The Internet of People and the culture of the small screen

Generating new opportunities for people getting connected

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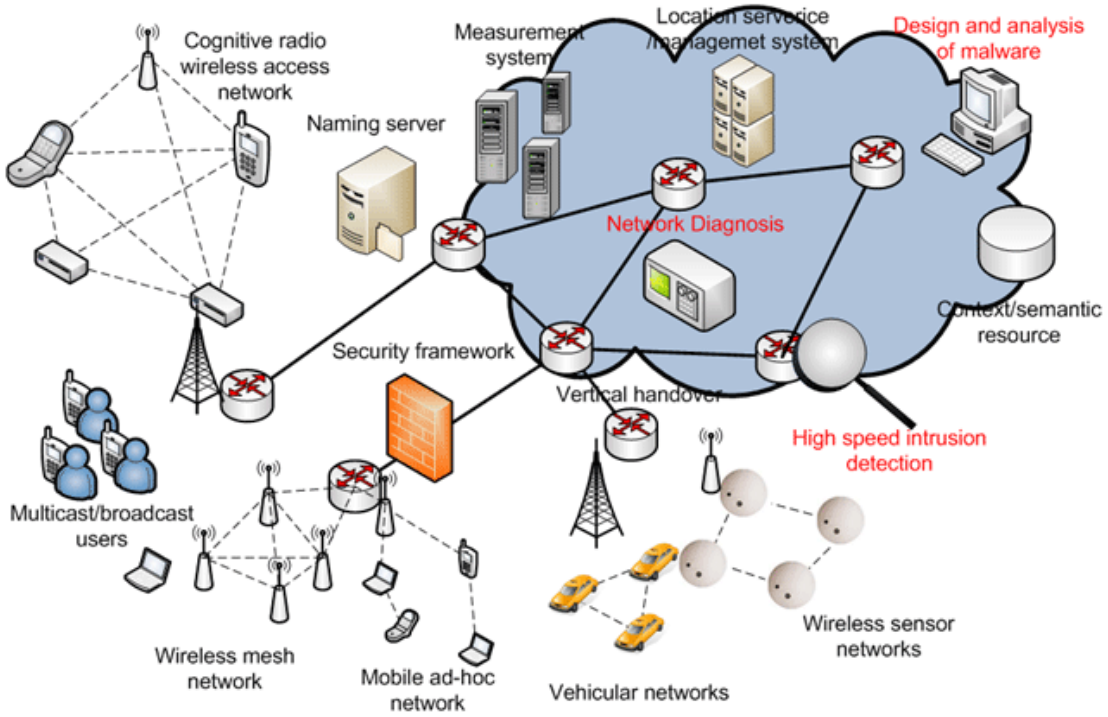
Internet of things driving the Internet of the future

- Connect wider variety of devices
- Be highly heterogeneous in terms of the types of networks it interconnects
  - Underlying the Internet of Things are technologies such as RFID (radio frequency identification), sensors and **smartphones**

- **Vision:**



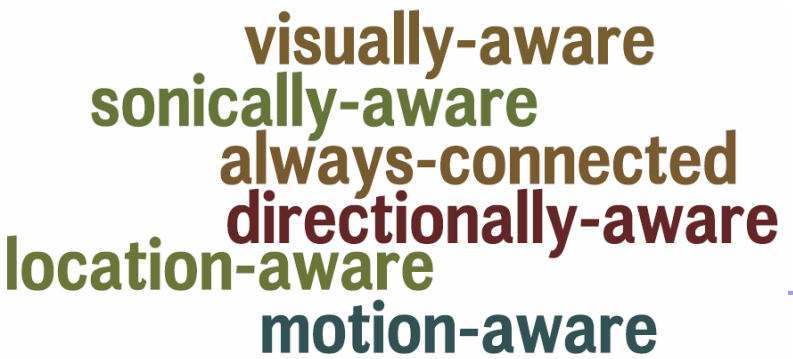
The **Internet of People** and the **culture of the small screen**

- The mobile phone phenomena
  - 1) Increasing proliferation
    - "…mobile phone usage is outpacing the rate of Internet adoption…"[WWW07]
    - 4.1 billions of mobile phones, 60.6% of the world population
  - 2) MIMO smartphones
    - **M**ultiple **I**nput (sensors, compass, cameras, GPS, video, microphone, speaker, etc)
    - **M**ultiple **O**utput (Bluetooth, WiFi, cellular network, etc)

Rank	Country	# phones	% Populat.
-	World	**4,100,000,000**	**60.6%**
1	China	765,970,000	57.3%
2	India	563,794,992	47.91%
3	US	276,610,580	89%
4	Russia	208,330,000	146.8%
5	Brazil	176,700,000	91.8%

[Wikipedia]

Have the potential of being:



New technology and applications, different connectivity opportunities

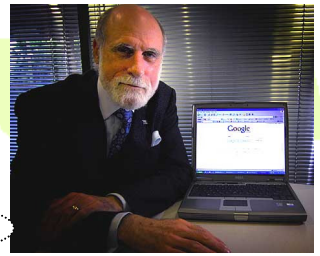
- The mobile phone phenomena:
  - "*What would the culture of the Mobile Phone be?*" (by Google CEO Eric Schmidt, http://fora.tv, *in Economic Club in Washington*)

