Empirical Evaluation of Hybrid Opportunistic

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Joint work with Anders Lindgren and Jon Crowcroft (University of Cambridge)

Introduction

- Two trends observed
  - Lots of work done on opportunistic networking/DTN
  - Coverage of WiFi and similar technologies increasing
  - So what's the point of opportunistic networks???
    - We have infrastructure!
  - Installing a wired base station costs as high as US$5,000!(Jupiter Research)
- Can opportunistic communication and infrastructured networks complement each

Introduction (2)

- Under which conditions is opportunistic communication necessary or useful for network operation?
  - Different levels of participation among mobile nodes.
- How is the performance of opportunistic networks improved by the addition of partial infrastructure?

Application Scenarios

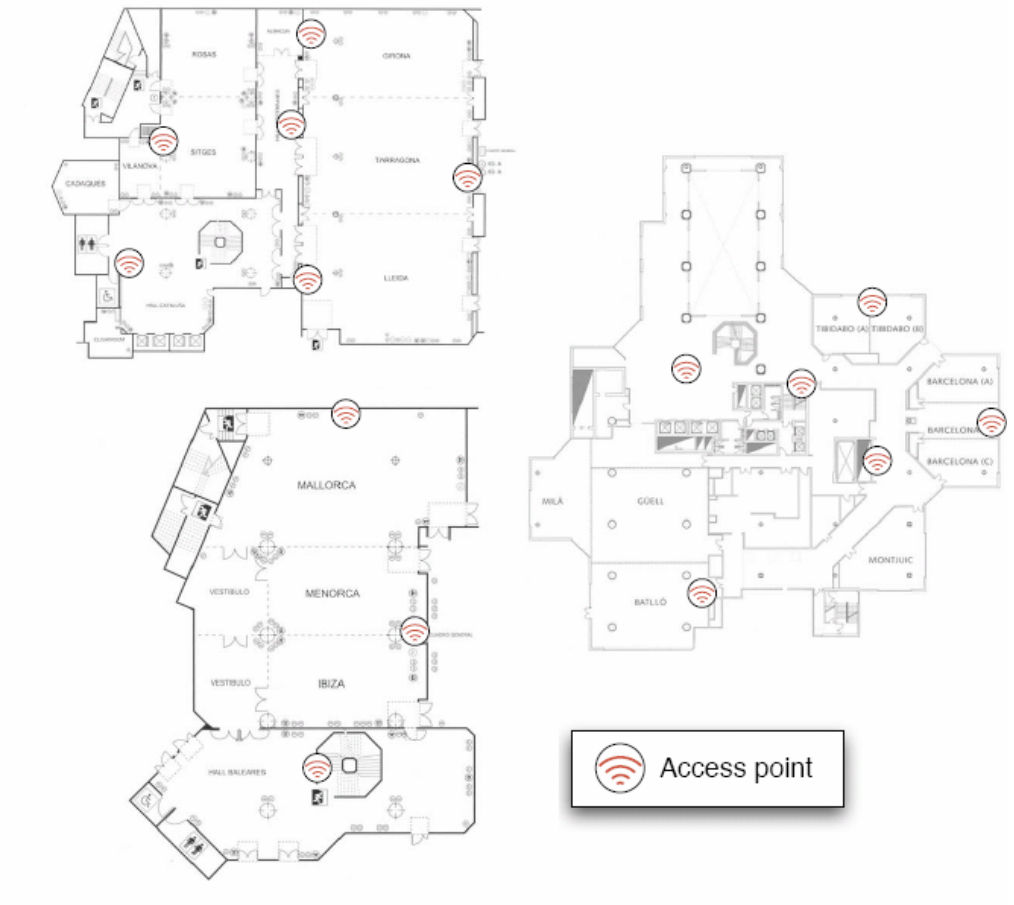
- Asynchronous Messaging
  - Peer-to-peer exchange of messages between mobile nodes
  - Direct contact, opportunistic forwarding, infrastructure support
- Data Push
  - Data delivery service (e.g. email delivery)
  - Messages generated at infrastructure
  - Delivered directly to destination upon contact with infrastructure, or with opportunistic forwarding

