Brief Encounter Networks

Vassilis Kostakos

Oxford University, 16 October 2007

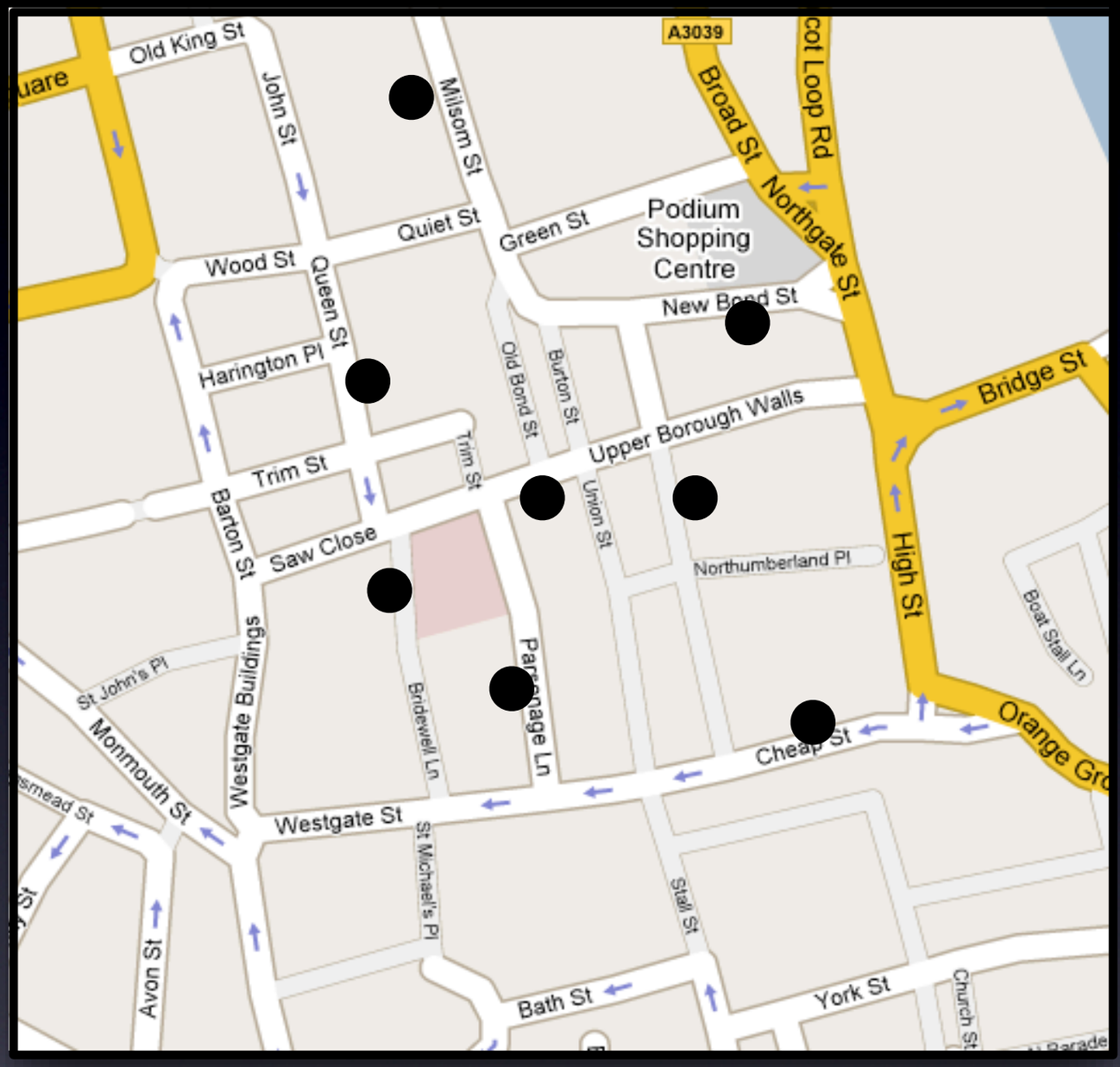
Motivation

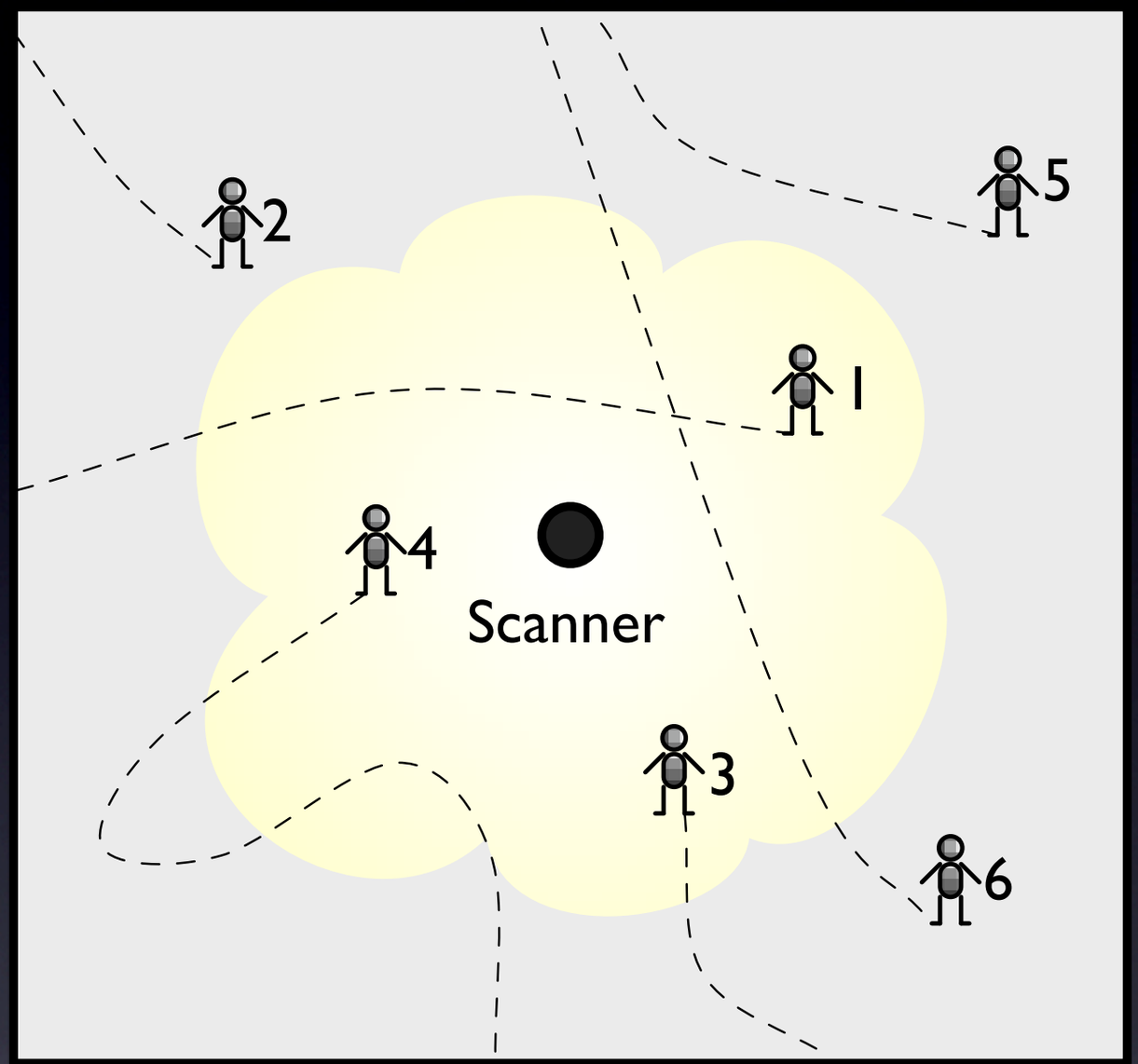
- Understand the “affordances” of people’s mobility, and
- identify opportunities for pervasive systems

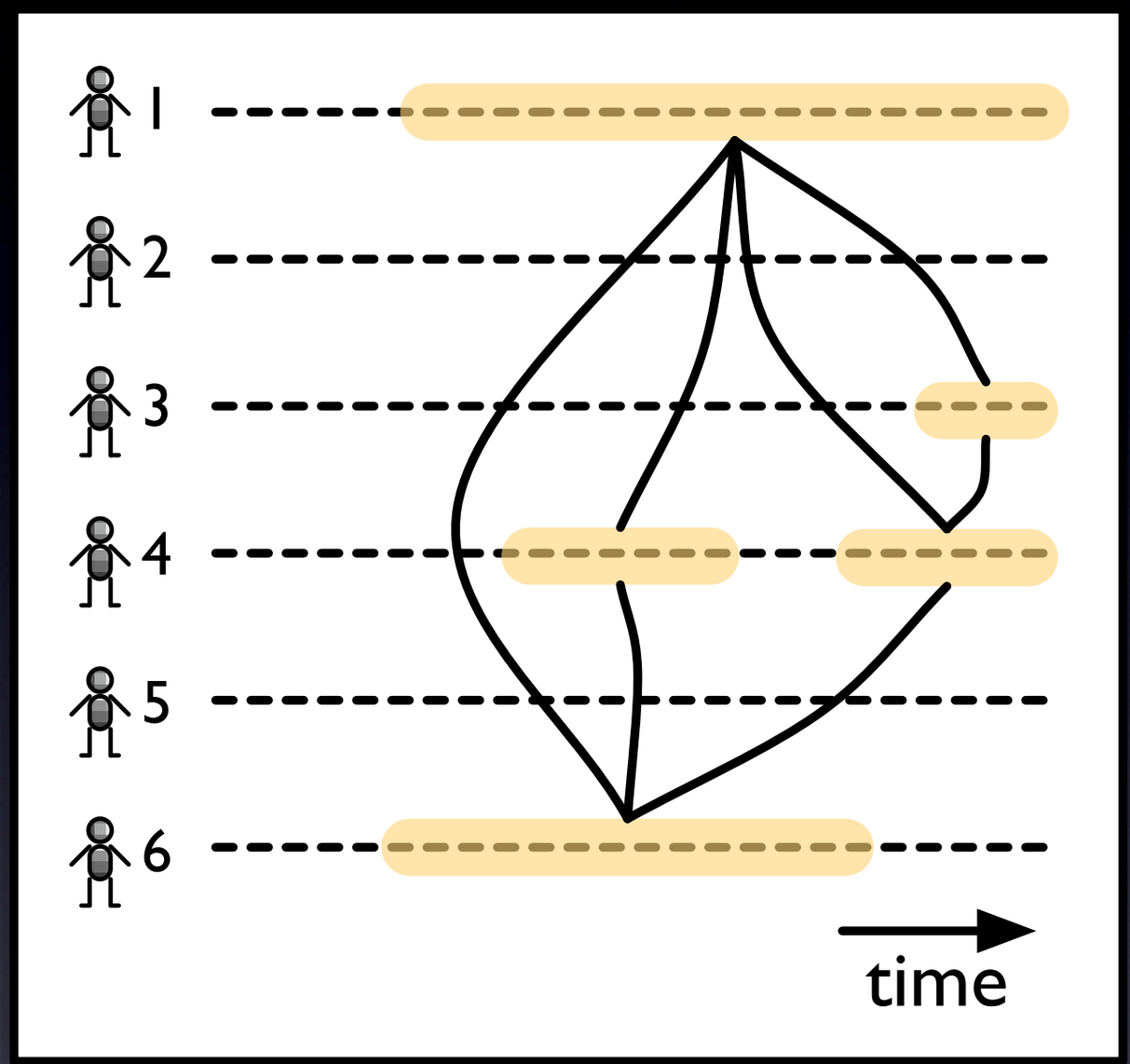
Overview

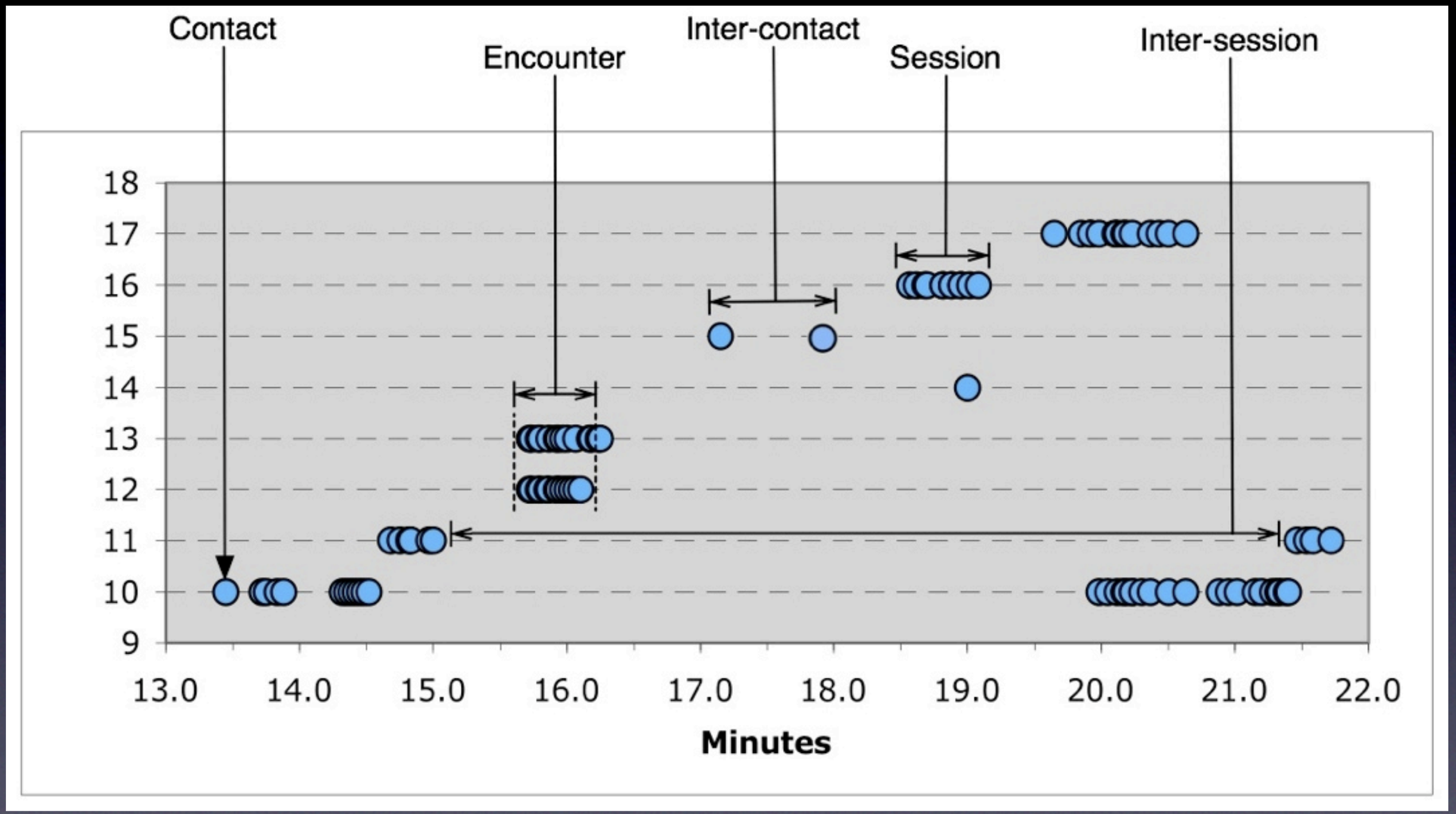
- Data collection
- Structural properties
- Dynamic properties
- Diffusion
- Ongoing work

