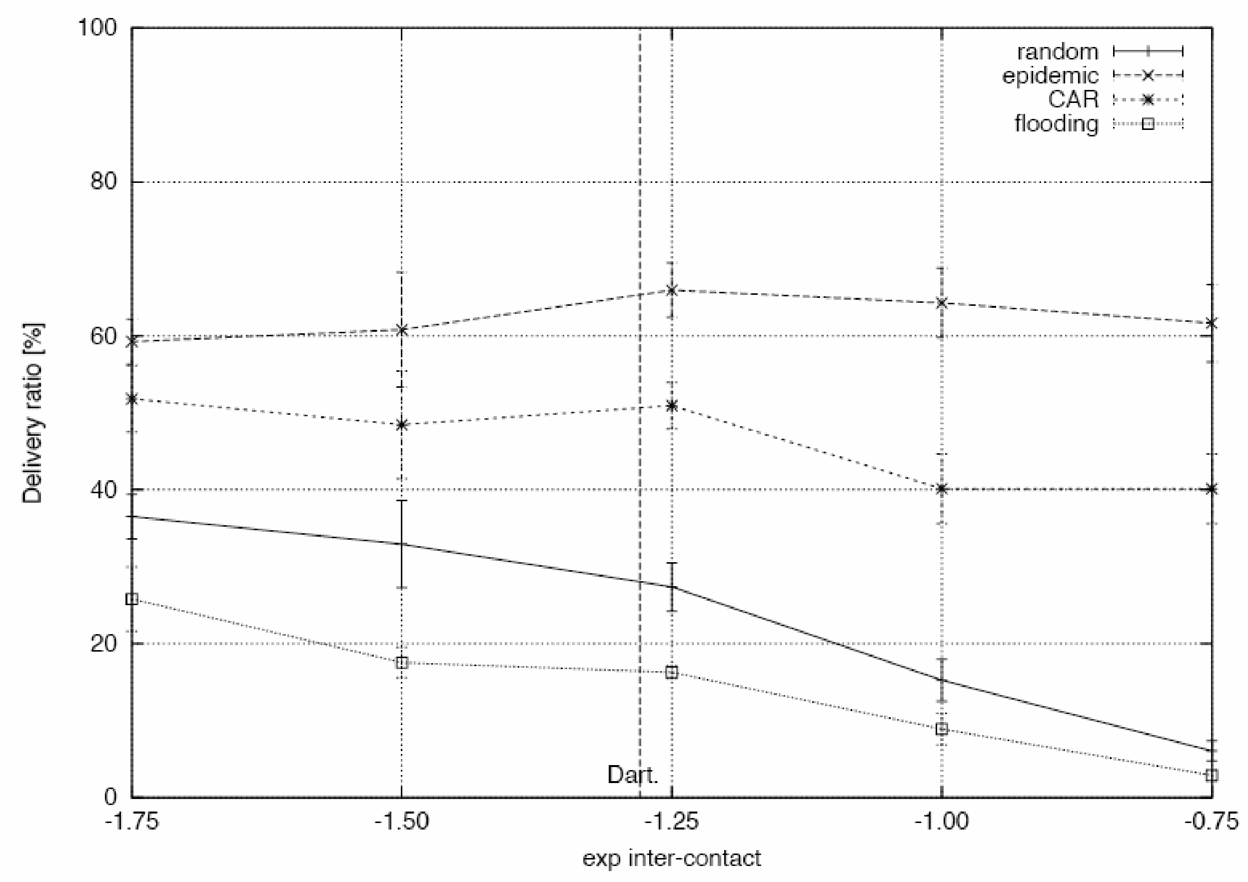
Protocol Performance Testing

- Four protocols:
  - Epidemic
  - Flooding (without store&forward)
  - Context-aware Adaptive Routing (CAR)
  - Random Walk
- 200 nodes
- 1000 messages in 8 simulated hours
- Default parameters taken from Dartmouth traces distribution