"…No idea of what people will do with mobile phones…"

"…diversity is the future… we should empower communities with access to information…"

  - *"What's Next with the Internet"* (by Google vice president Vint Cerf, http://fora.tv)
    - "*the father of the Internet*", well known for his predictions on how technology will affect future society

"…TCP/IP breaks when connectivity breaks, but DTN protocols are robust to it. So let's put DTN protocols in mobile phones…",



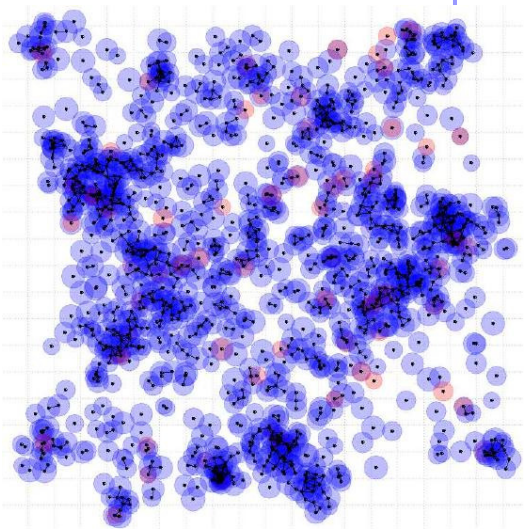
Outline

- Paradigm shift in communication
- Delay Tolerant Networks (DTN)
  - Reasons to believe!
- DTN research: Open issues
- Adaptive and/or opportunistic network deployment
  - Cover strategy
  - Opportunistic delegation strategy
- Conclusion

New opportunities to get connected anywhere/anytime

- Paradigm shift in the way end-to-end communication is viewed:
  - Social wireless communication into node-to-node interactions
    - people = switching nodes of a mobile network infrastructure
  - Node associations driven by contents and affinity of interest

- Support the deployment of Delay Tolerant Networks (DTNs)
  - Do not assume a continuous end-to-end connectivity
  - Since destination is not always available, the store-and-forward methods tolerates disruption in communication
    - Build the system and protocols to be tolerant to disruptions



But!

Fierce criticism to DTN and opportunistic research area

"The skeptics question the utility and benefits of these types of networks, especially in the face of the more and more ubiquitous presence of networking infrastructure in the Western world. For a seemingly small fee, cellular network coverage is available in most locations, often providing data services as well as voice communication."

"The Quest for a killer app for opportunistic and DTNs", CHANTS'09

Good motivations for thinking in killer applications for DTNs!

Re-considering challenges and solving open problems

Before we dive into all of this discussion…

In spite of the criticism…

…the sky has not fallen (yet) …

…3 reasons to believe in opportunistic DTNs

1) Attractiveness – "Network is the People"
   - Free communication
   - No surveillance of or charge for infrastructure operators
     - "*Sharing airtime with shair avoids wasting time and money*", HotMobile'09
   - Short-range device-to-device transfers do not require any networking infrastructure coverage
     - so, can be performed anywhere even underground!

2) Necessity
   - Disaster situations
     - Existent telecommunication or networking infrastructure was destroyed or temporarily overwhelmed
       - "*Engineers Help NGOs Get Online After Haiti Quake*" (http://spectrum.ieee.org/)

"*The Quest for a killer app for opportunistic and DTNs*", CHANTS'09

…3 reasons to believe in opportunistic DTNs (2)

3) Fairness and equality

- Groups in society, rural and mountain areas, developing regions
  - Unreliable infrastructure and not enough communication coverage
    - "*Networking in the land of northern lights – two years of experiences from DTN system deployments*", ACM WiNS-DR'08
- Cost reasons:
  - When operators network extending is economically infeasible due to low population density or low disposable income in the population
    - "*On connecting the world*", by Hector Ruiz, in TED.com
      - » CEO & executive chairman of semiconductor company AMD

"…it cost 100 dollars a month to have a broadband connectivity in South of Africa…",

DTN Research: Open issues

Resource management

- How to perform/manage resource sharing through contact opportunities?
  - Communication capabilities sharing
    - "*Sharing airtime with share avoids wasting time and money*", HotMobile'09
  - Storage capabilities sharing in a peer-to-peer basis
    - "*Media sharing based on collocation prediction in urban transport*", ACM Mobicom'08

- How to manage limited battery resources?
  - Context-aware battery management and battery lifetime prediction
    - "*Context-aware battery management for mobile phones*", IEEE Percom'08

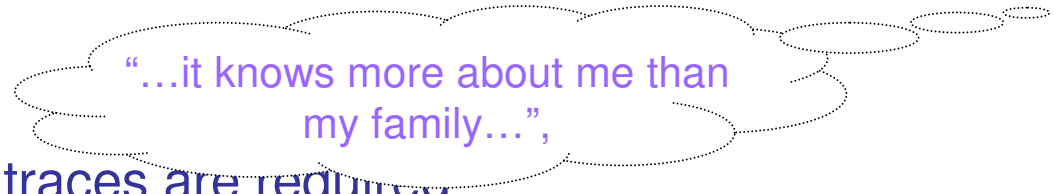
In-door localization / Privacy and Security issues