Data collection

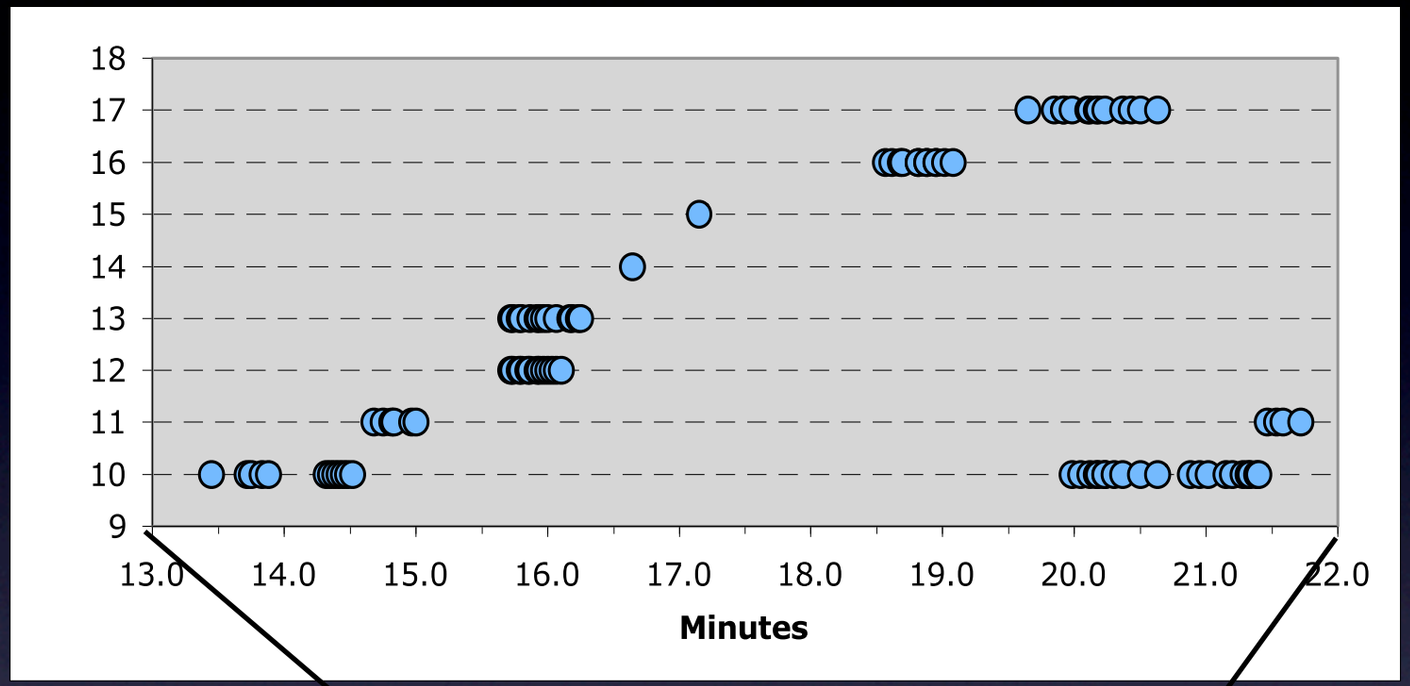

A3039
Old King St
John St
Milsom St
Broad St
Northgate St
cot Loop Rd
Quiet St
Green St
Podium
Shopping
Centre
Wood St
Queen St
New Bond St
Harington Pl
Old Bond St
Burton St
Bridge St
Upper Borough Walls
Trim St
Trim St
Barton St
Saw Close
Union St
Northumberland Pl
High St
Boat Stall Ln
St John's Pl
Westgate Buildings
Bridewell Ln
Parsonage Ln
Monmouth St
Cheap St
Westgate St
St Michael's Pl
Stall St
Avon St
Bath St
York St
Church St

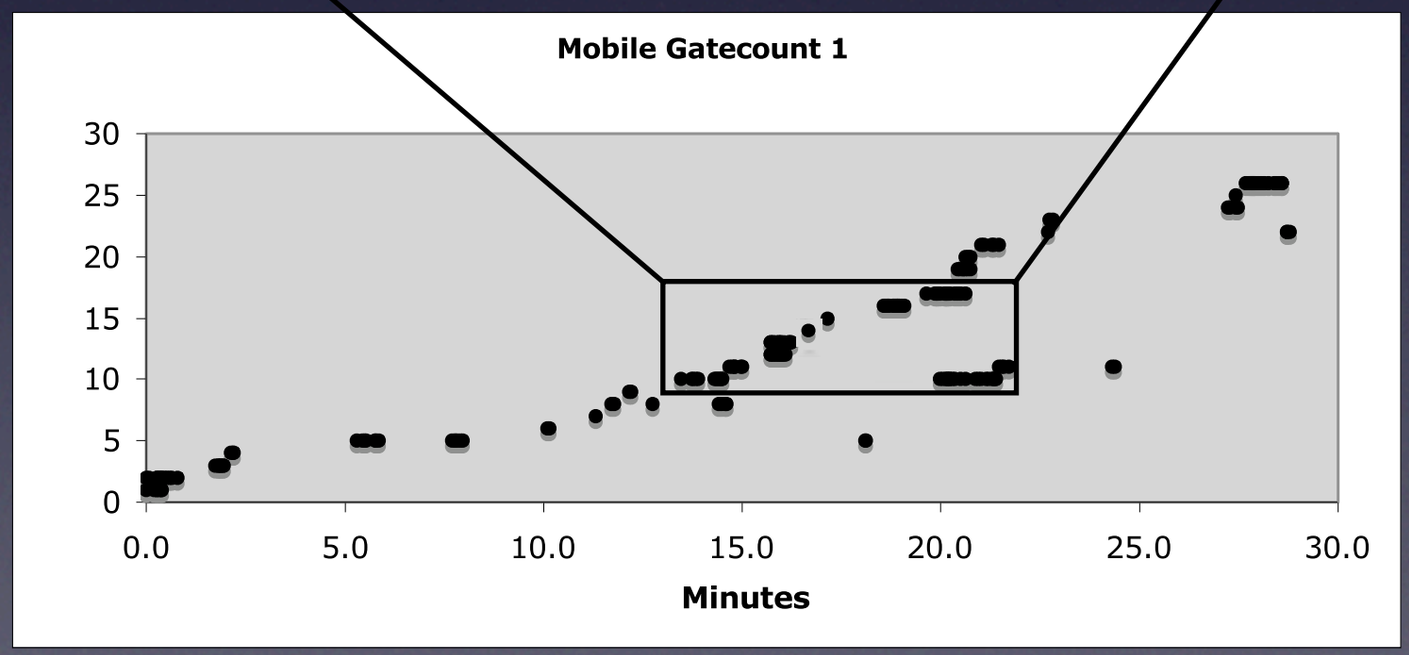

2
5
1
4
Scanner
3
6


1
2
3
4
5
6
time

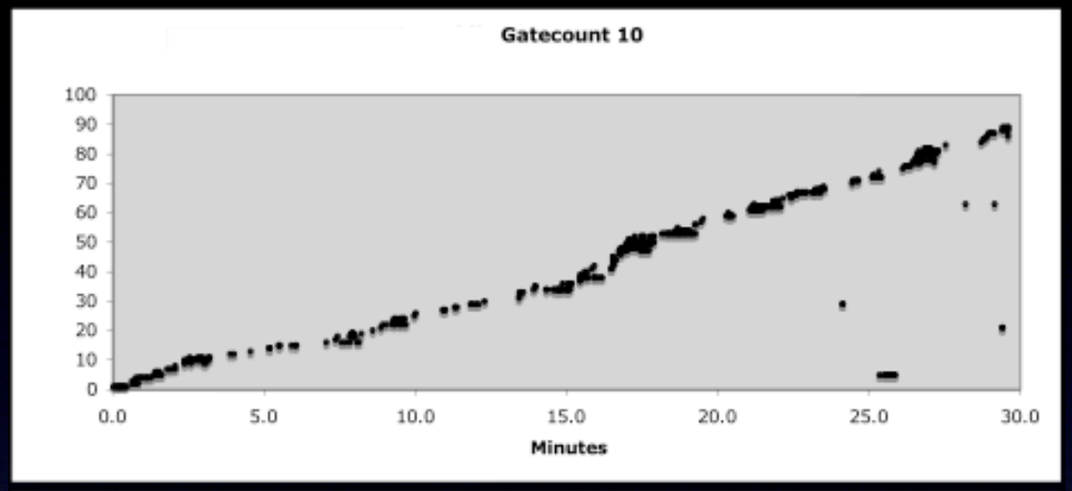

Contact
Encounter
Inter-contact
Session
Inter-session
18
17
16
15
14
13
12
11
10
9
13.0
14.0
15.0
16.0
17.0
18.0
19.0
20.0
21.0
22.0
Minutes