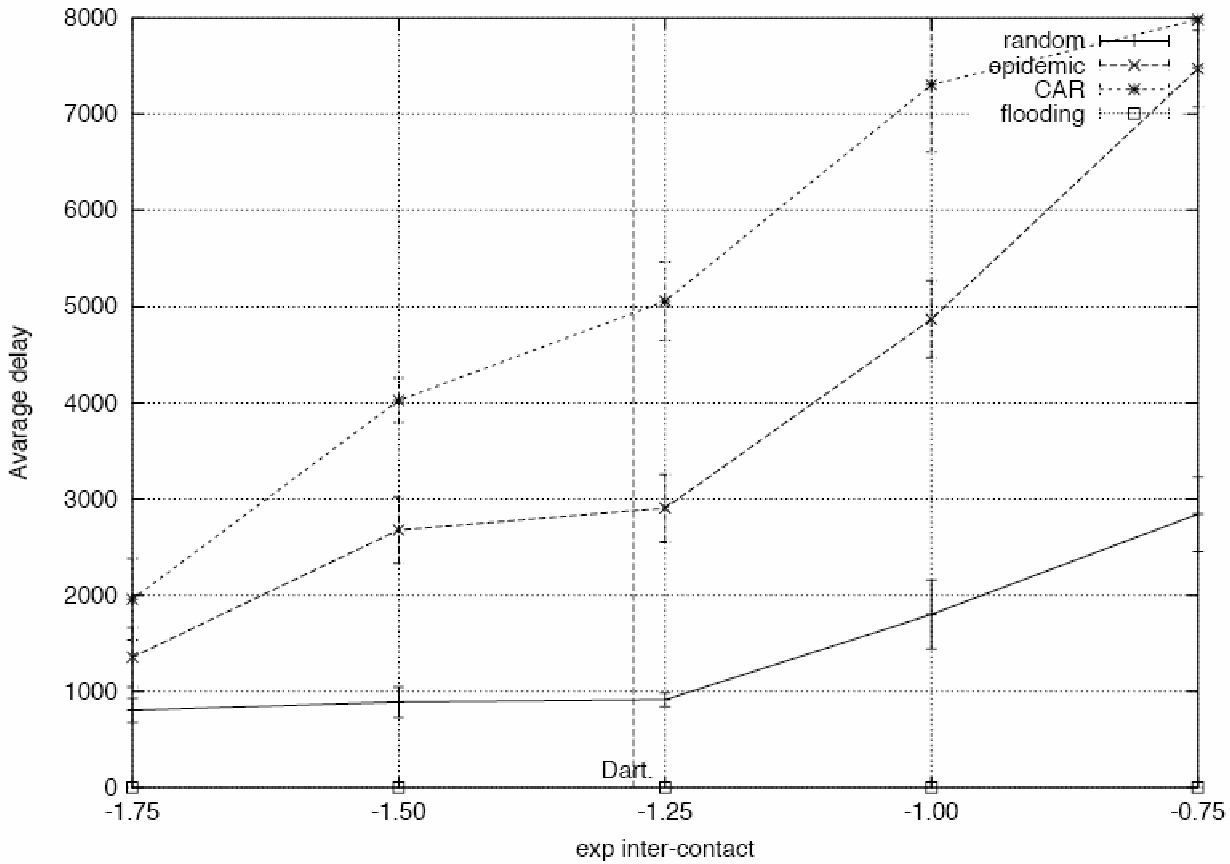
Performance of the Protocols with Dartmouth Traces

	Flooding	Epidemic	CAR	Random
Delivery	18.76%	62.7%	49.95 %	28.52 %
Delay [s]	2636.20	2636.30	4192.15	954.77
Overhead	3276463	397153	150516	158658