In-door localization

- The social investigation requires users' topographic tracking
- How to do it in in-door scenarios?
  - Take advantage of extra functionalities of smart phones
    - "*Indoor Localization Using Camera Phones*" IEEE WMCSA'06

Privacy/Secutity

- Smart phones will contain a very rich profile of owners
  - Mobility patterns, healthy information, activities, calls, etc
    - "*What's Next with the Internet*", by Vint Cerf
      - » Vice president and chief Internet evangelist at Google (http://fora.tv)



- Anonymizing traces are required
  - NSF Network Trace Sanitization and ANonymization Infrastructure
    - Increase network-trace sharing by making it safer and easier to sanitize

Predictions issues

- Contact prediction
  - Real measured traces are available in Crawdad website
    - But in a new environment, contacts can not be known in advance
  - How do encounters happen in casual applications?
    - "*Media sharing based on collocation prediction in urban transport*", ACM Mobicom'08
    - "*Design and Evaluation of an Agenda-Based Location Service"*, IEEE Globecom'08
    - "*Otiy: Locators tracking nodes",* ACM Conext'07
- Mobility prediction
- Traffic and usage models of users or regions

Adaptive and/or opportunistic network deployment

- Most focus on algorithm, limited interests in network deployment?
  - Adaptive and/or Opportunistic deployment of infrastructure nodes (static or mobile) could help in connecting people
    - Data collection, dissemination of software update, data delivery

On-going work!

Adaptive and/or opportunistic network deployment

In collaboration with:

Marcelo Dias de Amorim from University Paris VI, France
Greg Bigwood from University St. Andrews, Irland
Mathias Boc from CEA, France
Julinda Stefa, from University of Sapienza, Italy
Marco Barbera, from University of Sapienza, Italy

Potential applications ➡ ***new abilities*** *for collecting data*

- *Global sensing: human-centric sensing applications, participatory sensing, etc*
  - *"What is Participatory Sensing?"* (by Deborah Estrin, UCLA, http://radar.oreilly.com/)

"…systems to enable people with mobile phones to systematically observe, study, reflect on, and share their unique world."

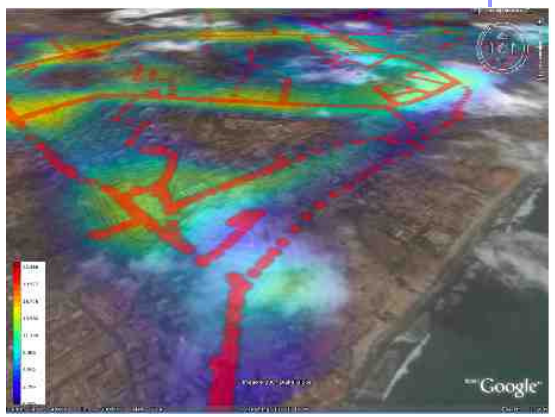
CENS: Participatory Urban Sensing

- Huge amount of generated traffic (data)
  - Ex.: "Track people in real time" application
    - 40-bytes packet with GPS per user, 10,000 subscribes to the service: 1.4Gbytes/hour
    - … the next wave of traffic in the Internet

Global Sensing application challenge: **data collection**

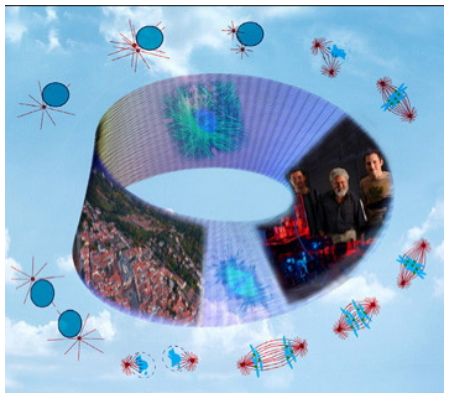
What about the literature?

- In Global Sensing literature: proposed architectures and middleware focused on:
  - the application features or do not address the management of large amount of collected traffic
    - [Metrosense, ACM SenSys'06], [MIT Senseable City Lab], [CENS]
- In Delay Tolerant Network literature: most focus on forwarding, limited interests in network deployment
  - [Maxprop], [Prophet], [Spry-and-focus], etc
- In Mobile Ad Hoc and WSNs literature:
  No architecture deployment leveraging social interaction or topography of nodes
  - [Data Mule], [Data Ferrying], [Smart-Tag]