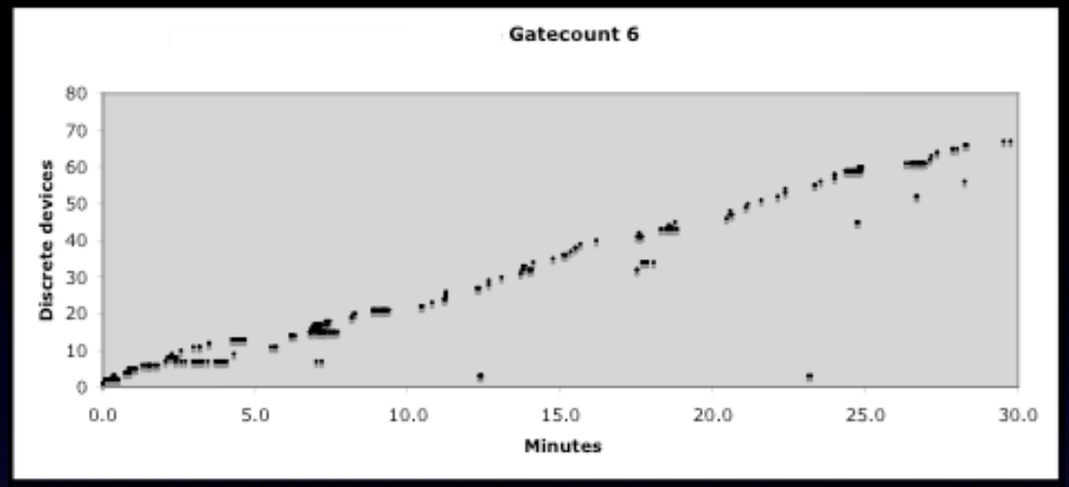
Timeline view

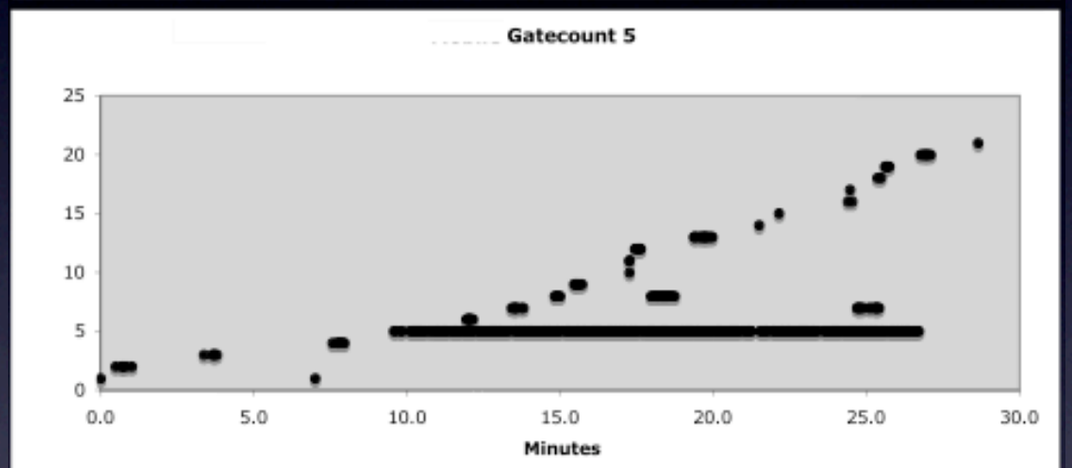


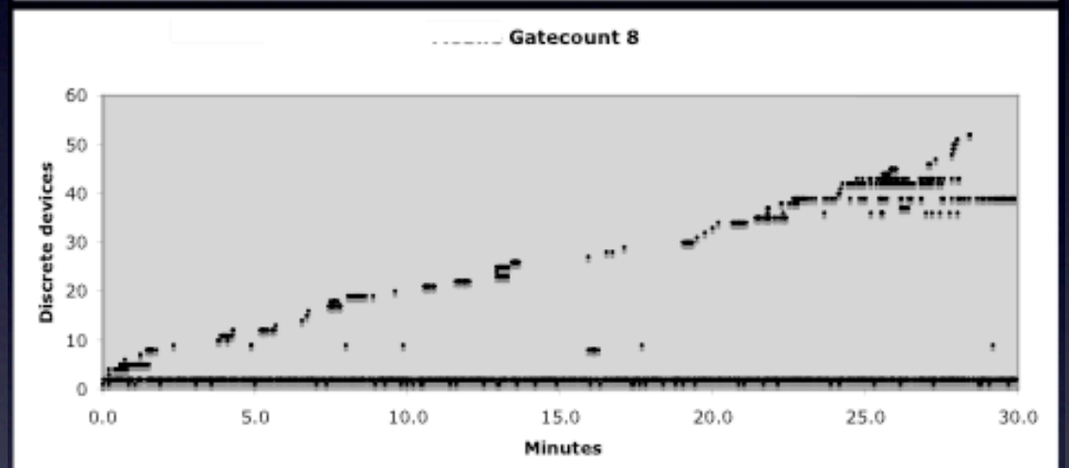


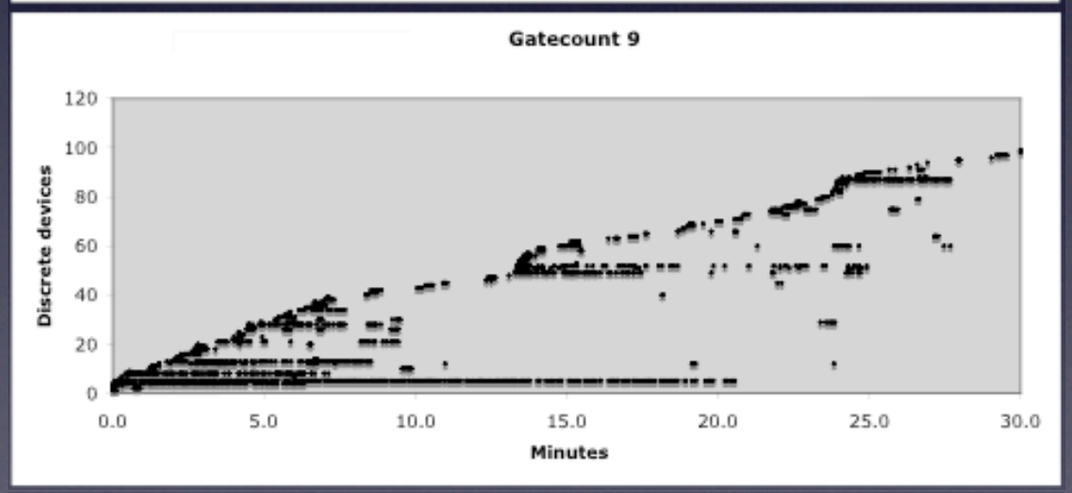
Gatecount timelines

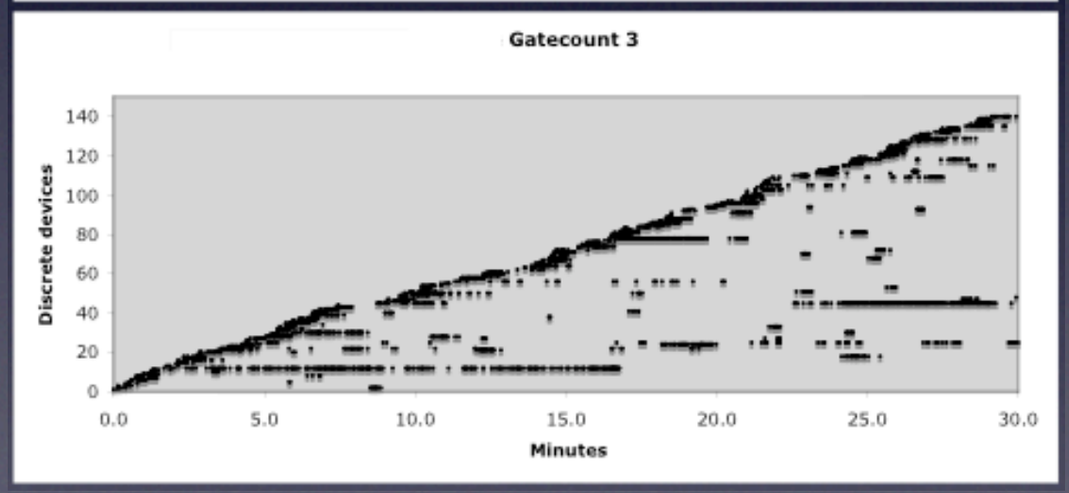








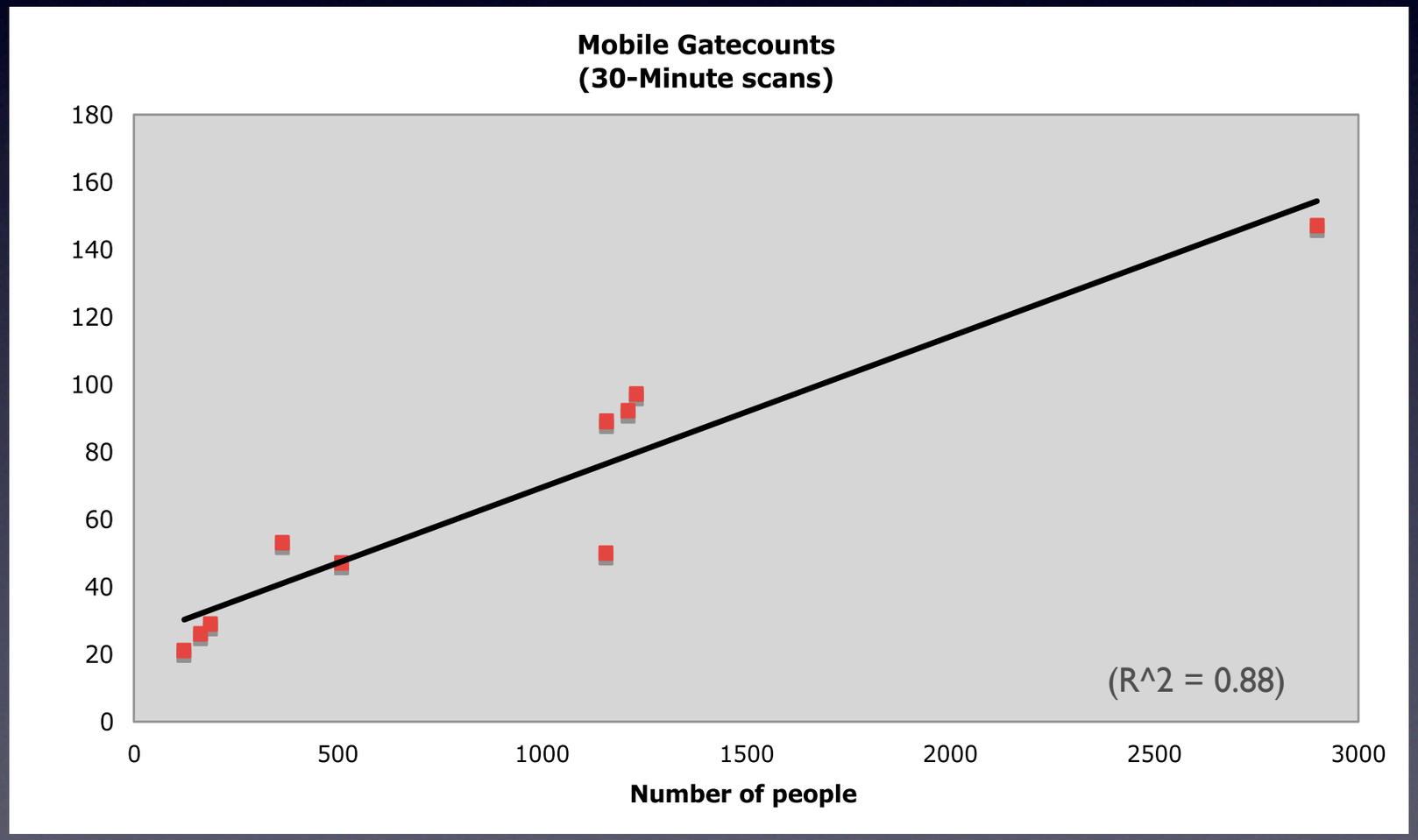




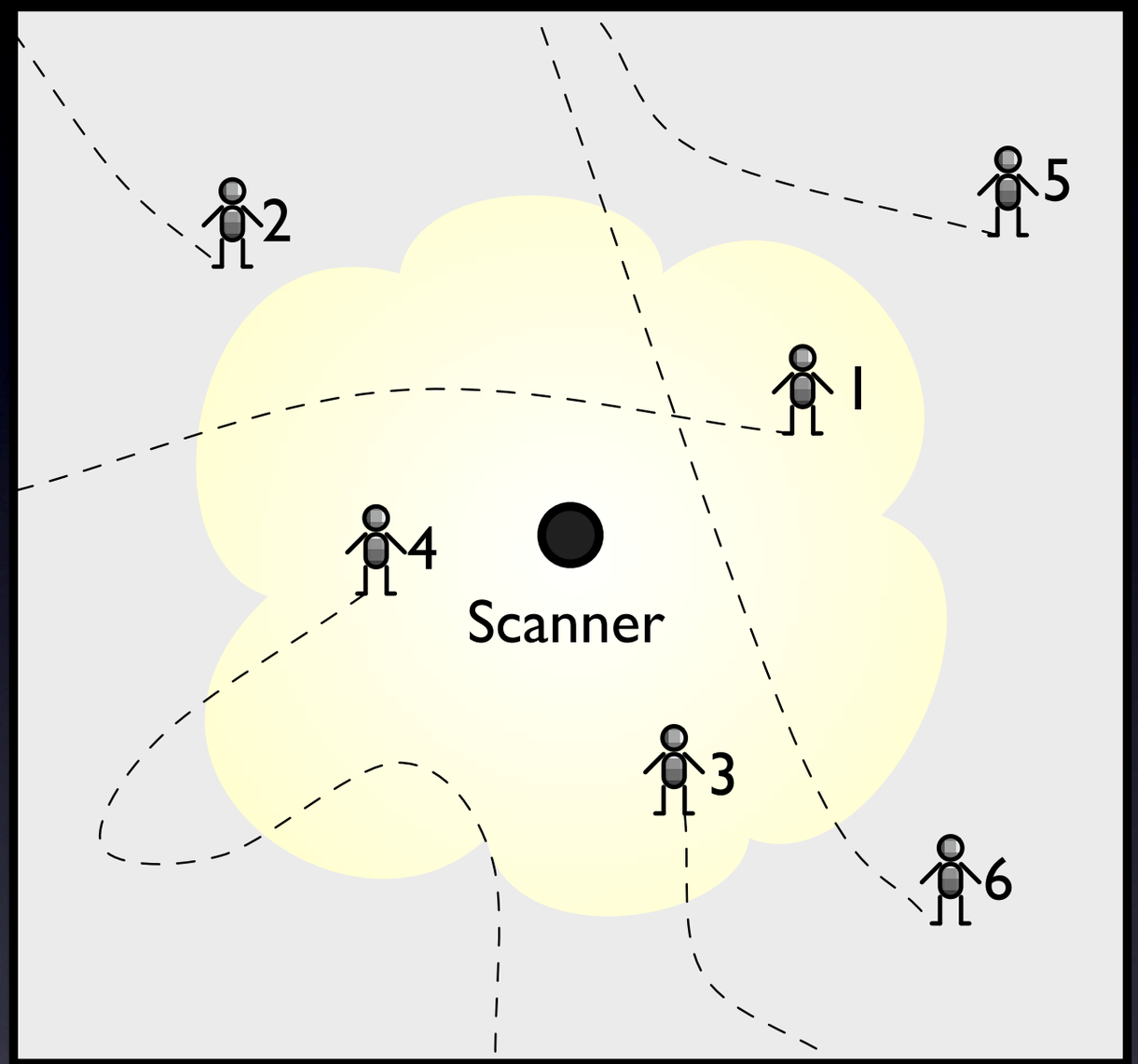
Gatecounts

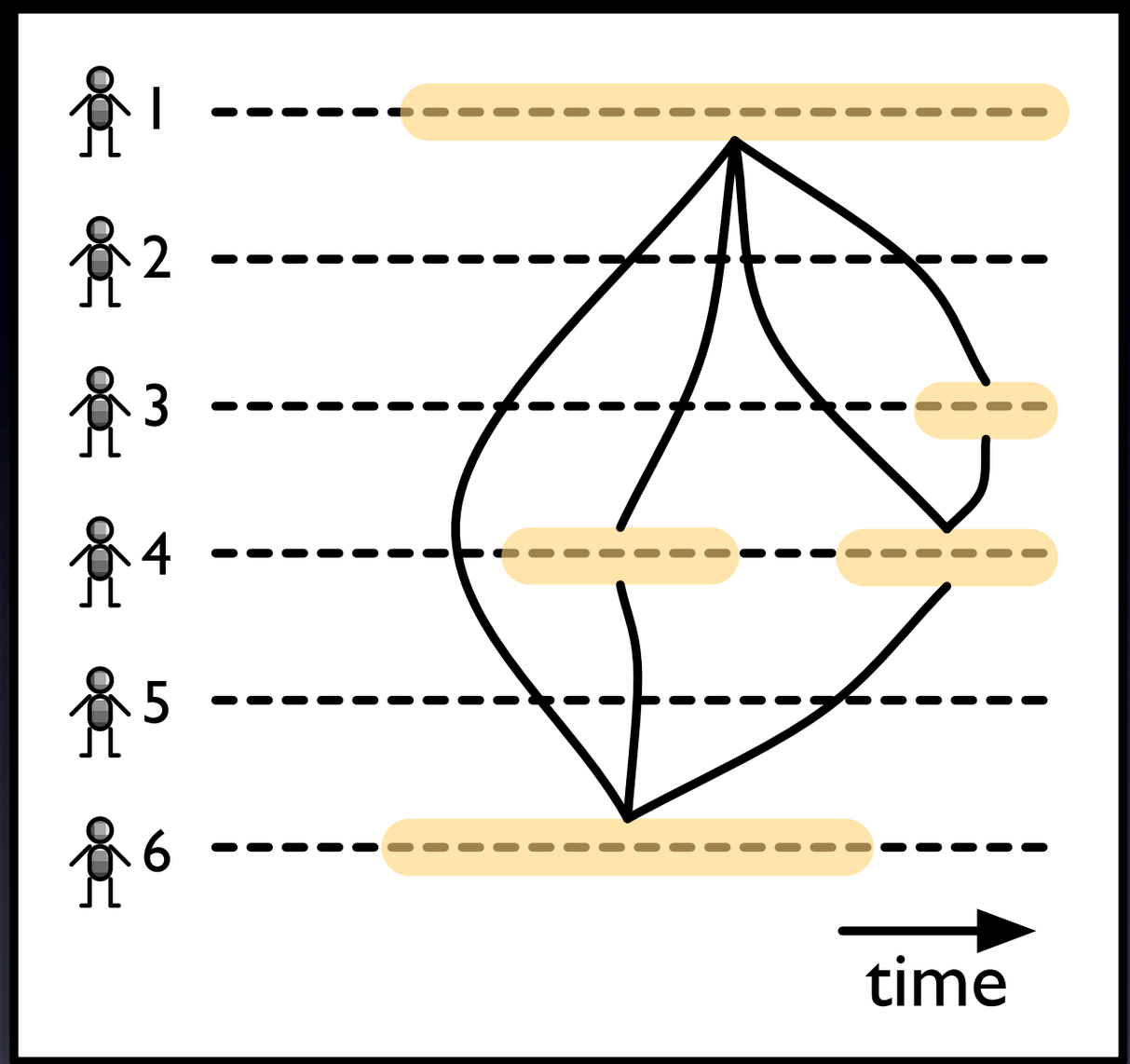
Bluetooth visibility

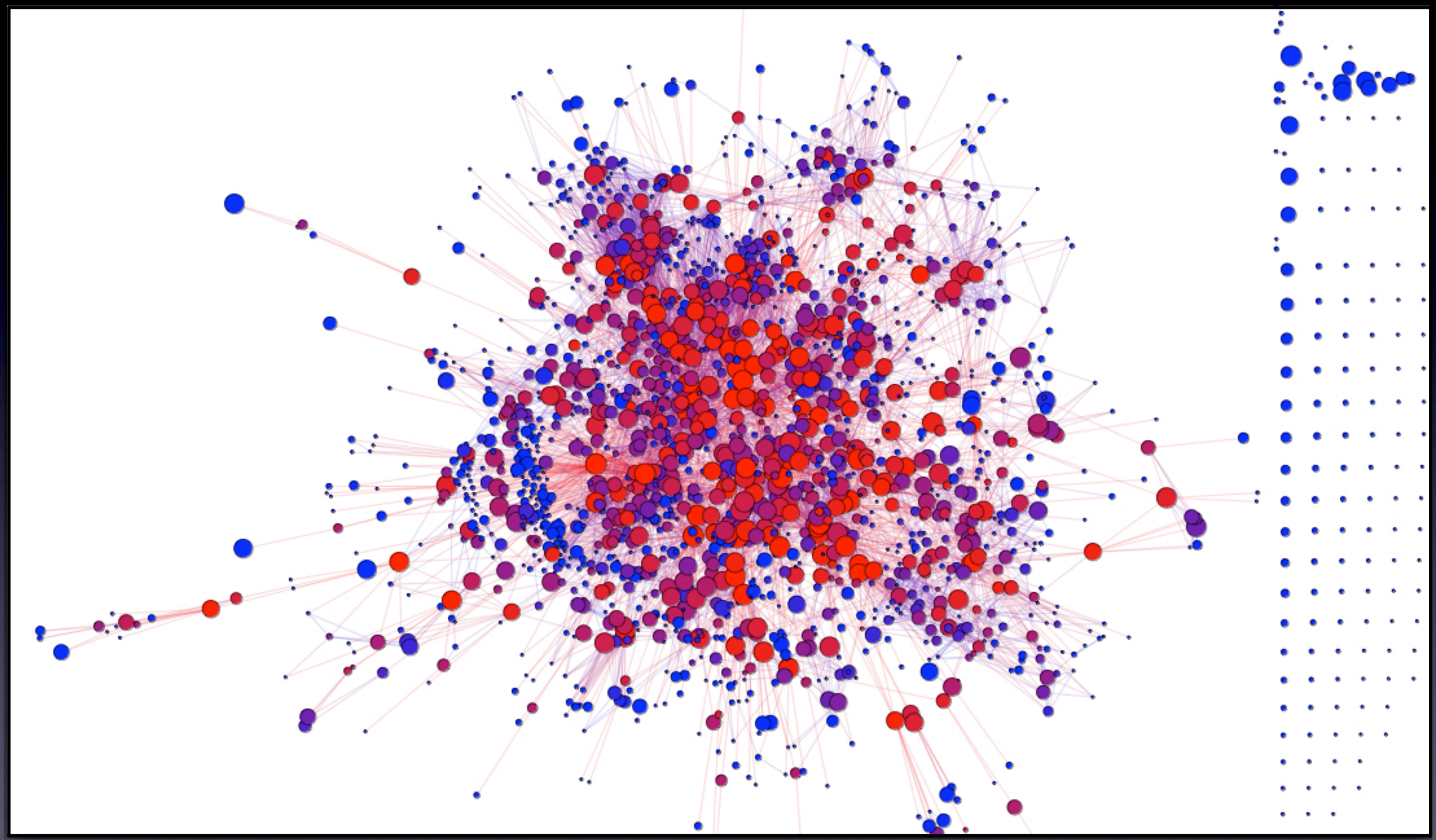
- Around 7.5% of observed pedestrians had discoverable Bluetooth devices