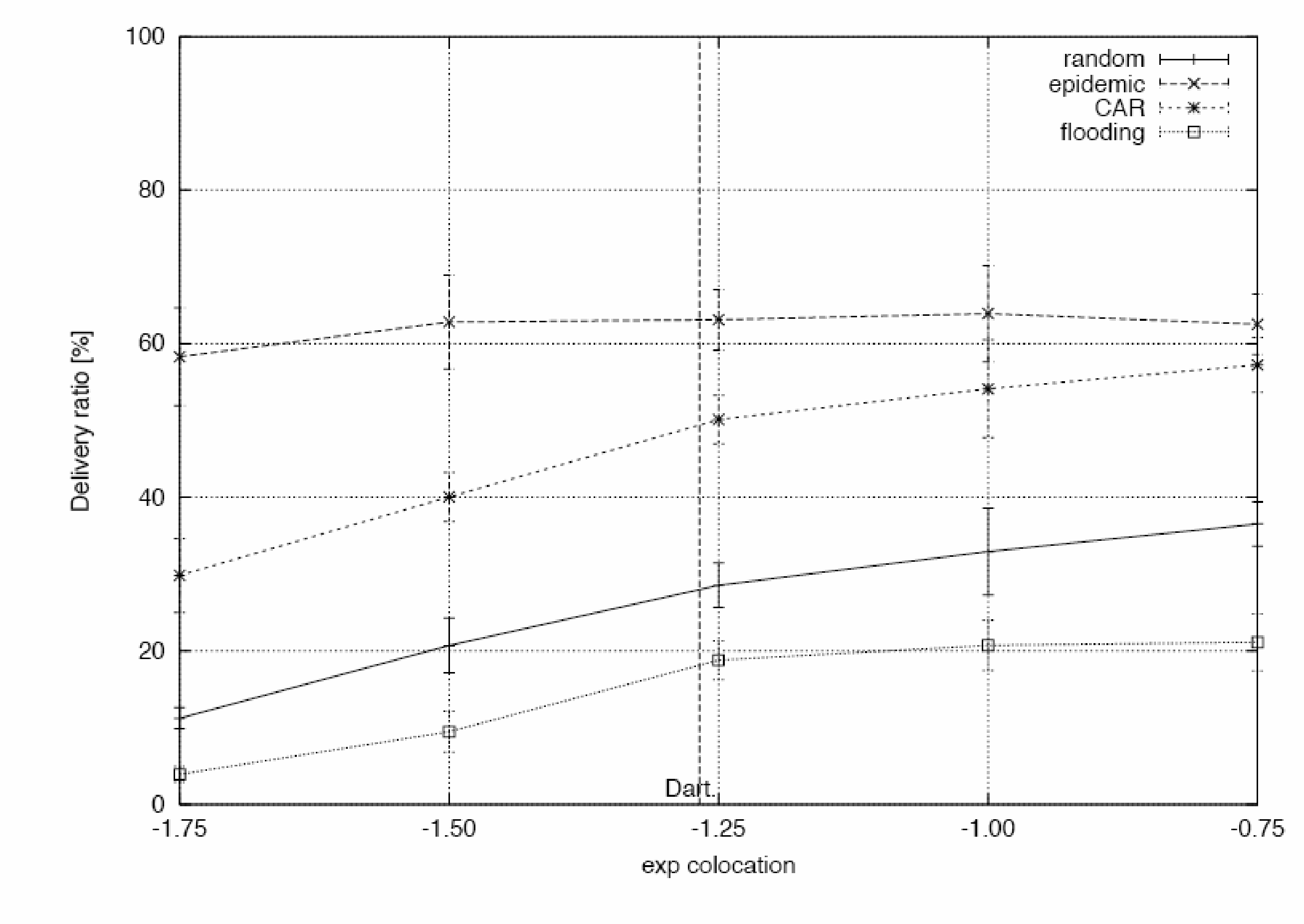
Impact of Inter-contacts Time Distribution: Delivery Ratio vs Inter-contacts time Exponent