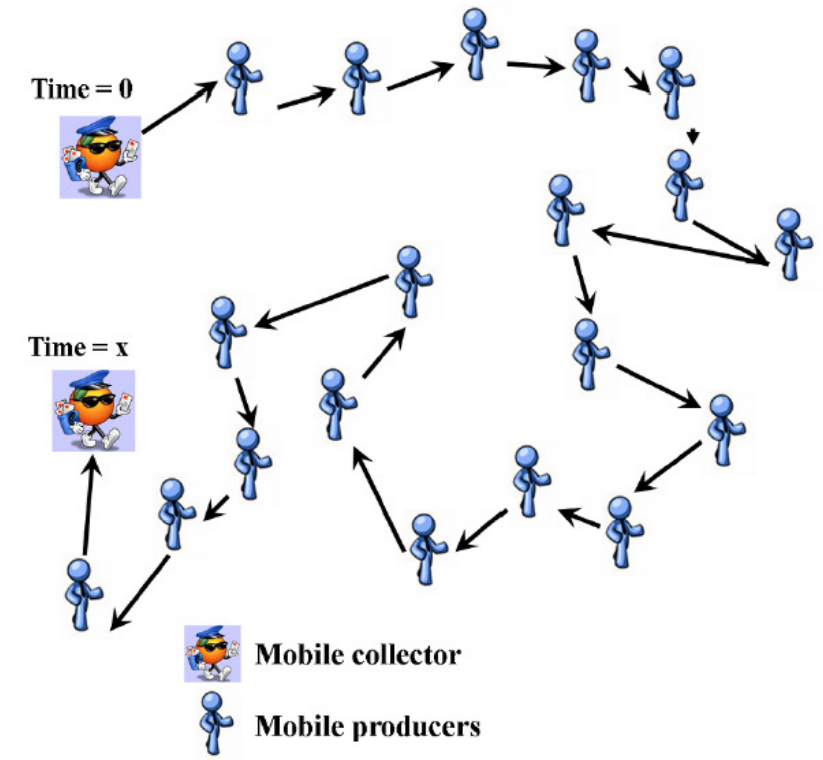


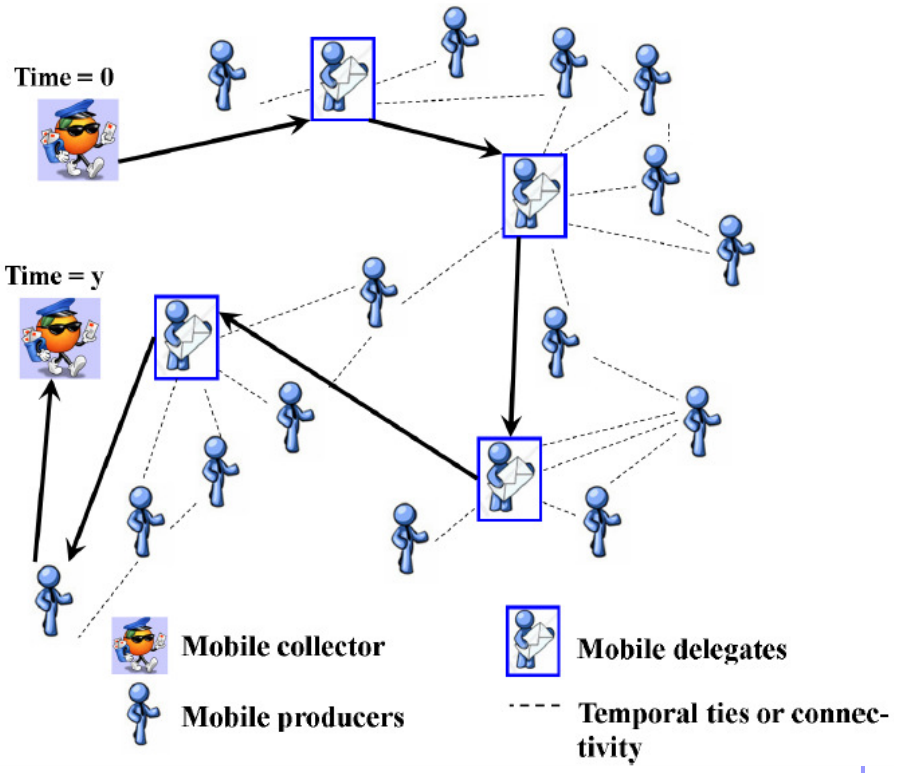
Adaptive and/or opportunistic network deployment

- Infrastructure nodes (static or mobile) could help in providing network services for producer nodes
  - Data collection, dissemination of software update, data delivery
- How producer nodes interact?
- How the network is used?
- How resource demanding are the network areas?
  - Intelligent and adaptive network deployment based on:
    - Habits of users
    - Traffic load and usage models of users or regions
    - Communication conditions of users or regions



Problem: Data collection in DTN-like global sensing scenarios





- How to deploy collectors?
  - Limit cost of deployment,
  - Collection guarantees
- How to visit nodes (when and where) to guarantee full coverage?

- How to select delegates?
- How to visit delegates (when and where) and missed nodes?

Goals: Opportunistic data collection through delegation

- Take advantage of social knowledge about users and regions:
  - Interaction between users
    - What are the most "important" nodes?
  - Topography behavior of users: mobility pattern
    - What are the most "important" regions in the network?