Datasets

Experimental Dataset	Infocom06	Reality	Kaist
Device	iMote	Phone	Phone
Network Type	Bluetooth	Bluetooth	GPS
Duration (days)	3	21	0.33
Granularity (seconds)	120	300	10
Number of experimental	98	97	92
Number of internal	191,336	11,962	40,218
Average no. of contacts/pair/day	6.7	0.061	14.412

- Infocom06, MIT Reality Mining, NCSU Kaist
- 9 months for Reality

Access point placement (1)



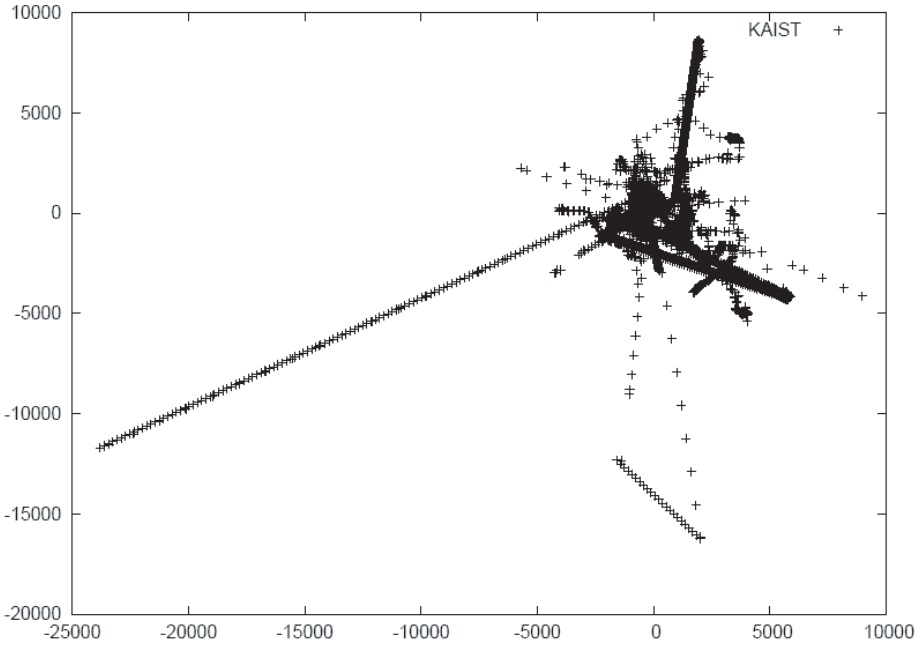
- Infocom06
- Conference reception desk, conference rooms, hotel concierge, hotel bar, the lifts of the hotel

Access point placement (2)

- Reality Mining
- Cellular tower logs
- In total 31,545
- Top 253 mostly accessed towers (the cell towers that have at
- least 100 contacts with mobile nodes logged)
- Mimic APs

Access point placement (3)

- Kaist
- GPS receivers take readings every 10 seconds
- Position accuracy < 3 meters for 95 percent of the time
- No physical deployment of wireless Aps
- Select area with most of the mobilities : (-5000, -5000) to (5000, 5000)
- Uniformly deploy virtual APs wi