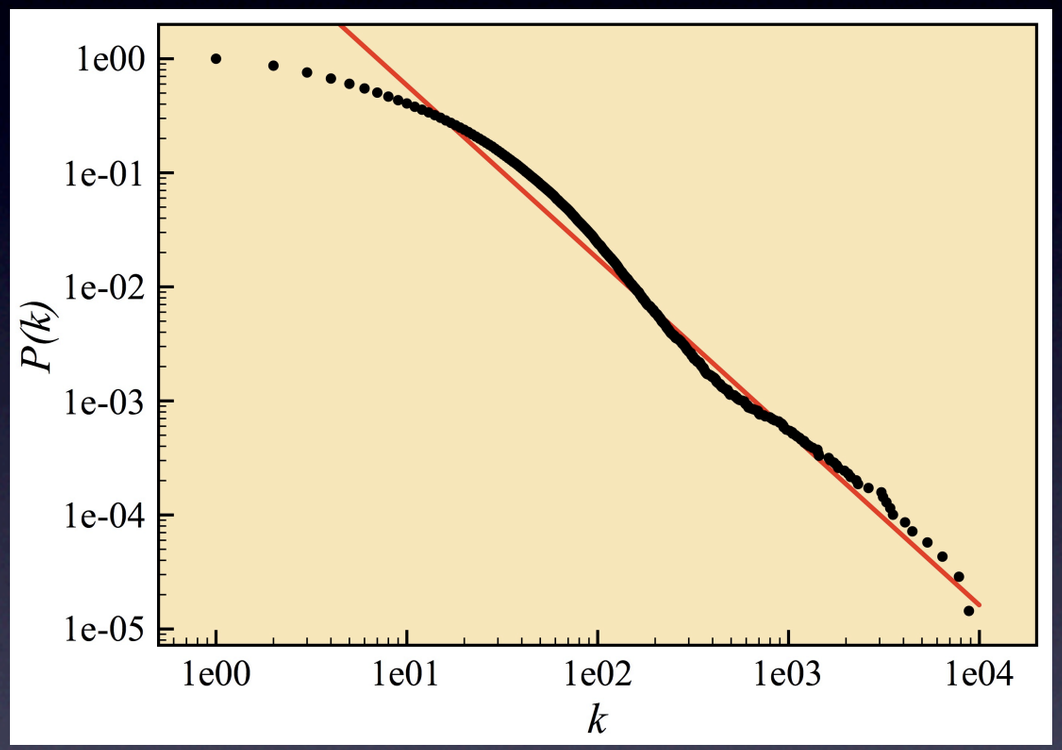
Structural properties

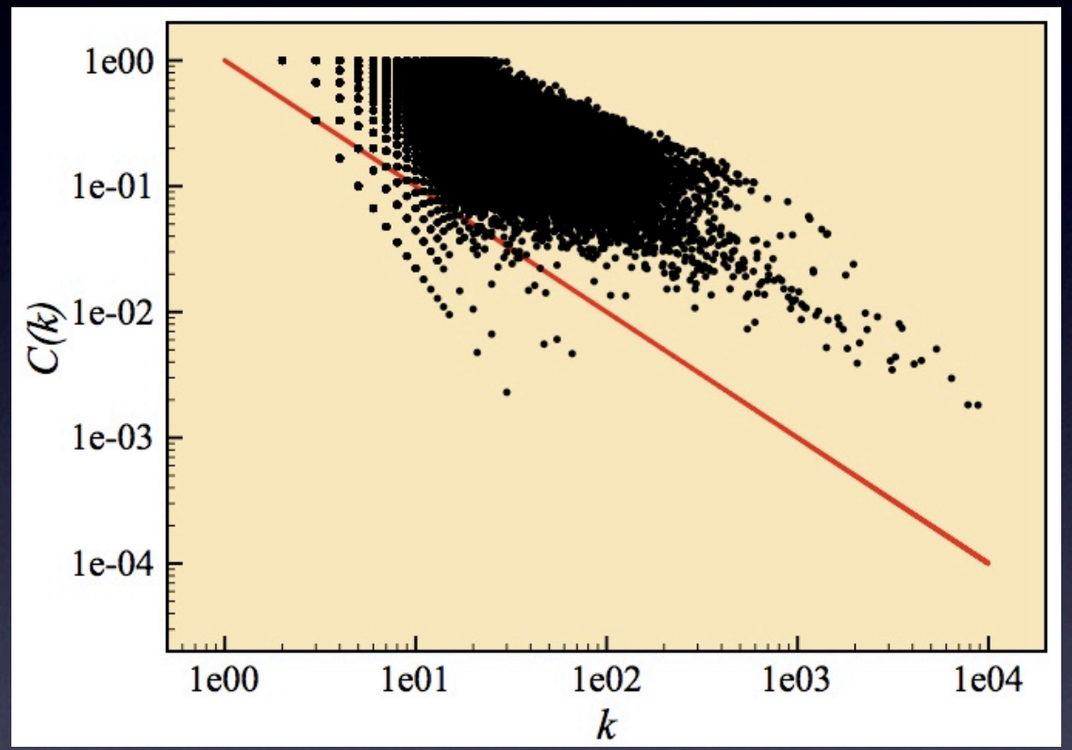

2
5
1
4
Scanner
3
6

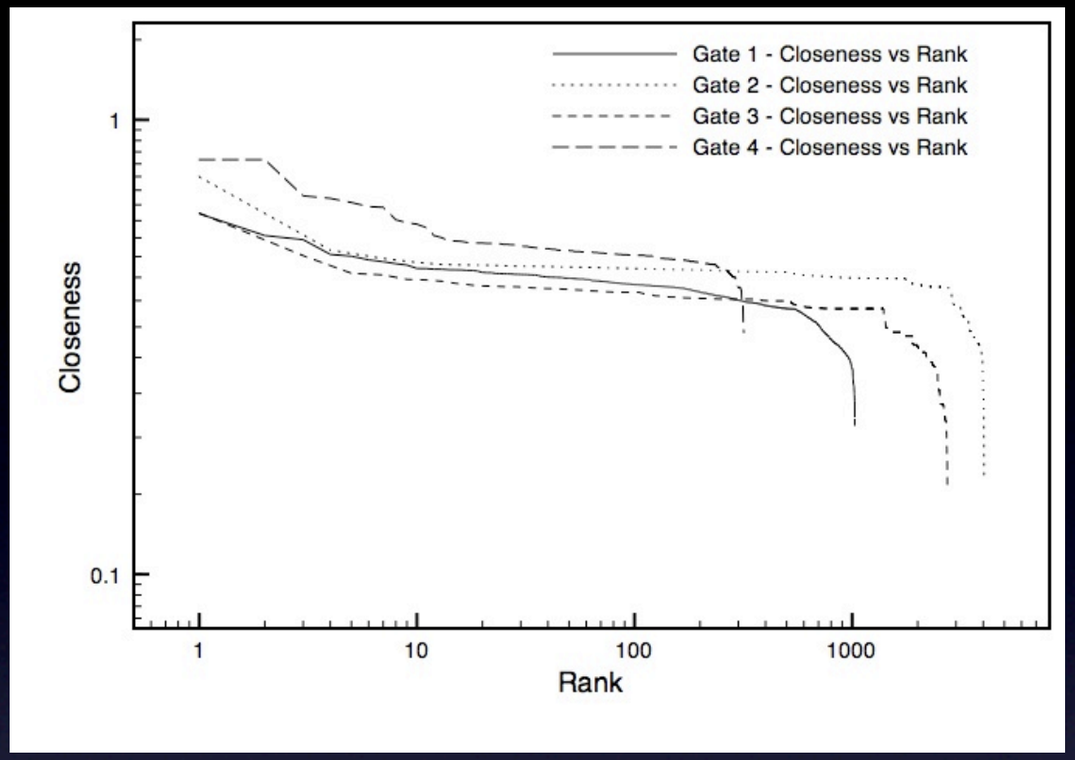

1
2
3
4
5
6
time

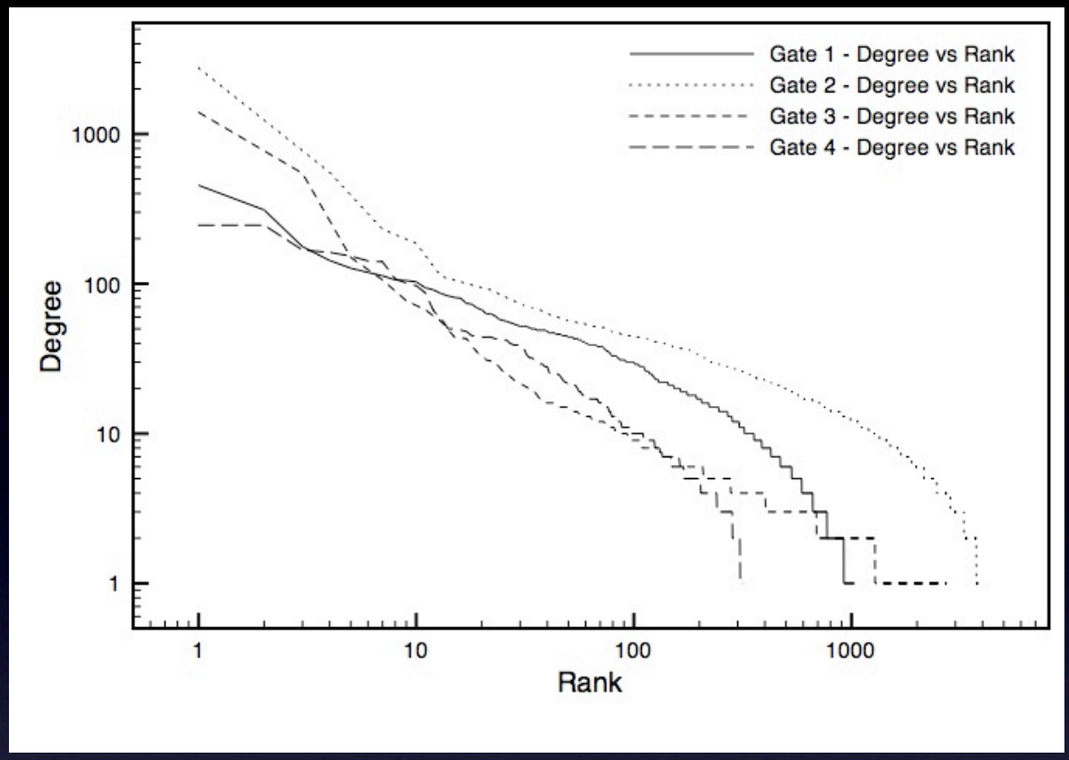


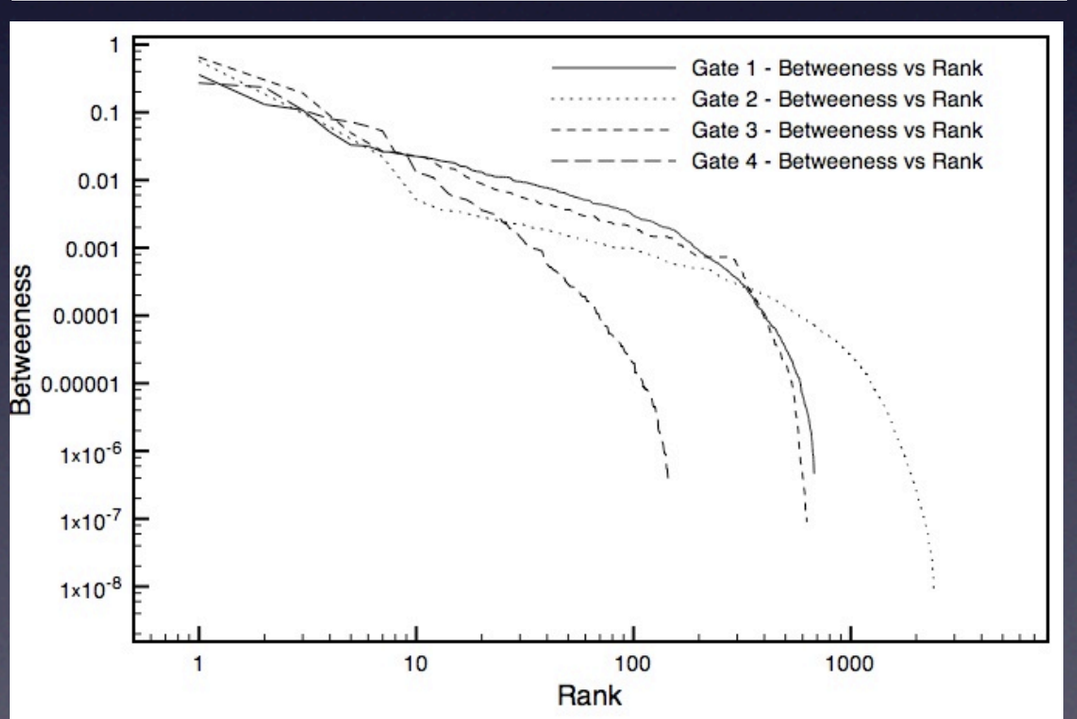
	Size	Edges	Density	Core	k	λ_{max}	λ	C
Bath	70516	652446	0.03%	69655	18.53	11	3.45	0.47
Campus	3109	120273	2.5%	3101	77.37	6	2.57	0.44
Street	11853	58111	0.08%	10584	9.80	12	3.23	0.28
Pub	13476	126768	0.1%	13383	18.81	9	2.61	0.10
Office	321	2419	4.7%	318	15.21	4	2.04	0.82

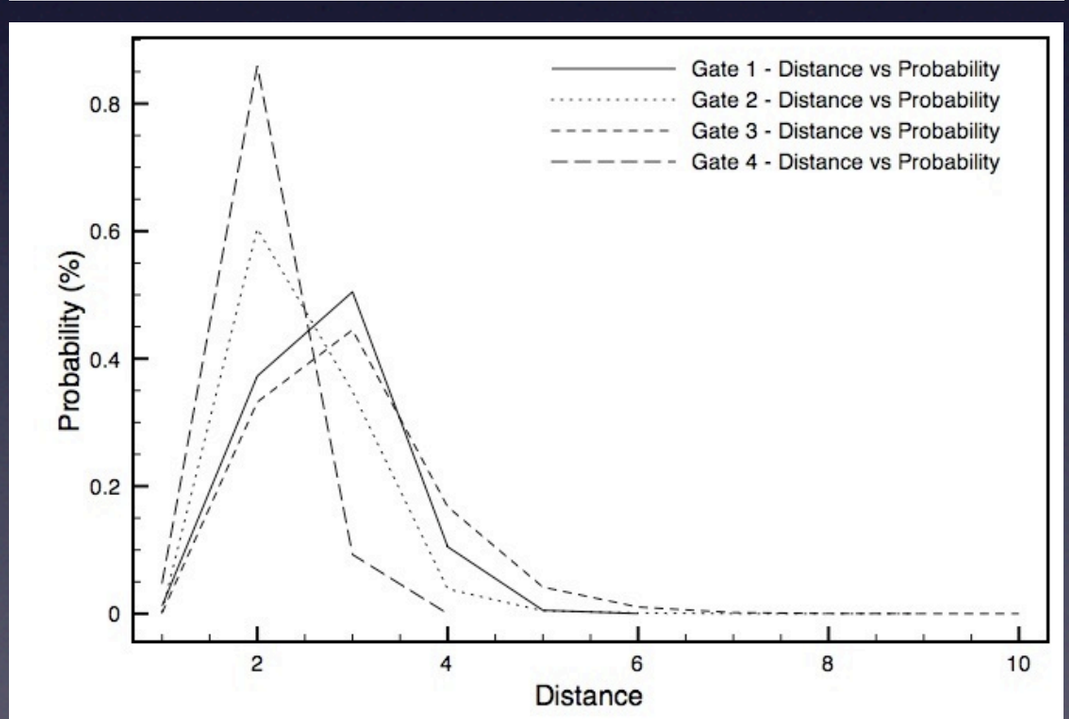

1e00
1e-01
1e-02
1e-03
1e-04
1e-05
P(k)
1e00
1e01
1e02
1e03
1e04
k


1e00
1e-01
1e-02
1e-03
1e-04
C(k)
1e00
1e01
1e02
1e03
1e04
k


Gate 1 - Closeness vs Rank
Gate 2 - Closeness vs Rank
Gate 3 - Closeness vs Rank
Gate 4 - Closeness vs Rank
Closeness
1
0.1
1
10
100
1000
Rank


Gate 1 - Degree vs Rank
Gate 2 - Degree vs Rank
Gate 3 - Degree vs Rank
Gate 4 - Degree vs Rank
Degree
1000
100
10
1
1
10
100
1000
Rank