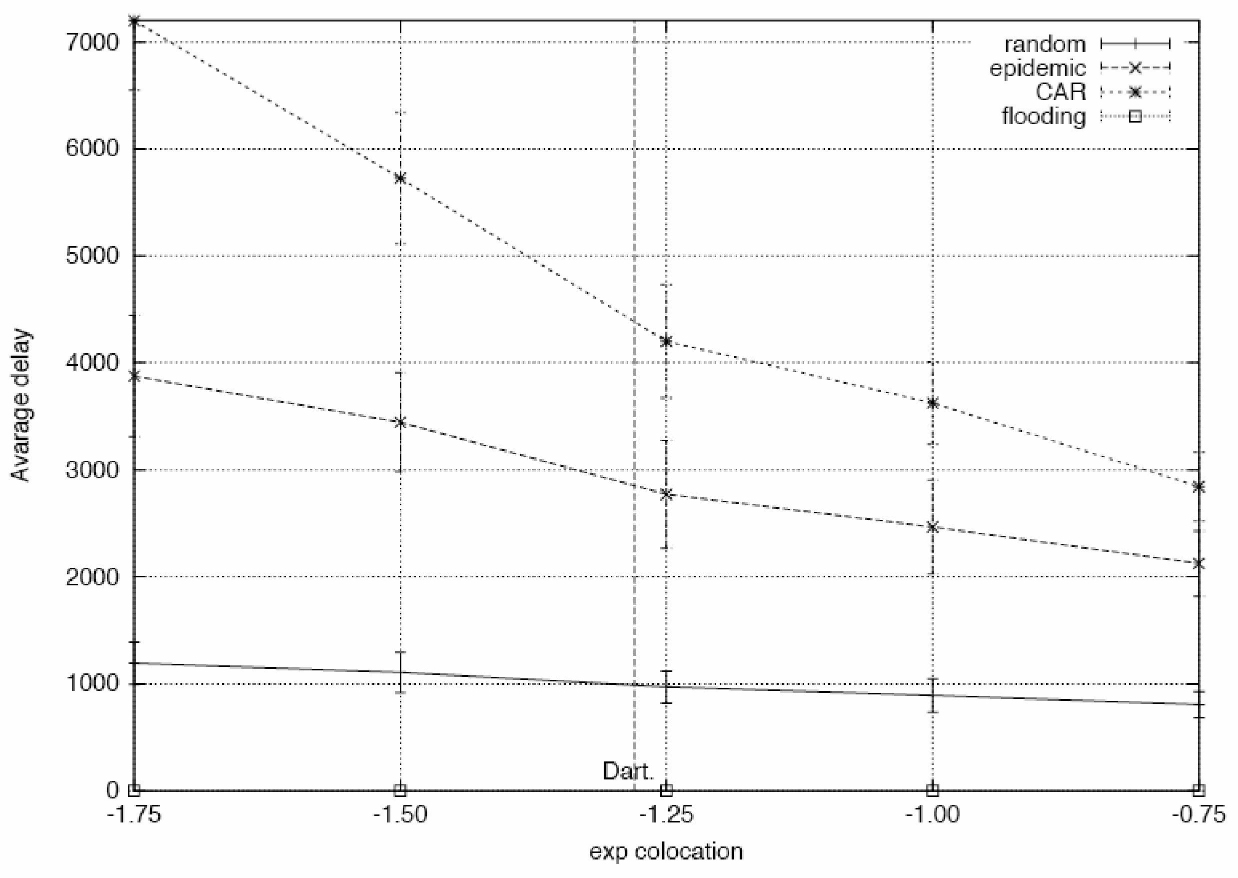
Impact of Inter-contacts Time Distribution: Average Delay vs Inter-contacts Time Exponent



Impact of Colocation Distribution: Delivery Ratio vs Colocation Exponent



Impact of Colocation Distribution: Average Delay vs Colocation Exponent



Current Research Directions

- Improvement of the current model
  - Relaxation of the assumption that users' behaviours are independent
  - Relaxation of the assumption that users' behaviours are uniform
  - Clustering
- Study of the emergence of power-laws distributions in human connectivity patterns
- Socially-aware traffic model

Questions?

Roberta Calegari, Mirco Musolesi, Franco Raimondi and Cecilia Mascolo. *CTG: A Connectivity Trace Generator for Testing the Performance of Opportunistic Mobile Systems* Proceedings of ACM/IEEE ESEC/FSE. September 2007

Roberta Calegari, Mirco Musolesi, Franco Raimondi and Cecilia Mascolo. *A Human Connectivity Model for Opportunistic Mobile Systems.* Submitted for Publication.

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