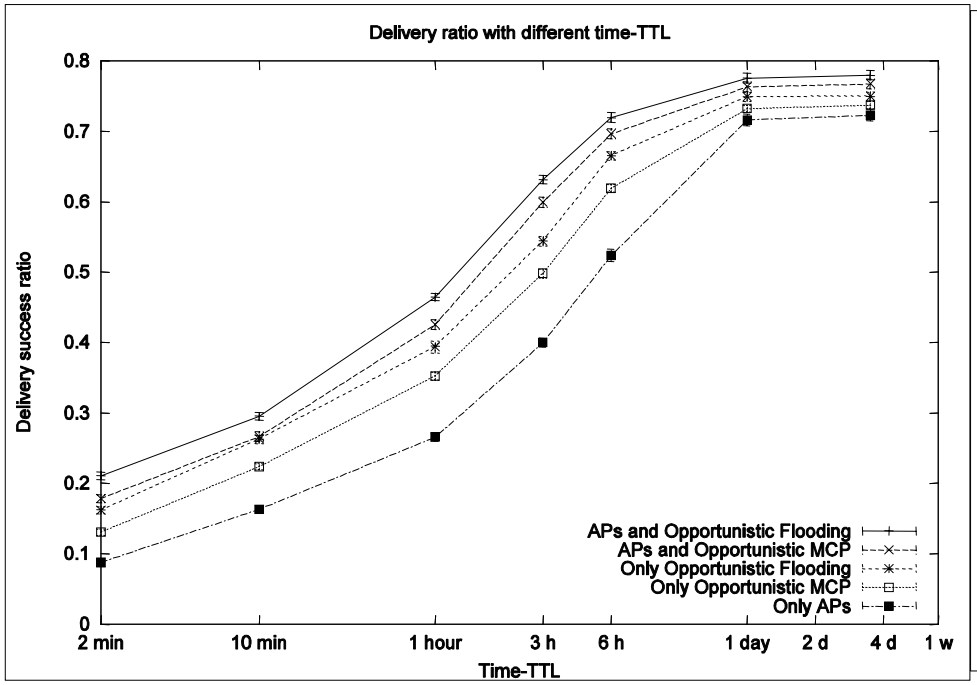
Simulations

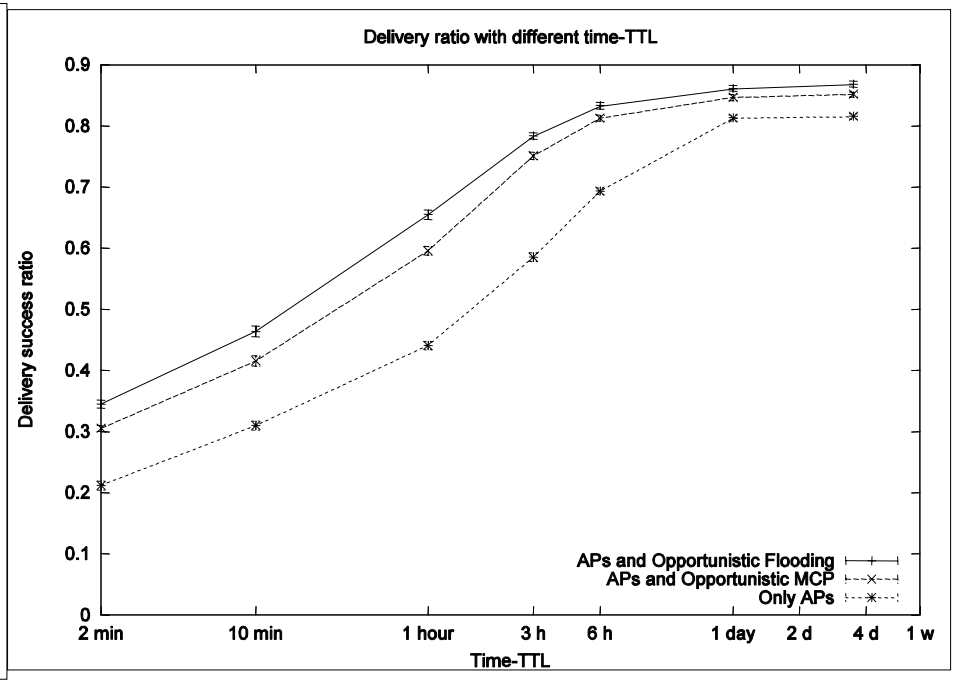
- HaggleSim
- Trace driven simulator
- Forwarding schemes
  - Opportunistic flooding (epidemic)
  - Opportunistic MCP (Movie-Cricket-Politics☺?)
  - Only APs
- Metrics
  - Throughput, given TTL
  - Utility
    - $U(O) = \frac{T(O + I) - T(I)}{T(O + I)}$