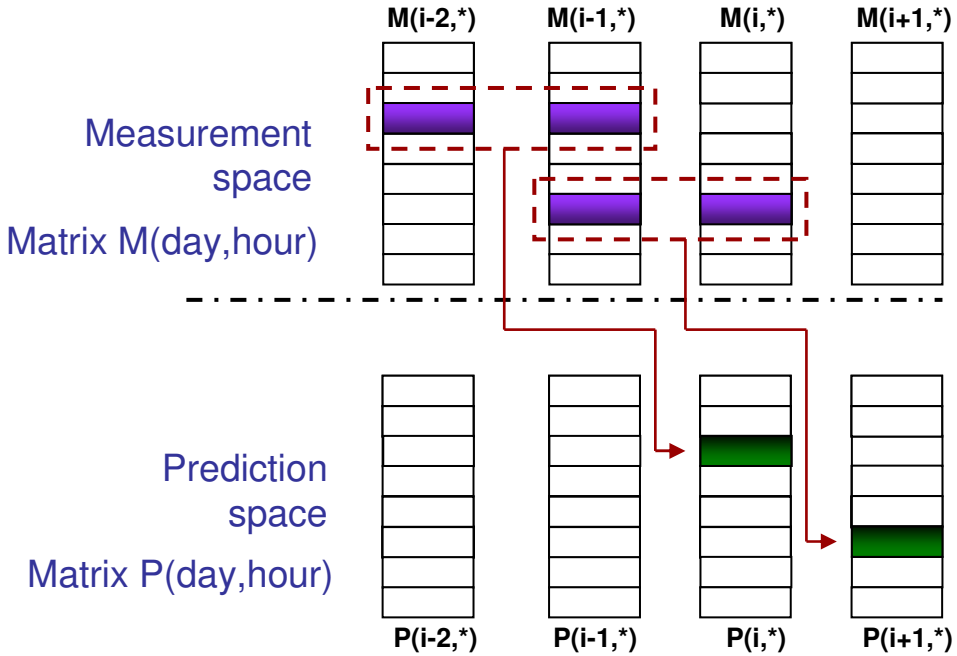
For delegates selection

For collectors trajectory design

- Motivation:
  - Human social relationship provide quite a stable network of contact opportunities
  - Individuals are often linked by a short chain of acquaintances and encounters are sufficient to build a connected relationship graph

How to know in advance the nodes' encounters?

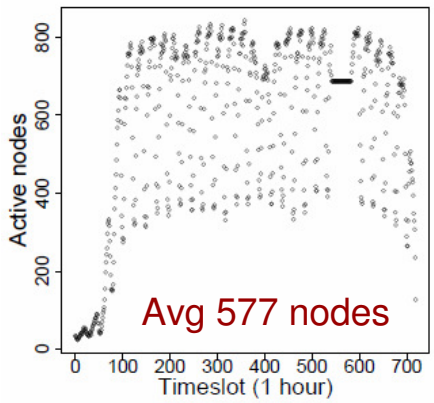
- Simple prediction strategy: quick computation, short measurement



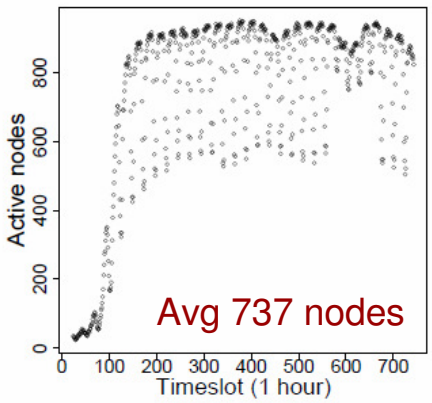
- History window of 2 days
- Based on 2 previous slot history (1-hour slots)

- Two real measured traces
  - Dartmouth College campus
    - 1000 nodes: avg. number 577 active nodes, 6 contacts per node/per hour
  - Taxi cabs in San Francisco
    - 542 nodes: avg. number of 506 active nodes, 130 contacts per node/per hour

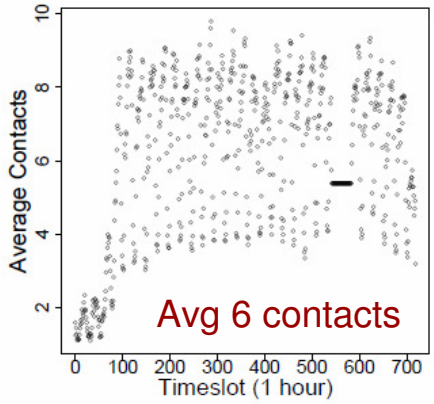
Prediction vs Measurement comparison



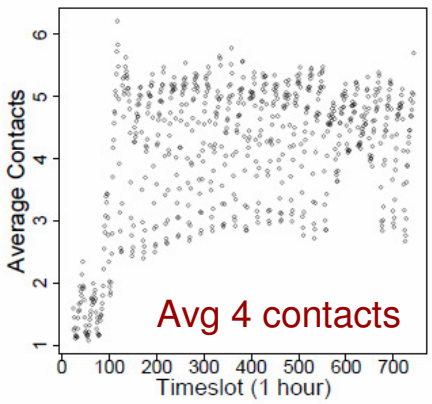
(a) Measured traces.