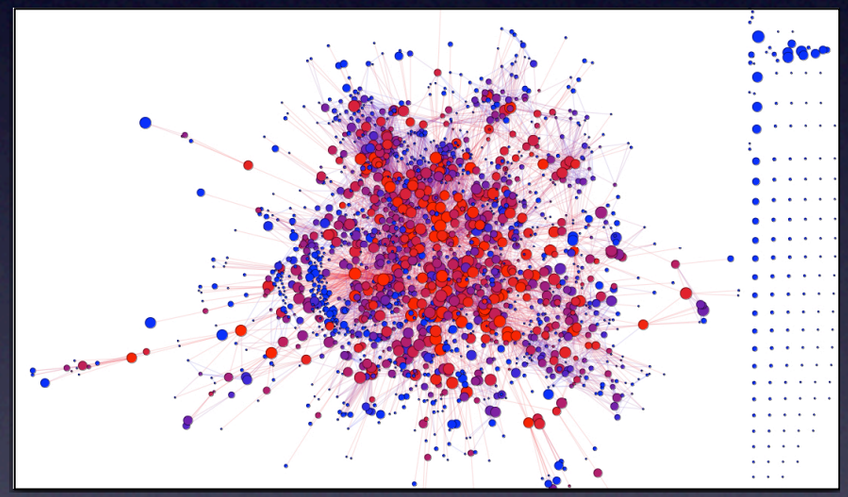

Gate 1 - Betweeness vs Rank
Gate 2 - Betweeness vs Rank
Gate 3 - Betweeness vs Rank
Gate 4 - Betweeness vs Rank
Betweeness
1
0.1
0.01
0.001
0.0001
0.00001
1x10-6
1x10-7
1x10-8
1
10
100
1000
Rank

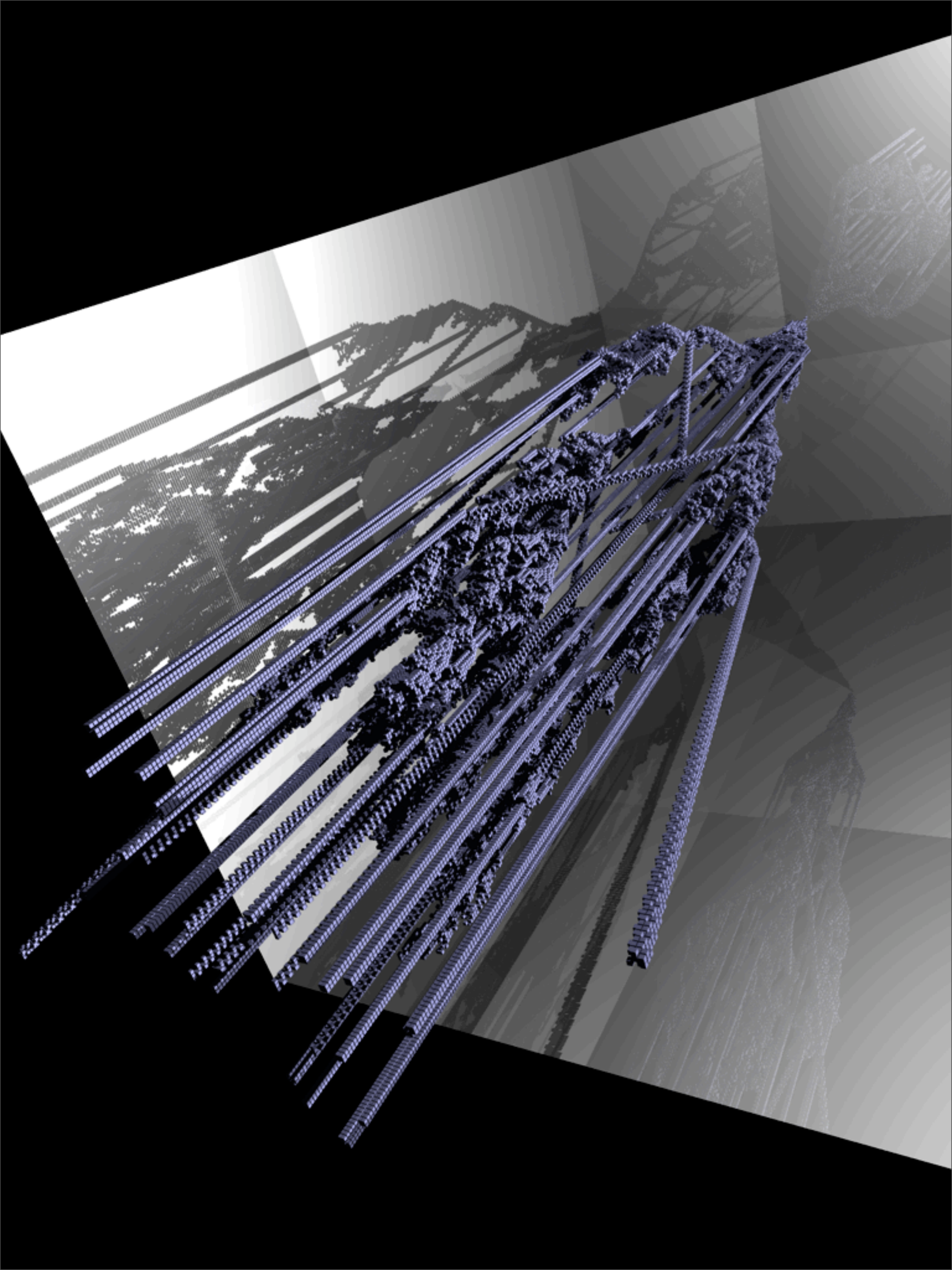

Gate 1 - Distance vs Probability
Gate 2 - Distance vs Probability
Gate 3 - Distance vs Probability
Gate 4 - Distance vs Probability
Probability (%)
0.8
0.6
0.4
0.2
0
2
4
6
8
10
Distance