Results and Evaluations

- Delivery ratio
- Utilities of opportunistic network
- Utilities of APs

Delivery - Infocom06 Dataset

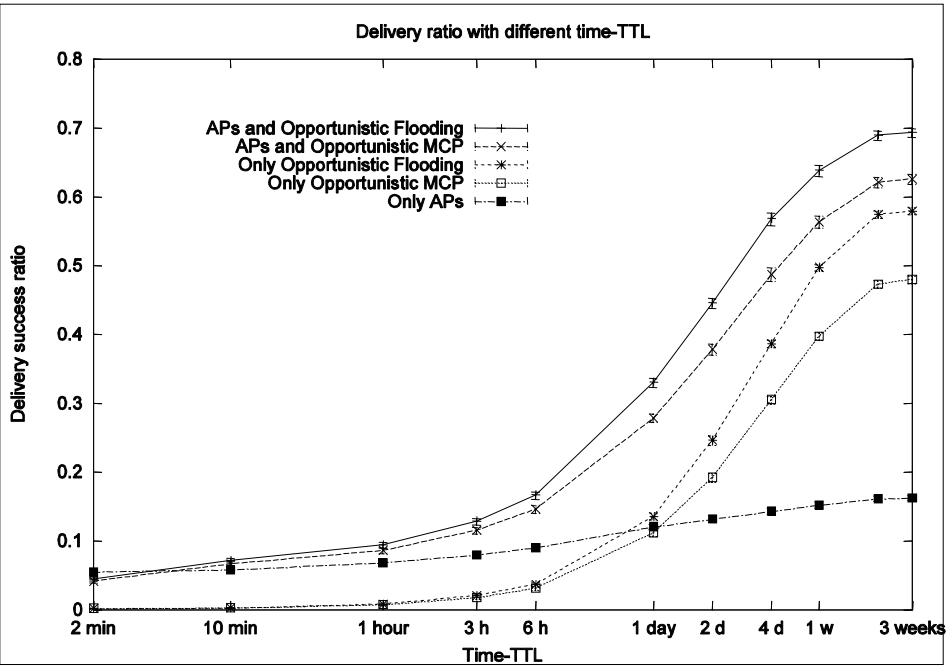