(b) Predicted traces

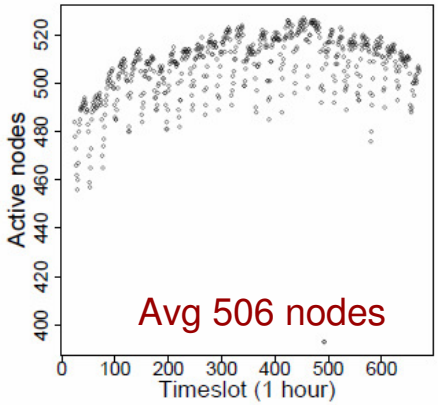


(c) Measured traces.



(d) Predicted traces.

Dartmouth trace



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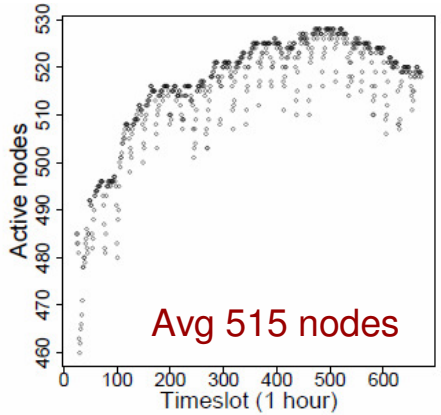
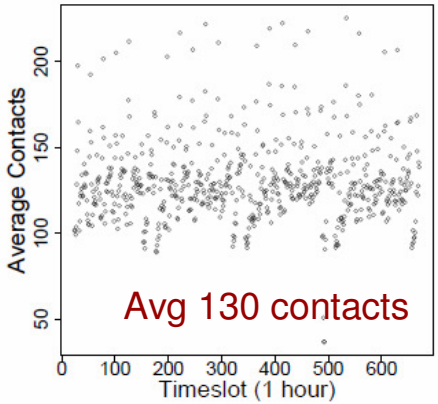
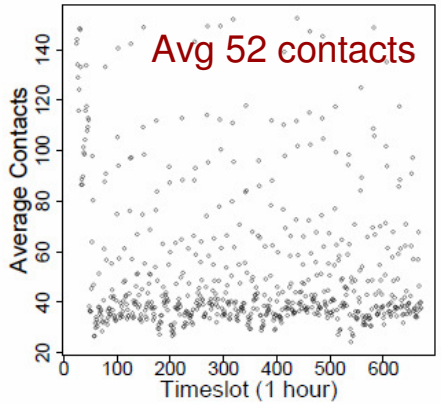


(b) Predicted traces.



(c) Measured traces.



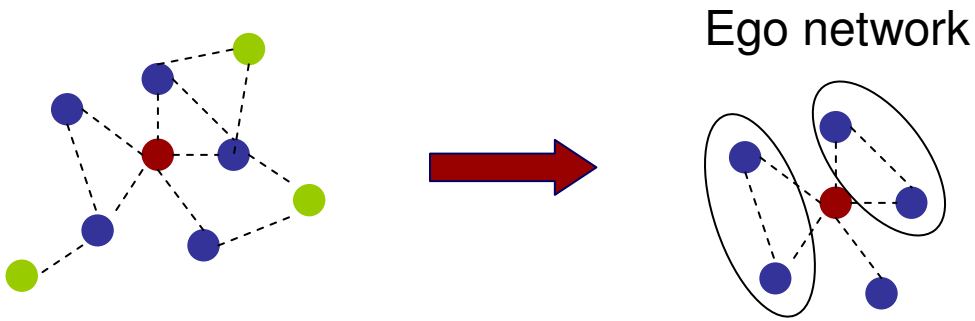
(d) Predicted traces.

Taxi trace

Delegates selection strategies

- Different Social-inspired metrics
  - Degree centrality (DC)
    - Select as delegates Δ most popular nodes
  - Betweenness centrality (BC)
    - Select as delegates Δ higher betweenness nodes
      - Nodes that often lie on the paths linking other nodes: bridging nodes
  - Betweenness and Degree centrality (BDC)
    - Select as delegates 1/Δ most popular nodes + 1/Δ higher betweenness nodes

- With nodes having different topology awareness
  - Complete network (C)
  - Ego-centric networks (E)



Delegation selection - Results

- Benchmark approach: Minimum Dominating set
  - 2-hop knowledge, define size of Δ set
- For delegation selection applied in time slots of 1 hour
- Average results for:
  - Benchmark, DegreeC-Complete, BetwC-Complete, BDC-Complete

Data set	Traces	$\|\Delta\|$	% delegates
Dartmouth	measured	304.36	56.14
	predicted	508.43	70.97
Taxi	measured	326.06	64.22
	predicted	419.33	81.38