Dynamic properties

Dynamic properties

- Our data is not static
- 3D structure
- Chain of events

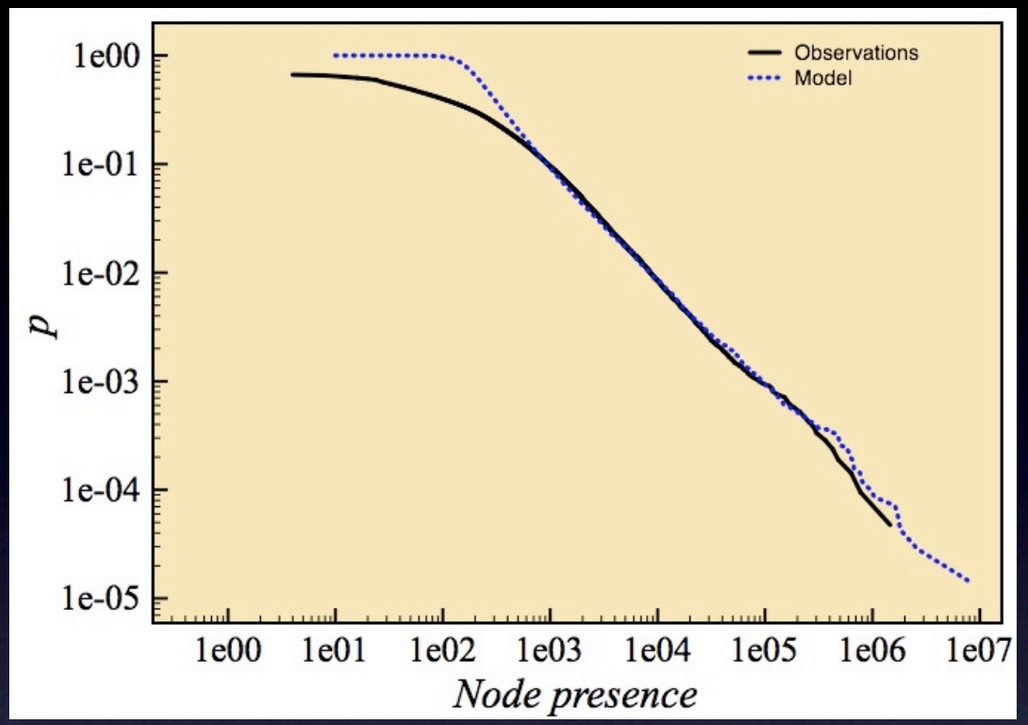


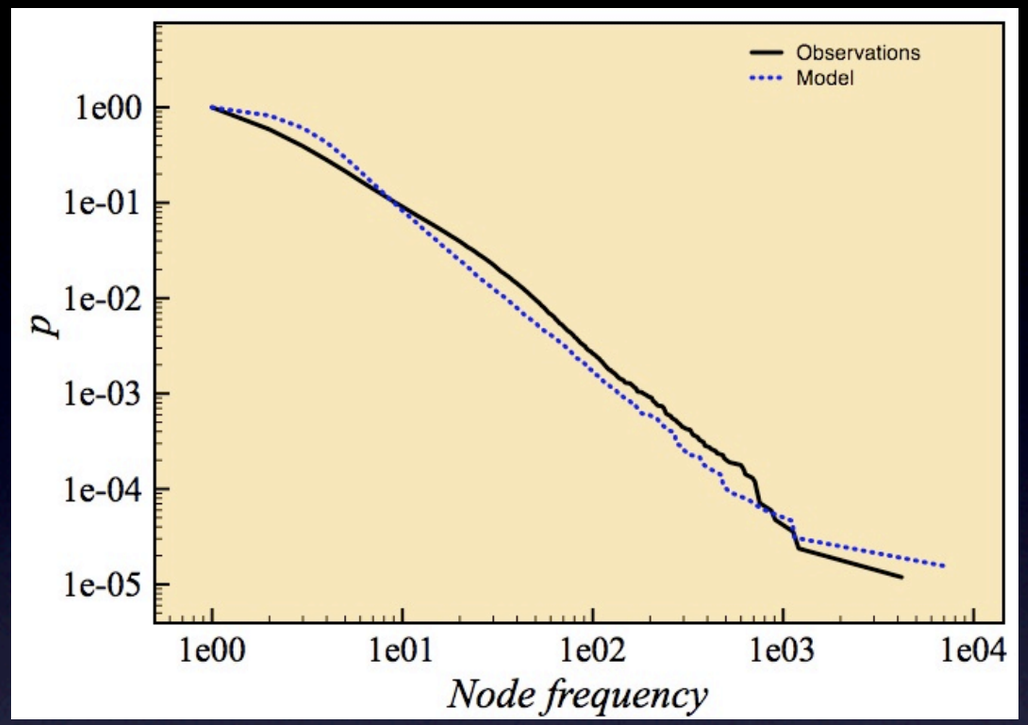


Presence

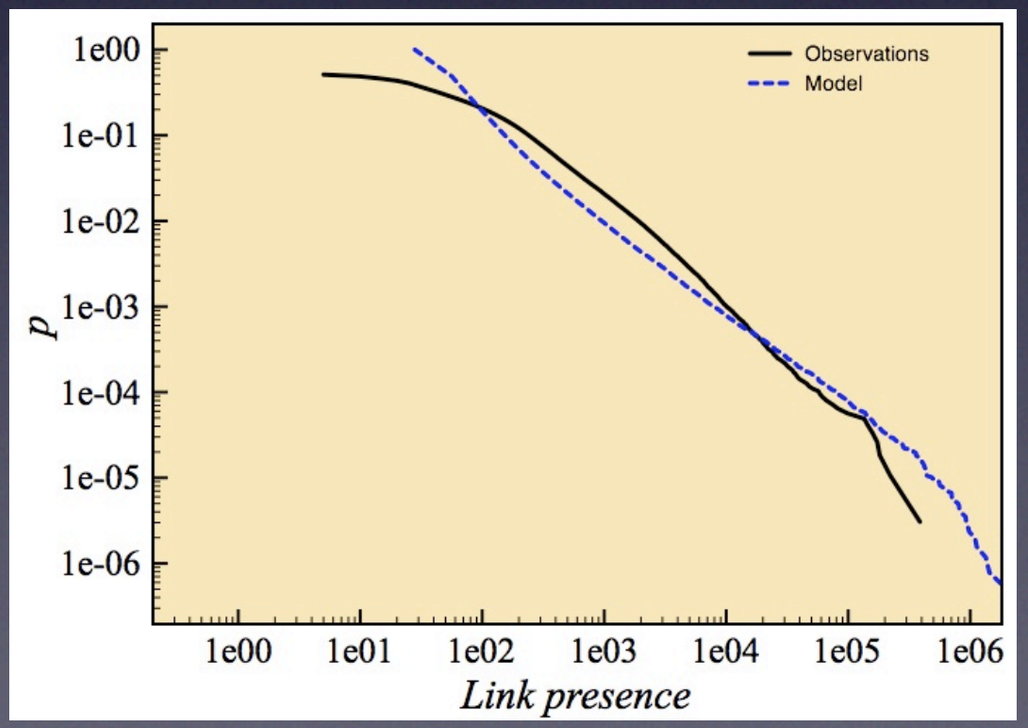
Frequency

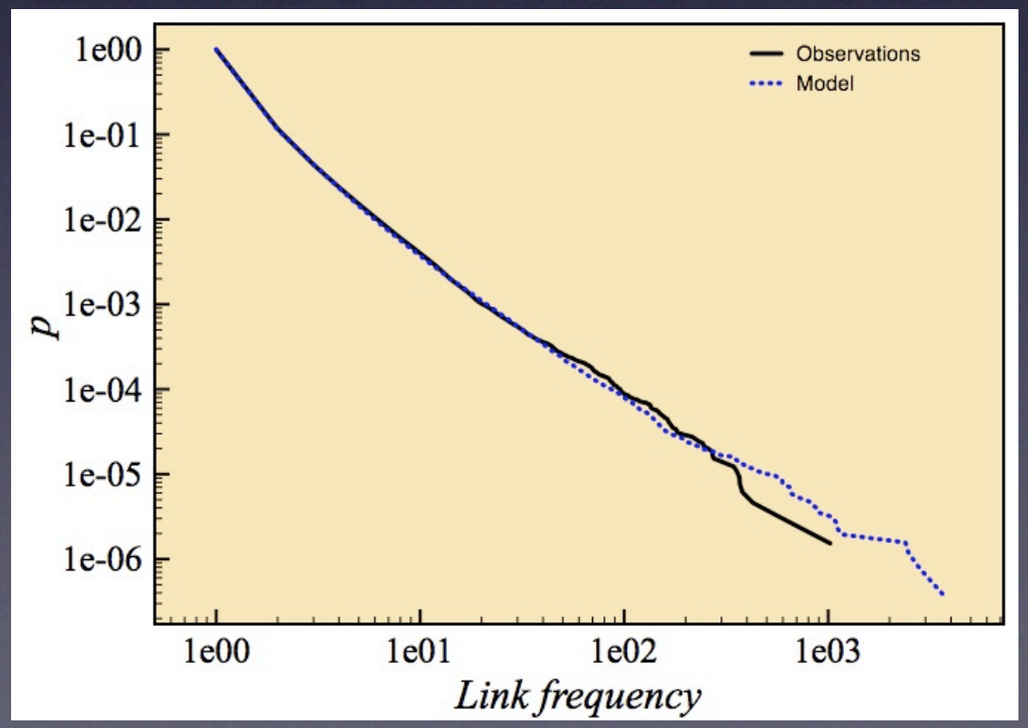
Nodes





Links

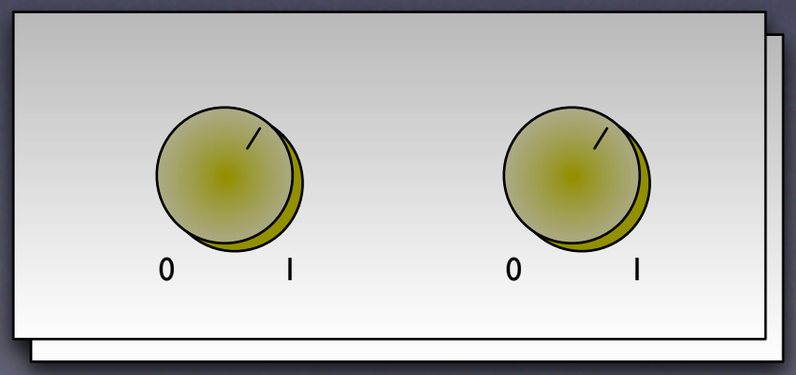


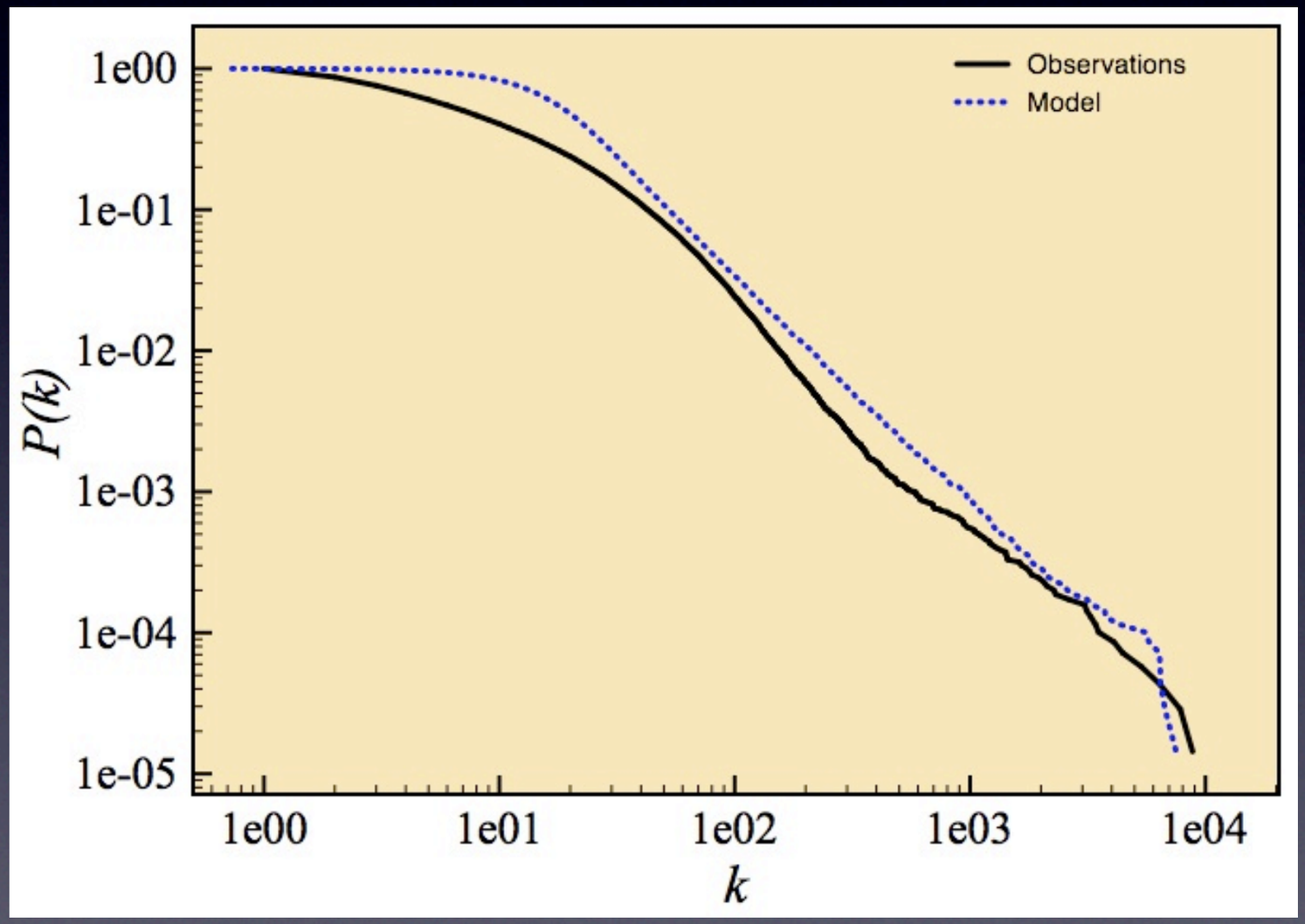


Model

- Fixed population size n
- Each node assigned probability *f* and *p*
- At each iteration, node is activated with probability *f*
- If a node is activated, it remains active for *p* times length of previous inactivity
- If two nodes are simultaneously active, they are linked to each other


No Street
Drinking Zone
6
Clarks
42442
AND
THE
HOP
€5
£10


0
I
0
I


Observations
Model
1e00
1e-01
1e-02
1e-03
1e-04
1e-05
P(k)
1e00
1e01
1e02
1e03
1e04
k

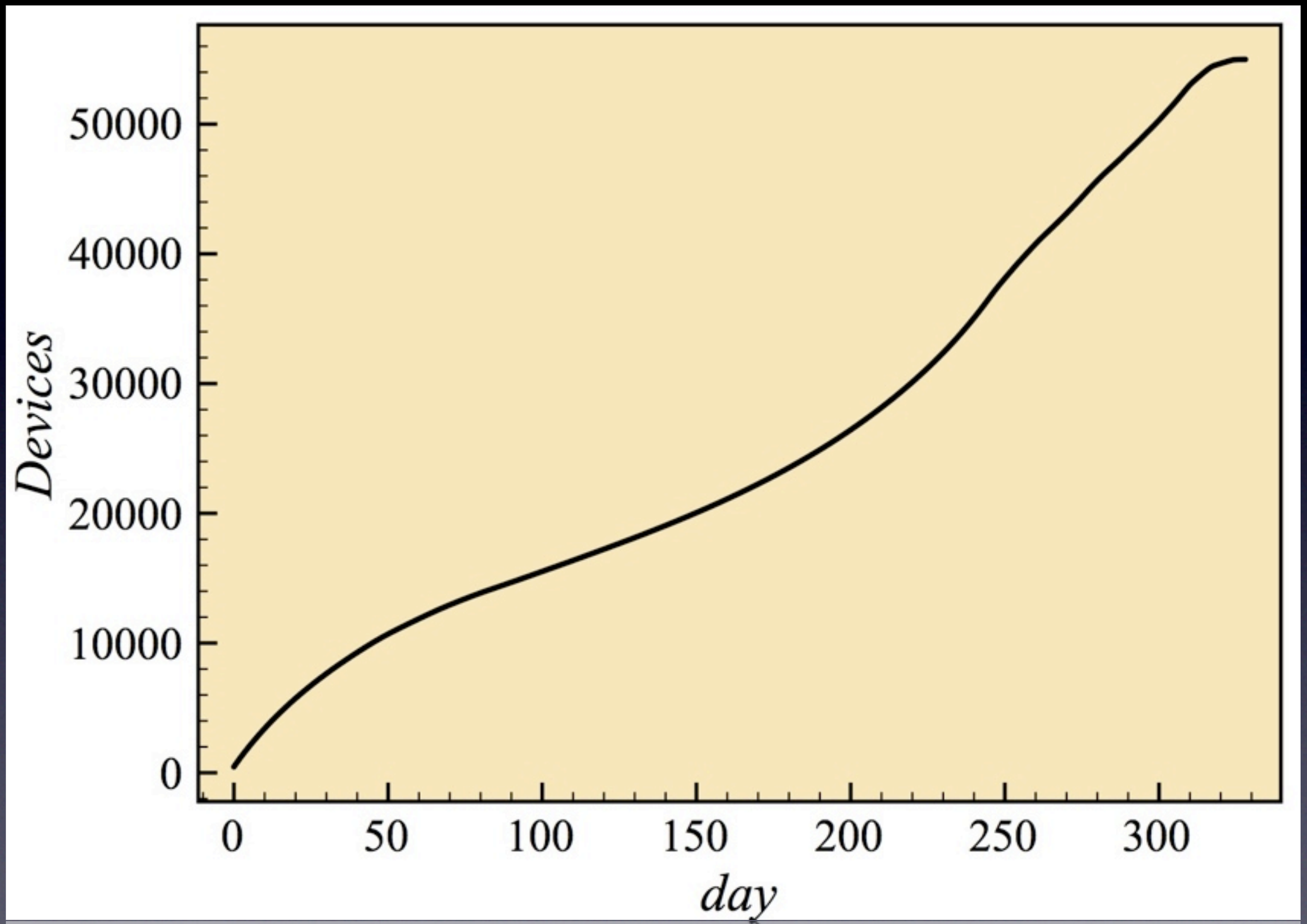
Diffusion

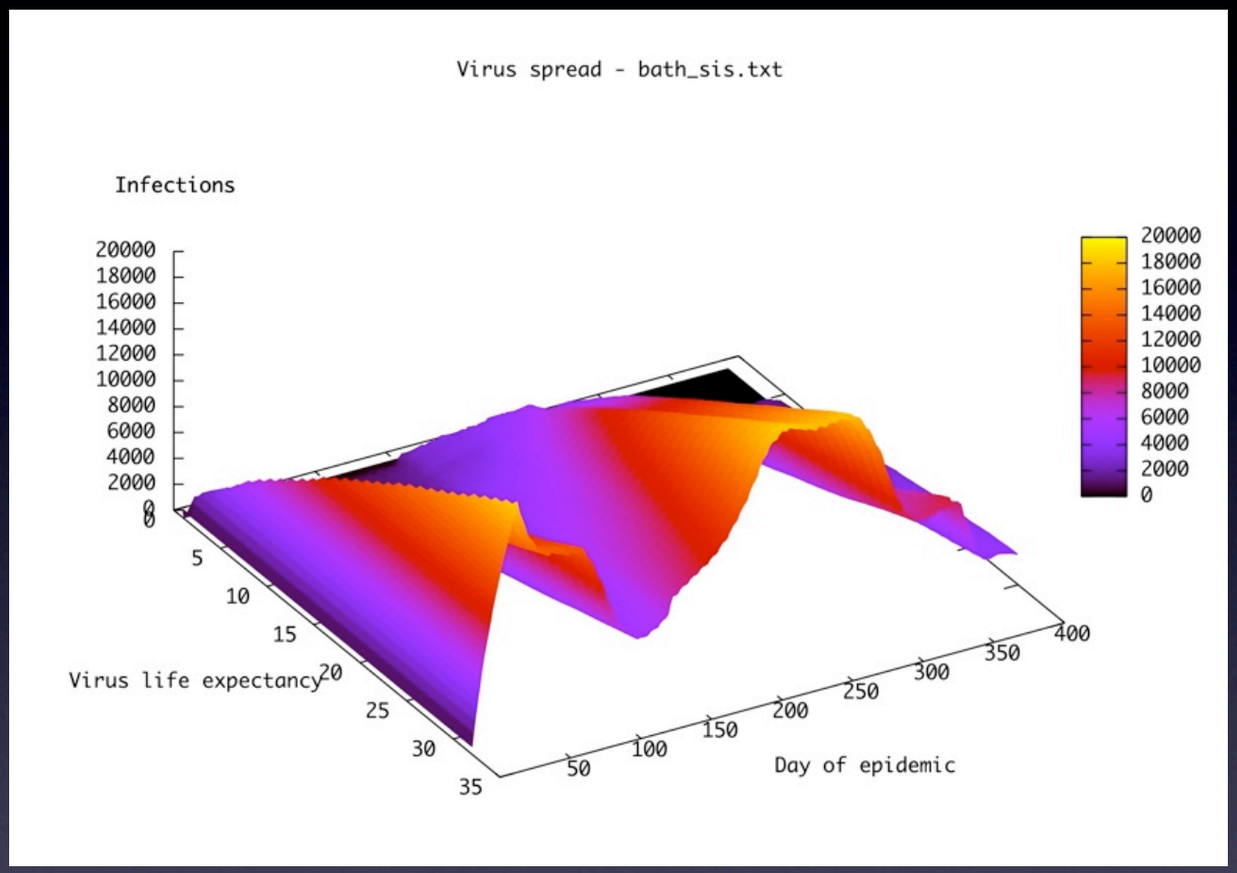
Chain of events

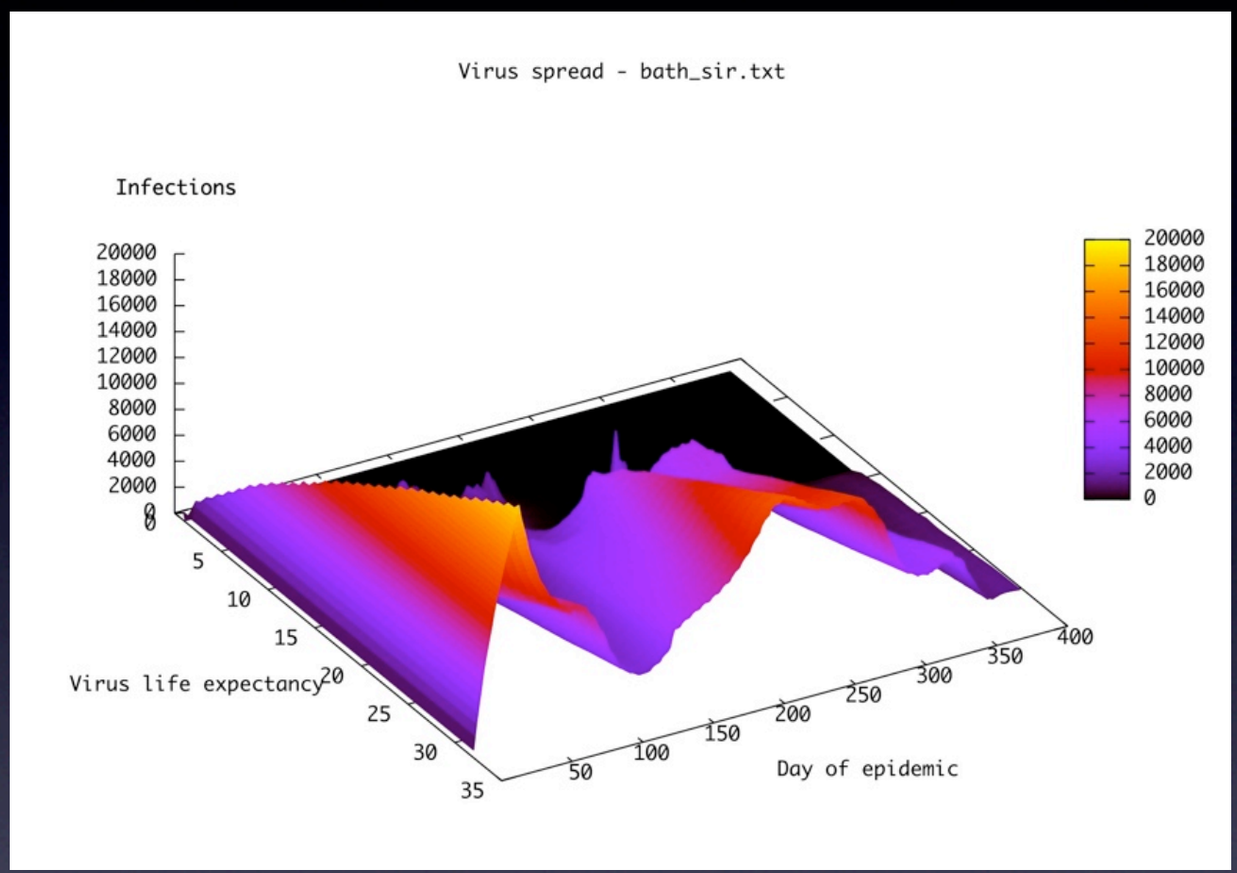
- John, Mary, 14:20:30
- John, Paul, 14:20:32
- Mary,Nick, 14:20:33
- ...