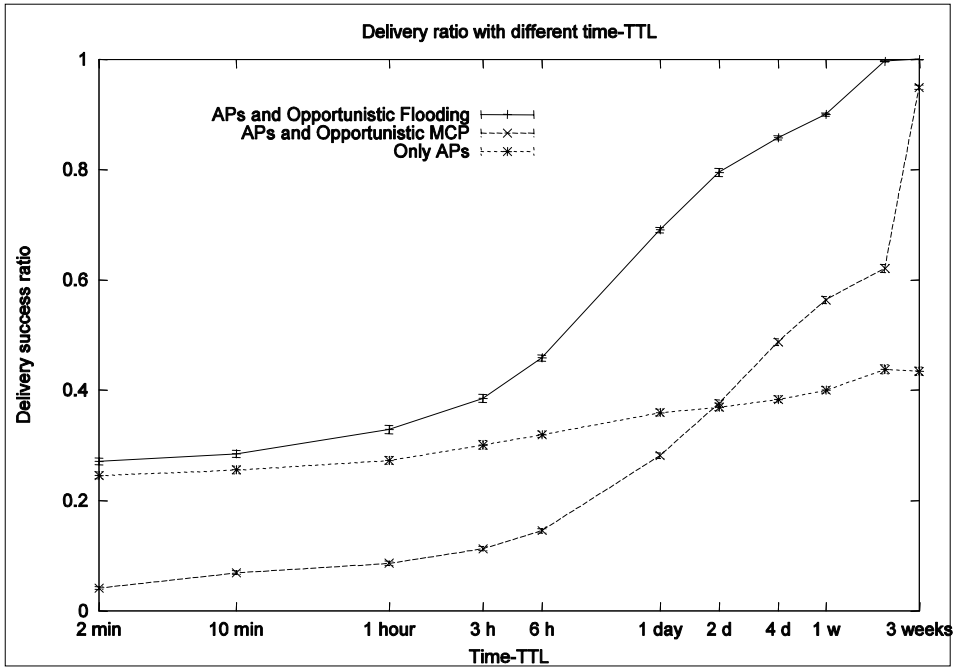


Asynchronous Messaging

Data Push

Delivery - Reality Dataset

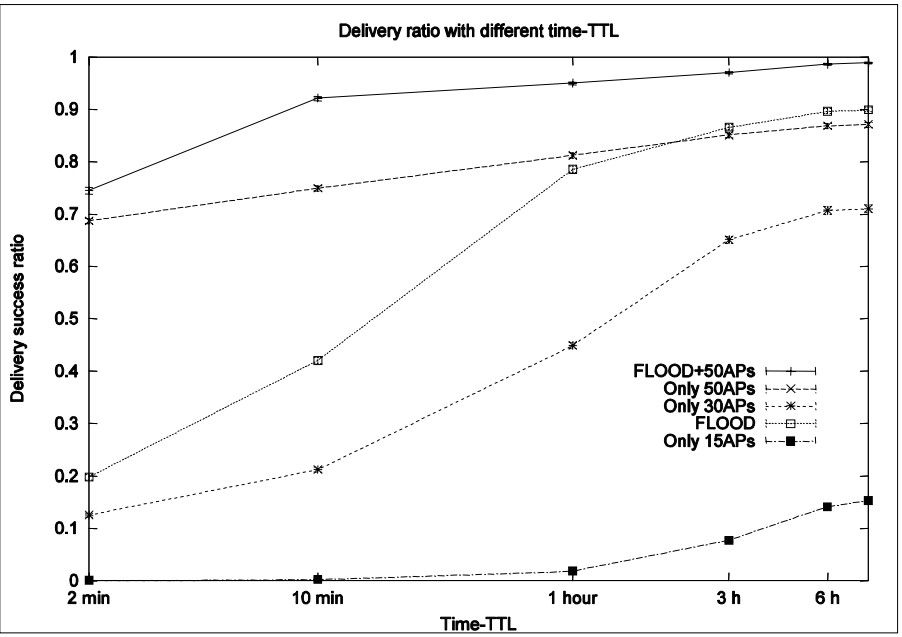