- Average results for:
  - DegreeC-Ego, BetwC-Ego, BDC-Ego

		DC-E		BC-E		BDC-E	
Data set	Traces	$\|\Delta\|$	% delegates	$\|\Delta\|$	% delegates	$\|\Delta\|$	% delegates
Dartmouth	measured	159.62	32.6	110.06	21.78	174.75	35.29
	predicted	255.22	38.9	190.88	28.34	292.54	44.02
Taxi	measured	33.15	6.57	31.67	6.27	37.71	7.48
	predicted	84.93	16.48	80.58	15.64	97.93	19.01

Delegation selection - Results

Dartmouth College

Strategy	% missed	% delegates
Benchmark	5.7	70.97
DC-C	9.22	70.97
BC-C	7.31	70.97
BDC-C	8.04	70.97
DC-E	11.85	38.9
BC-E	15.7	28.34
BDC-E	10.67	44.02

Taxi Cabs

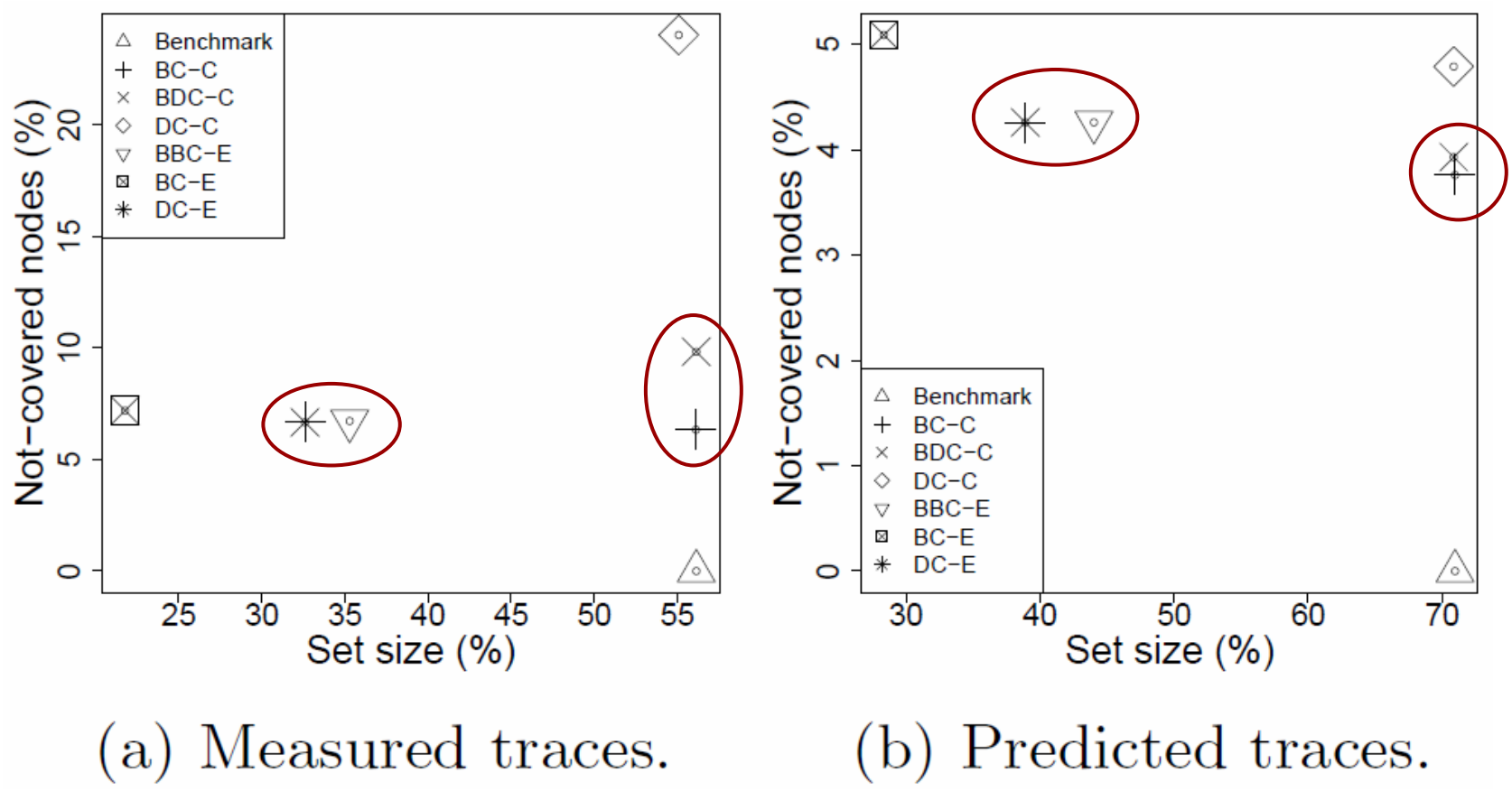
Strategy	% missed	% delegates
Benchmark	0.08	81.38
DC-C	0.59	81.38
BC-C	0.13	81.38
BDC-C	0.23	81.38
DC-E	1.88	16.48
BC-E	1.91	15.64
BDC-E	1.48	19.01

Missed nodes: when using selected delegates at the measured traces
Selected delegates: from the predicted sets