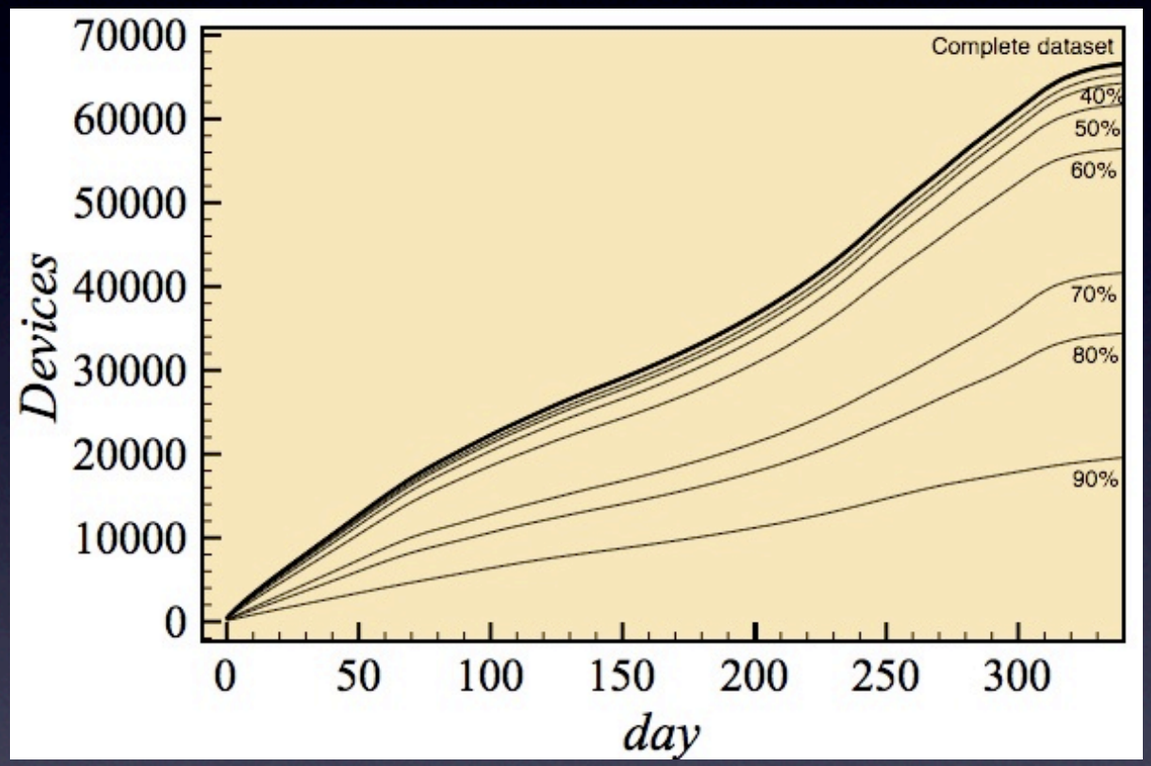
Emulation

- Class “device”
- Class “virus”
- During encounter, virus is transmitted
- Device recovers (SIS) or dies (SIR)

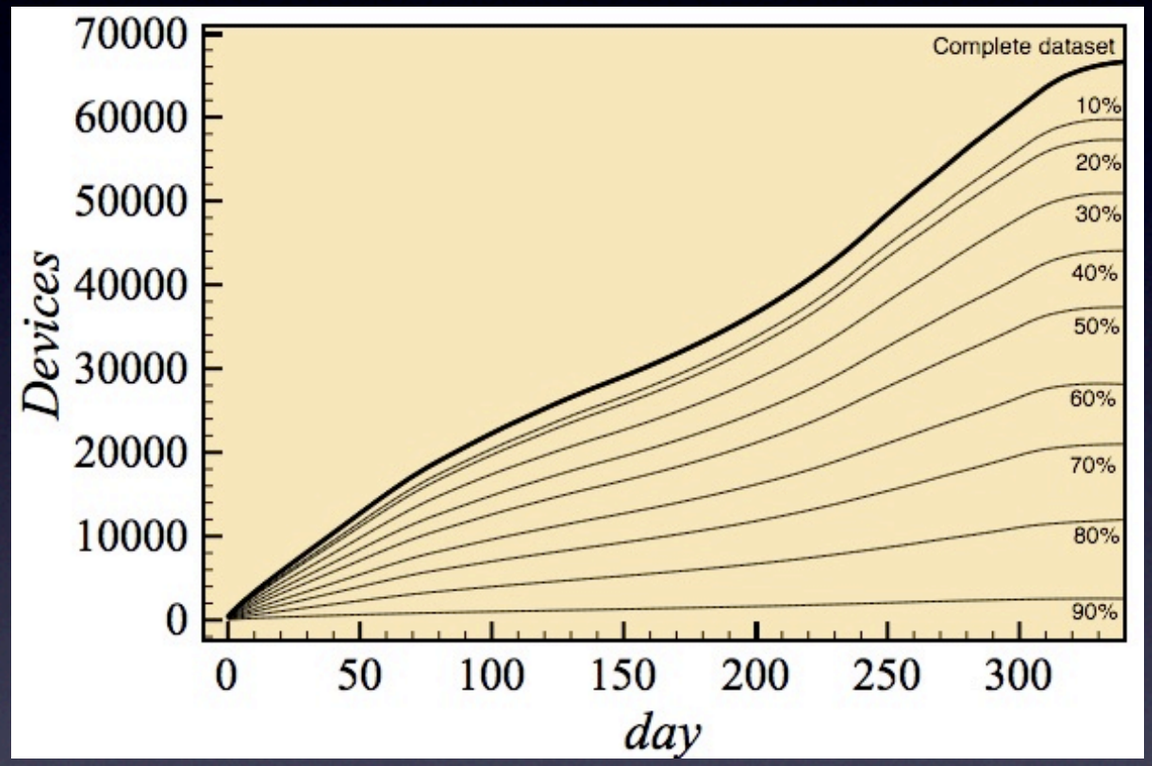

50000
40000
30000
20000
10000
0
Devices
0
50
100
150
200
250
300
day


Virus spread - bath_sis.txt
Infections
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
Virus life expectancy
0
5
10
15
20
25
30
35
Day of epidemic
50
100
150
200
250
300
350
400


Virus spread - bath_sir.txt
Infections
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
Virus life expectancy
0
5
10
15
20
25
30
35
Day of epidemic
50
100
150
200
250
300
350
400

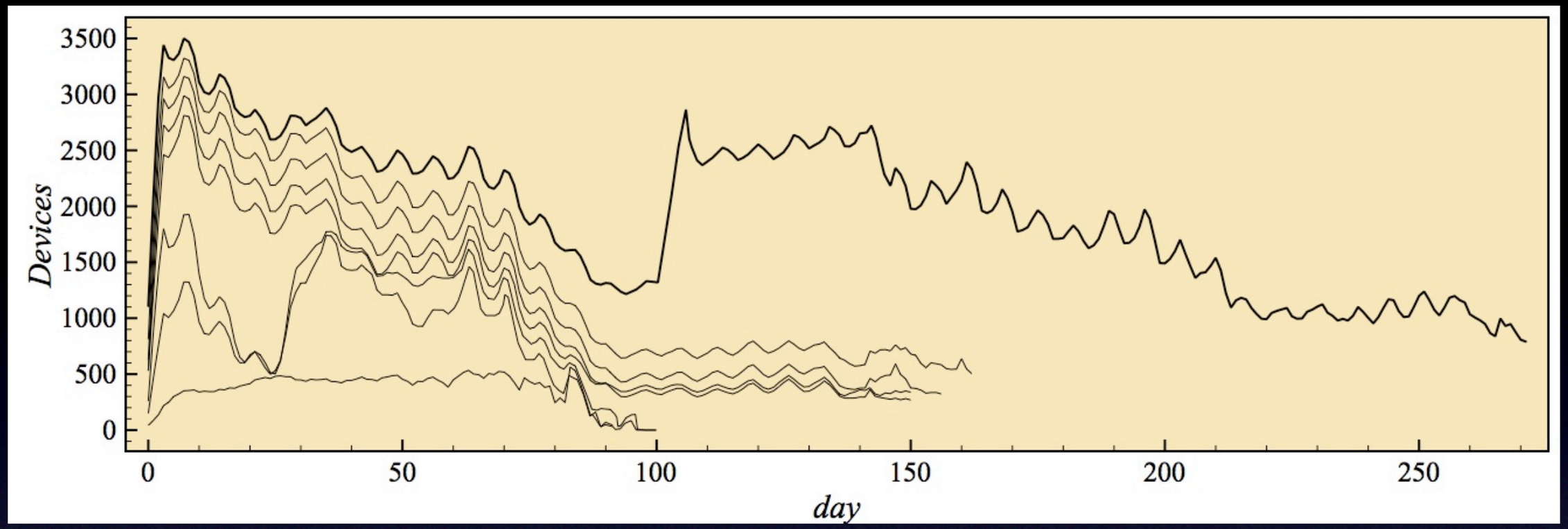


Remove
Persistent Encounters

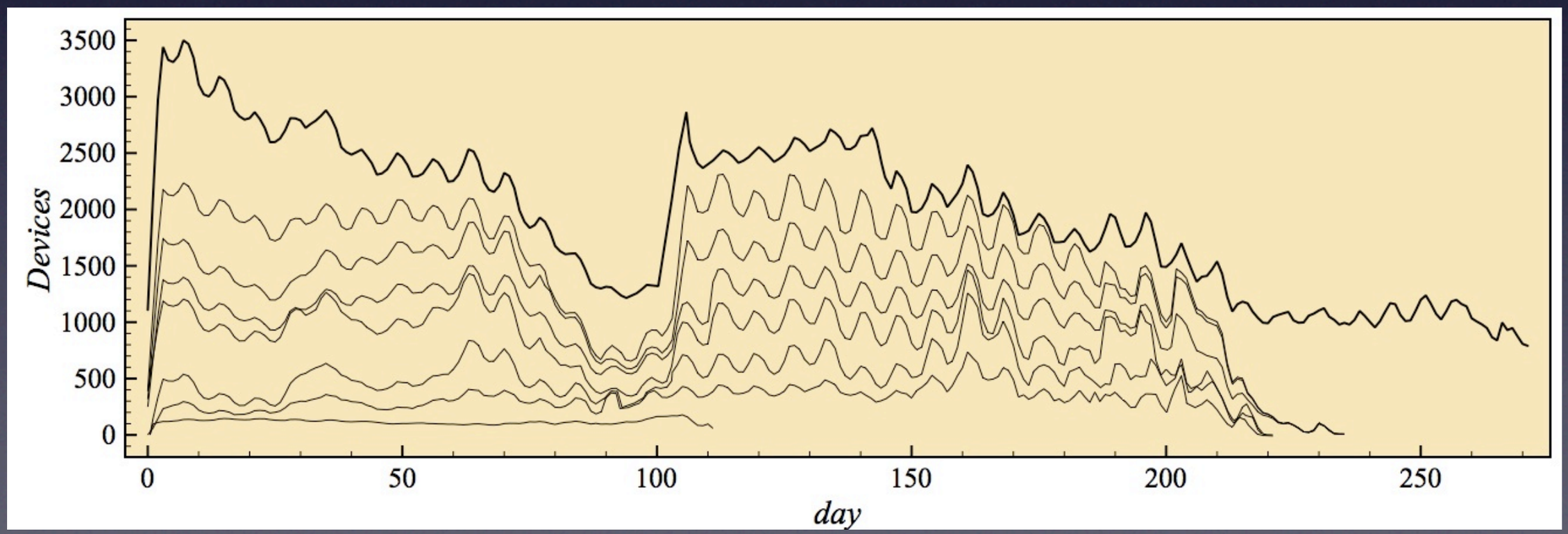


Remove
Brief Encounters

Remove
Persistent Encounters



Remove
Brief Encounters

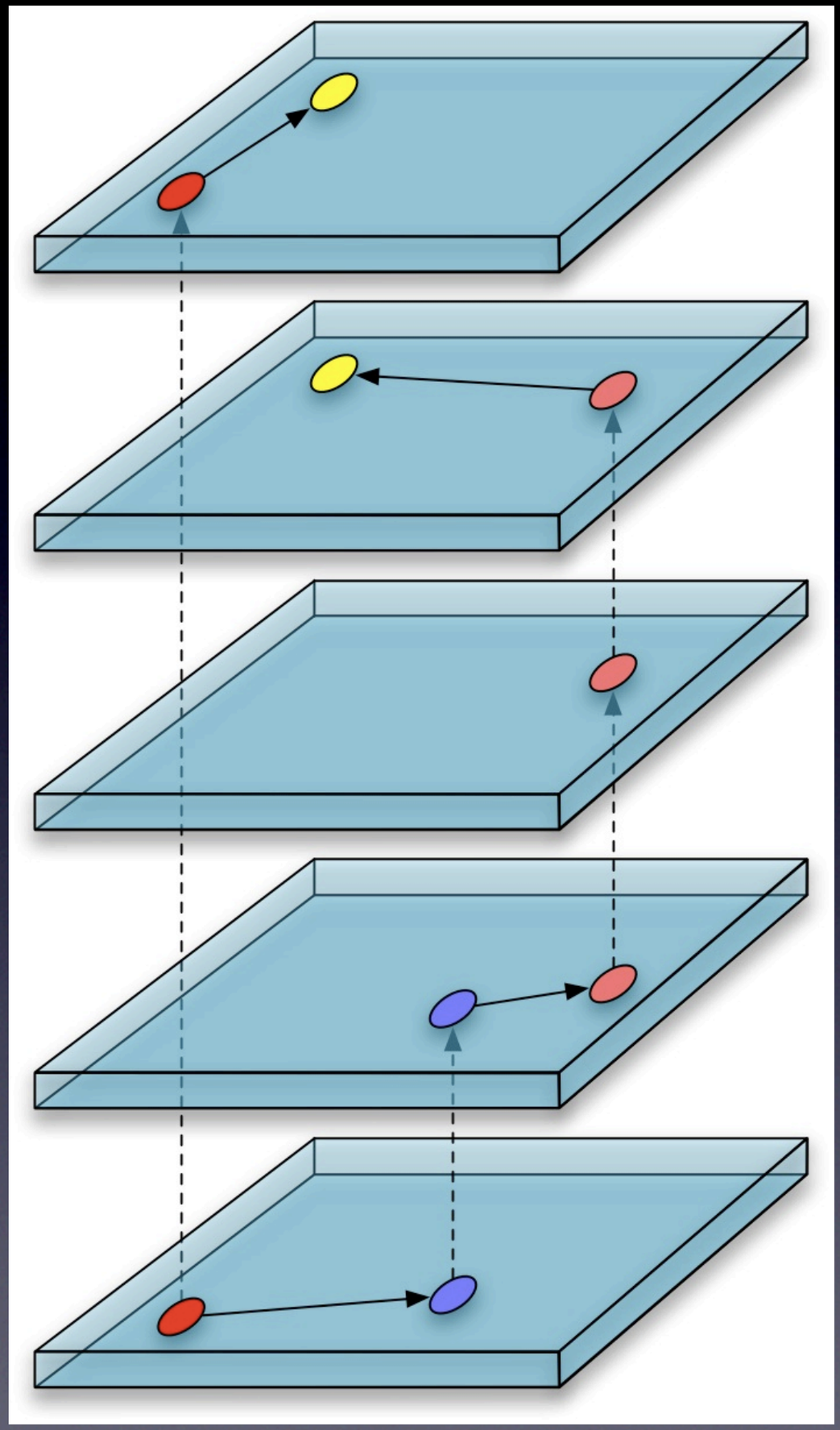


Ongoing work

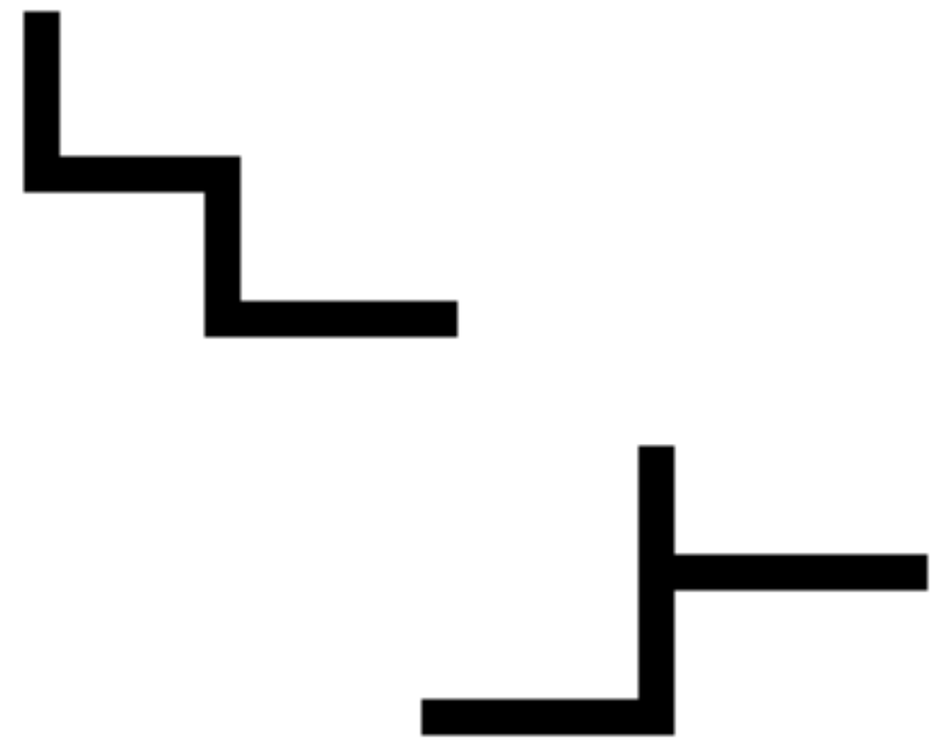
DTN forwarding algorithm

- Static features
  - Node degree
  - Node betweenness
  - Node closeness
  - Average geodesic path (Bath = 3.3)
  - Community detection (21 using Newman)