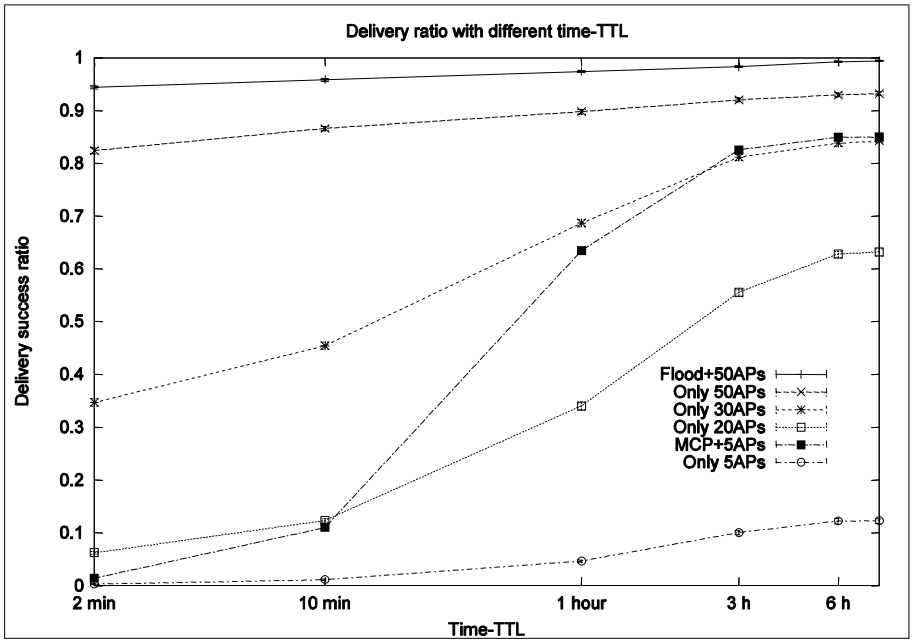


Asynchronous Messaging

Data Push

Delivery - Kaist Dataset

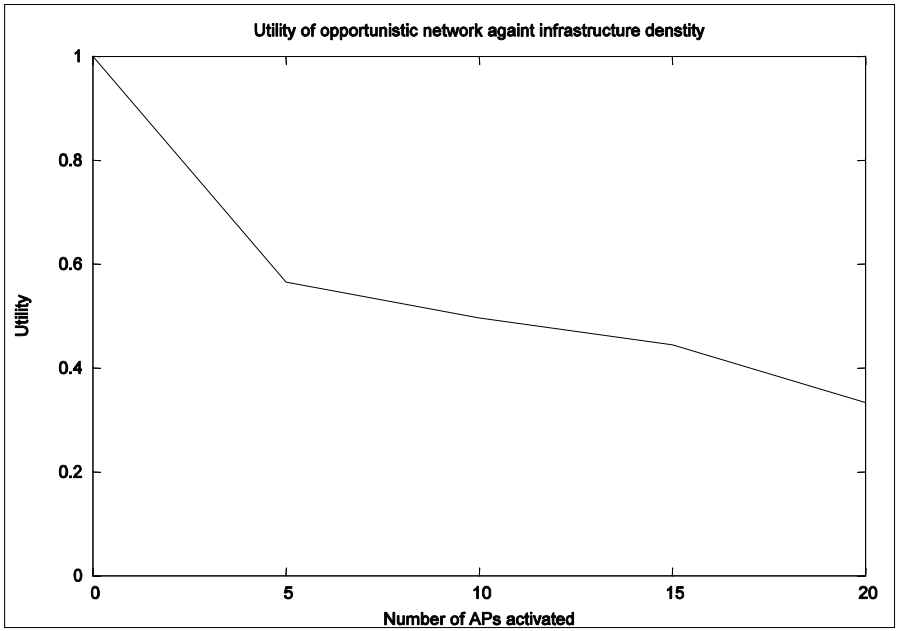


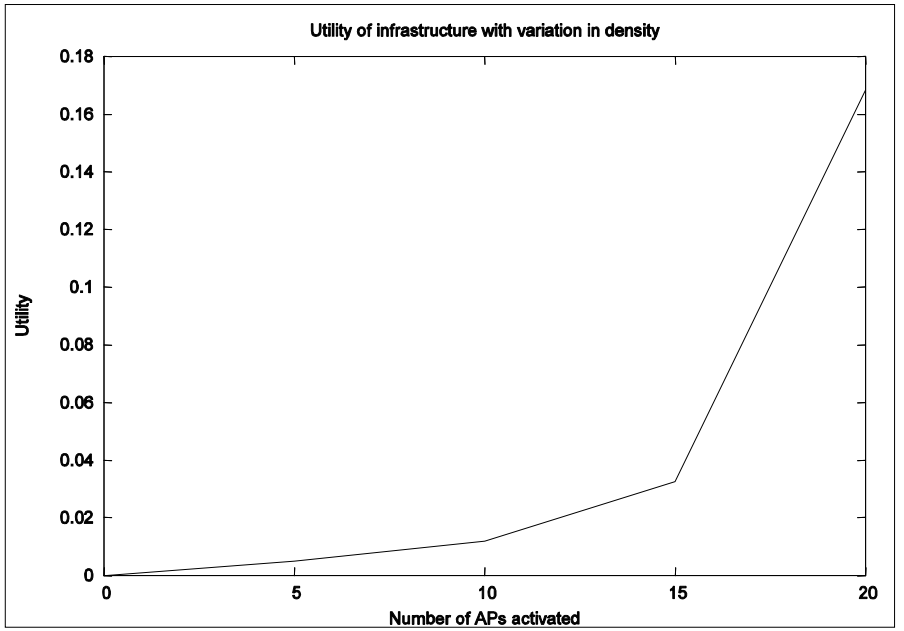