- Ego: equivalent coverage to benchmark, smaller number of delegates
- Taxi traces: more contacts, better results
- Get smaller delegate sets, if time slots of 24 hours are used

Delegation selection - Results

Dartmouth College

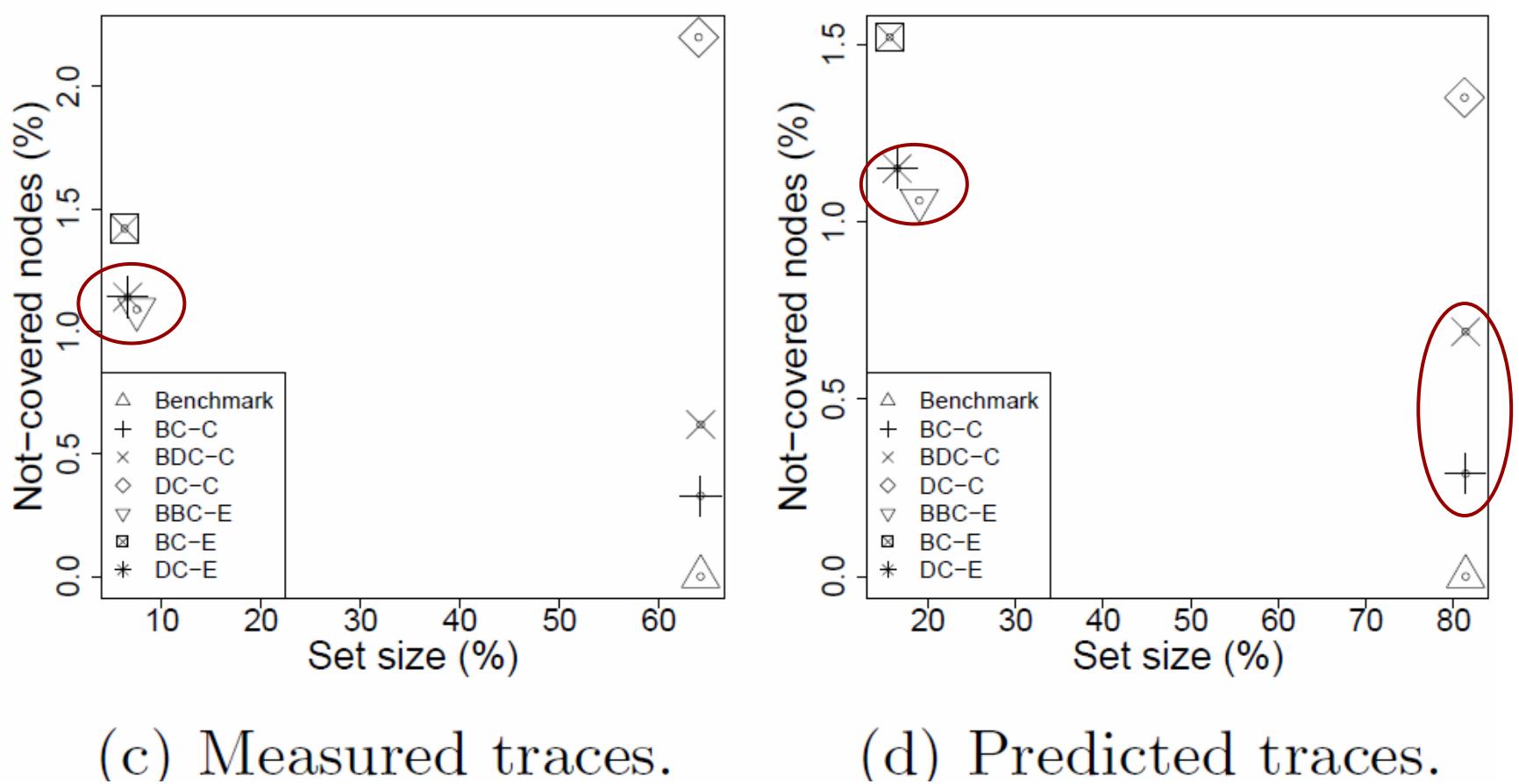


(a) Measured traces. (b) Predicted traces.

- Prediction provides equivalent results in terms of clustering properties

Delegation selection - results

Taxi Cabs



- Despite differences in mobility, 2 traces present similar clustering properties of strategies: BDC and BC provide a good tradeoff

Opportunistic data collection through delegation

- Conclusions
  - Two-tier architectures can help improving network services in global sensing systems and DTN-like scenarios
    - Much can be extracted from the inherent nodes mobility
  - Our prediction strategy is effective, though simple
  - Local knowledge of the network (ego) is more than enough to achieve high collection ratios

- On-going work in submission:
  - Use of synthetic traces generated by the SWIM simulator
  - Consider duration and identity of contacts in the selection strategies
  - Consider centrality of regions and combine it with topographic behavior of delegates
  - Design of trajectory of collectors in time and space to visit the delegates and missed nodes

- On-going work with researchers from Univ. Sapienza and Univ. of Paris IV

"SWIM: A simple model to generate small mobile worlds," IEEE Infocom 2009

Obrigada!

Questions?