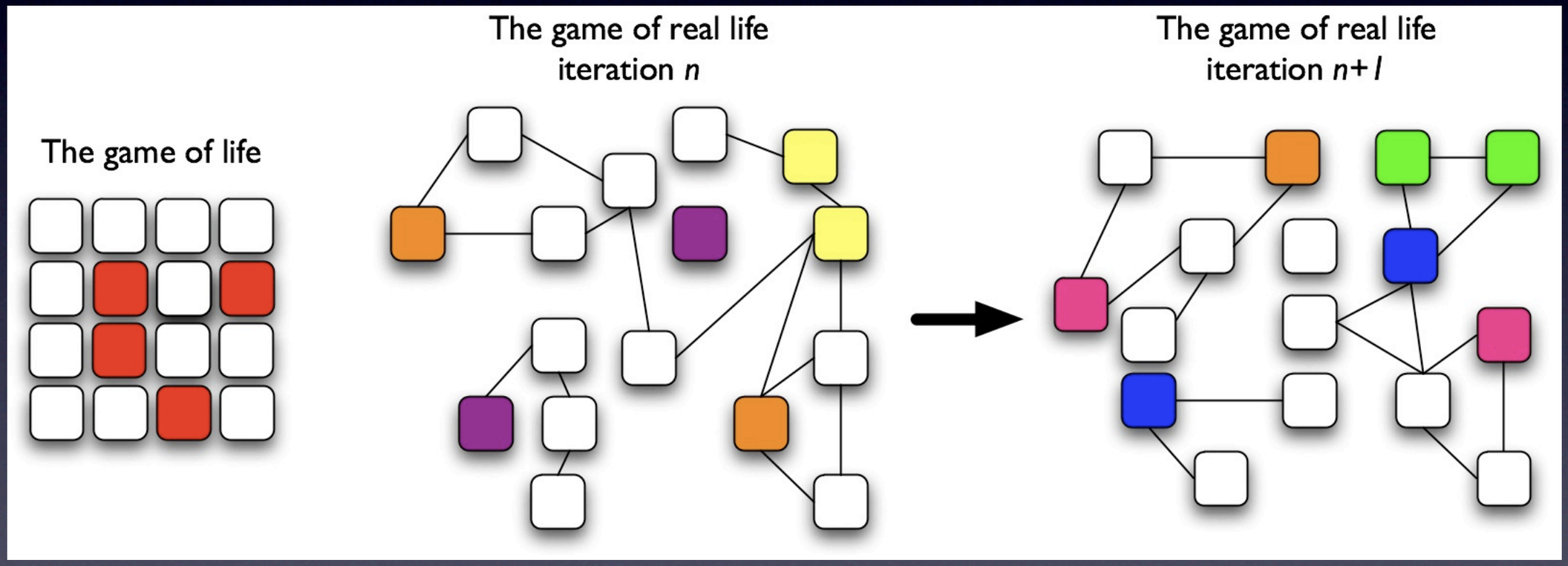
Considering time



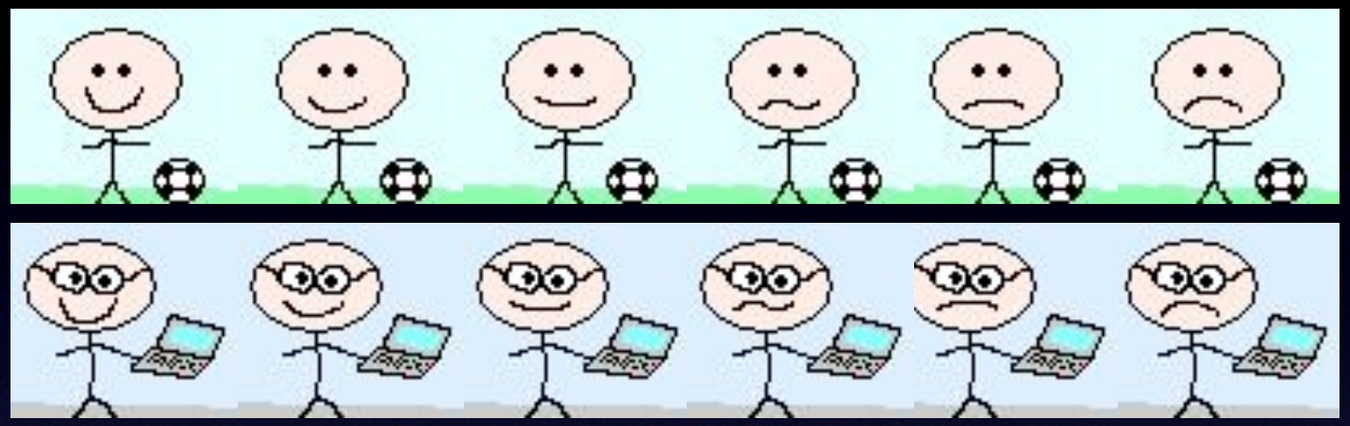
Generation: 1 Creatures: 41

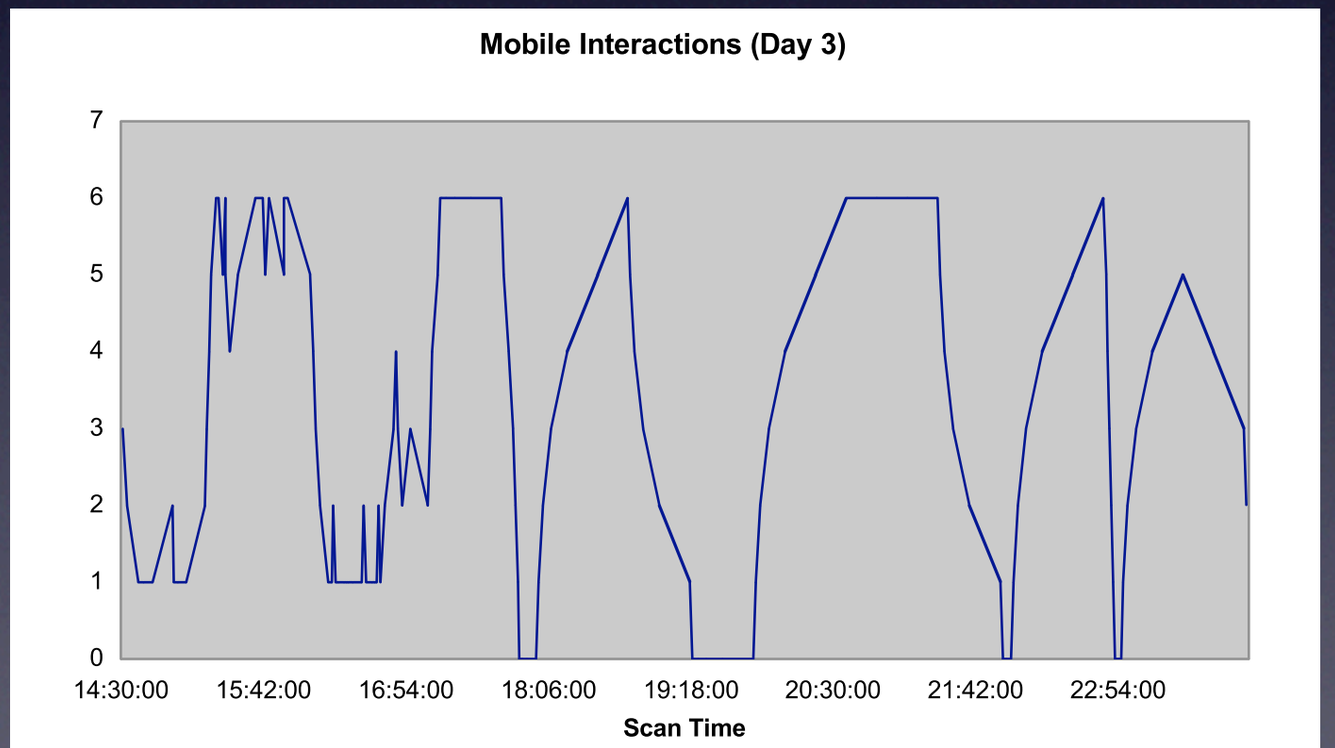


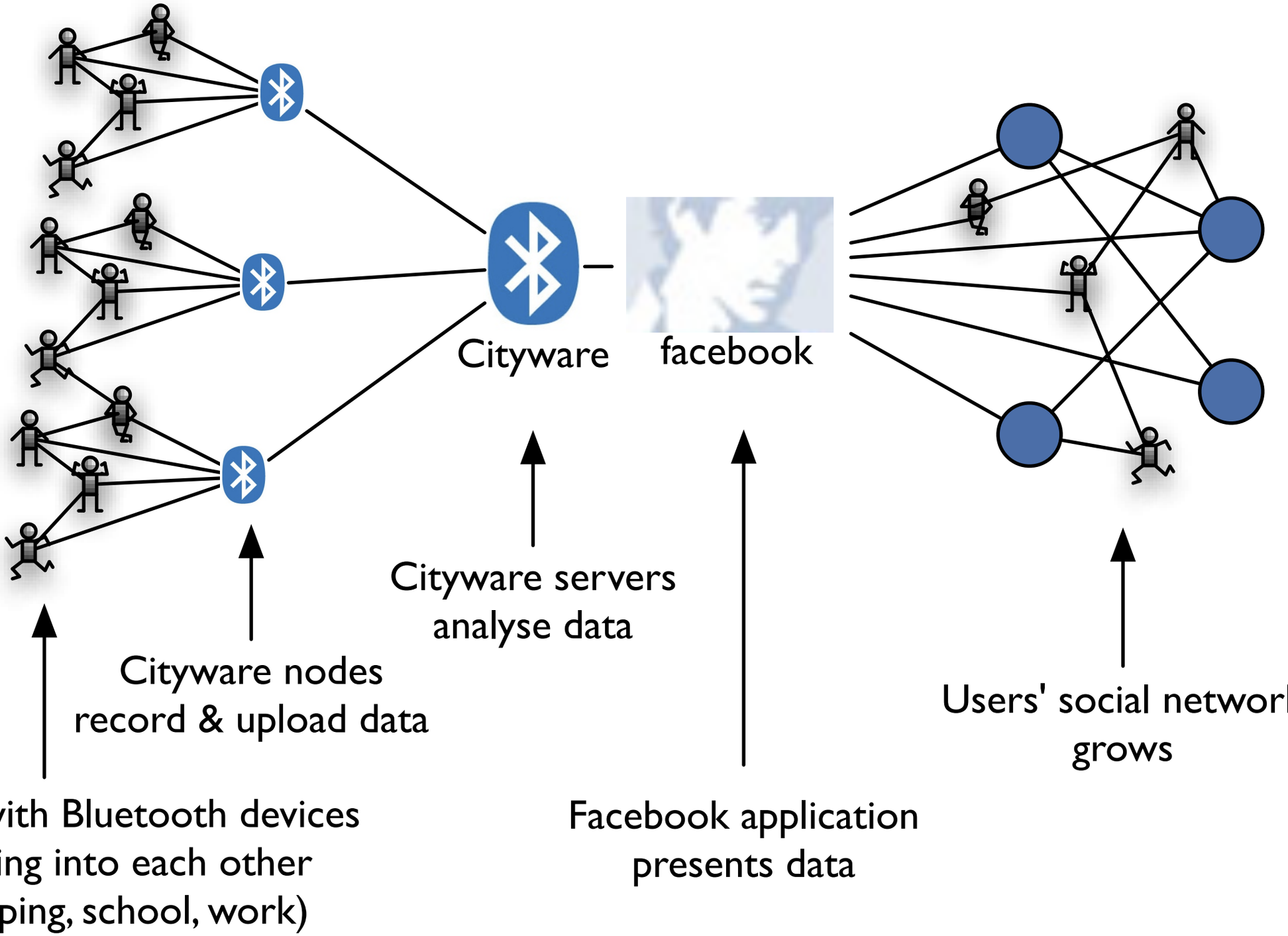
Game of real life

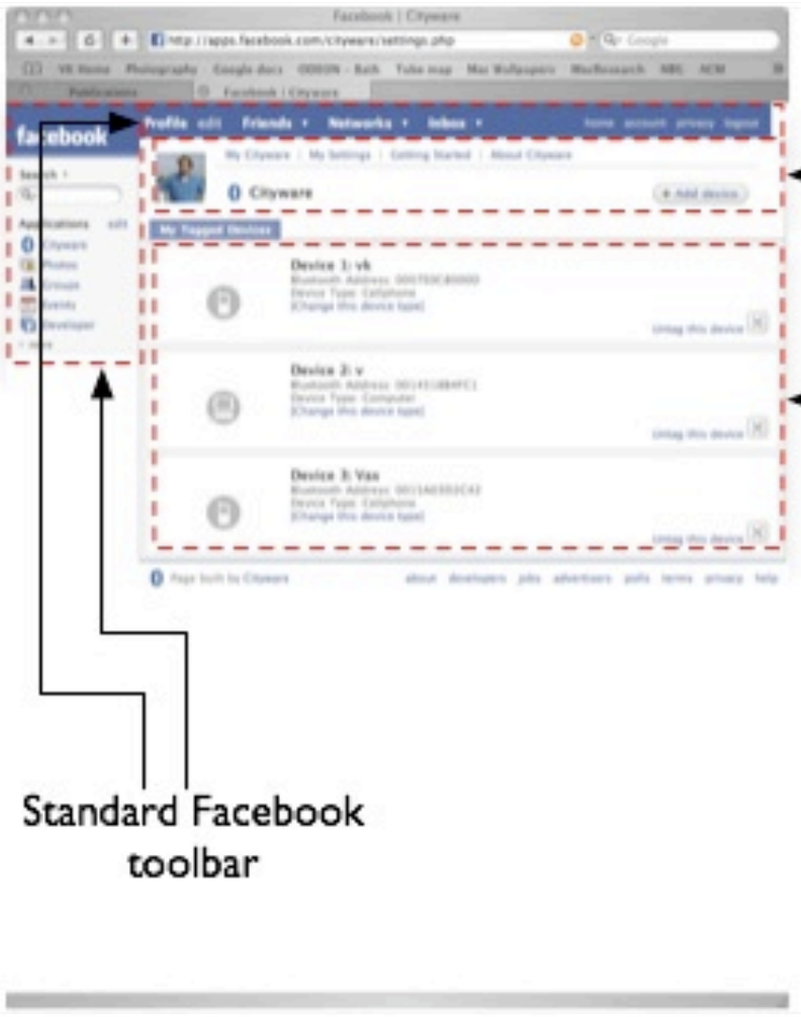


Tamagotchi




Mobile Interactions (Day 3)
7
6
5
4
3
2
1
0
14:30:00
15:42:00
16:54:00
18:06:00
19:18:00
20:30:00
21:42:00
22:54:00
Scan Time


Cityware
facebook
Cityware servers
analyse data
Cityware nodes
record & upload data
Users' social network
grows
People with Bluetooth devices
bumping into each other
(shopping, school, work)
Facebook application
presents data



Cityware toolbar

Bluetooth devices linked to a user's profile

Encounters grouped by recency, duration, frequency

Encounter with a device linked to a profile

Encounter with an unknown device

Standard Facebook toolbar

News Front Page

Africa
Americas
Asia-Pacific
Europe
Middle East
South Asia
UK
Business
Health
Science/Nature
Technology
Entertainment
Also in the news

Video and Audio

Have Your Say
In Pictures
Country Profiles
Special Reports

RELATED BBC SITES
SPORT
WEATHER
ON THIS DAY
EDITORS' BLOG

Last Updated: Thursday, 16 August 2007, 14:37 GMT 15:37 UK

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Bluetooth helps Facebook friends

A team of UK researchers is combining the power of social network Facebook with communications tool Bluetooth to learn more about human interactions.

Cityware nodes have been set up in Bath and London

Bath University scientists have created a tool which can use the unique ID of Bluetooth devices, like a mobile phone, to build new friendship networks.

Users register with the Facebook tool, called Cityware, that tracks encounters in the real world via Bluetooth.

It is part of a wider project backed by Nokia, HP Labs and Vodafone.

Dr Vassilis Kostakos, research associate at the University of Bath, said: "Networks are everywhere - social and digital.

"The really nice thing about Bluetooth is that when you are walking down the street, although you are not talking to anyone, your Bluetooth device can be talking to other devices.

"People with Bluetooth devices are actually creating an ad hoc communications infrastructure where information can

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New challenges

- Best utilisation of this platform?
  - Create a “world socio-map”?
- Develop adaptable systems
- Develop more secure systems
- Put numbers on human relationships
- Put numbers on “fabric of everyday life”

Thank you

Vassilis Kostakos
vk @ cs. bath. ac. uk

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