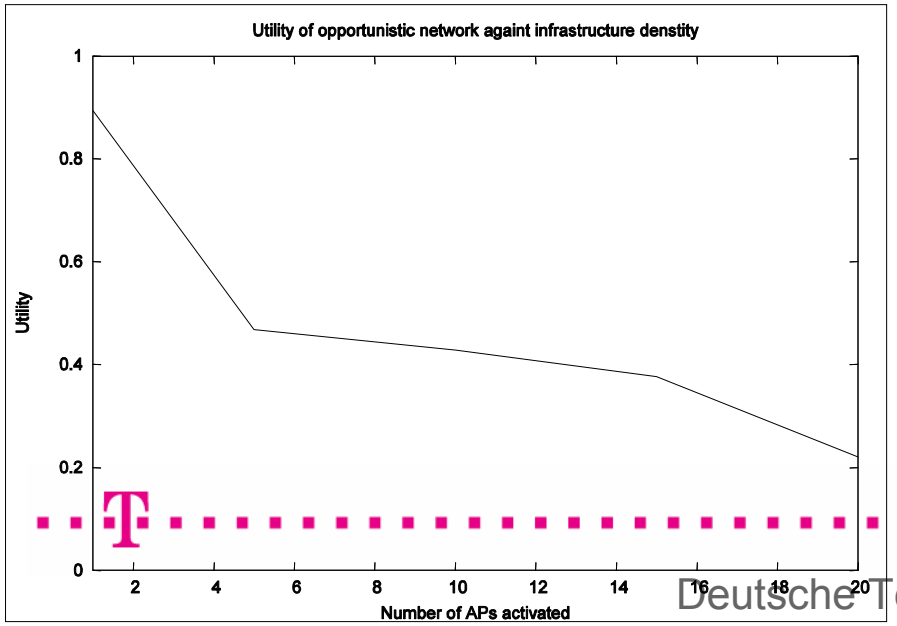
Asynchronous Messaging

Data Push

Utilities – Infocom06 Dataset





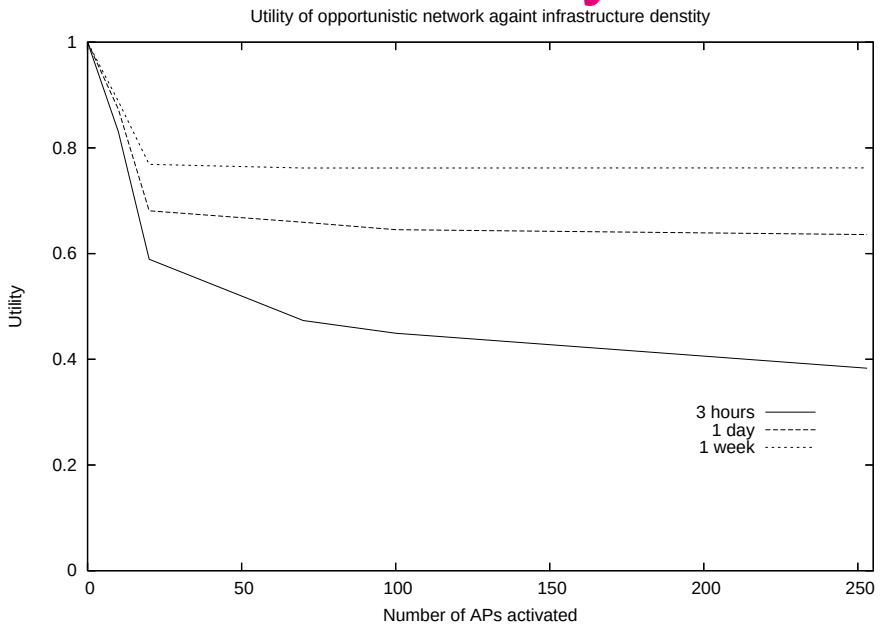


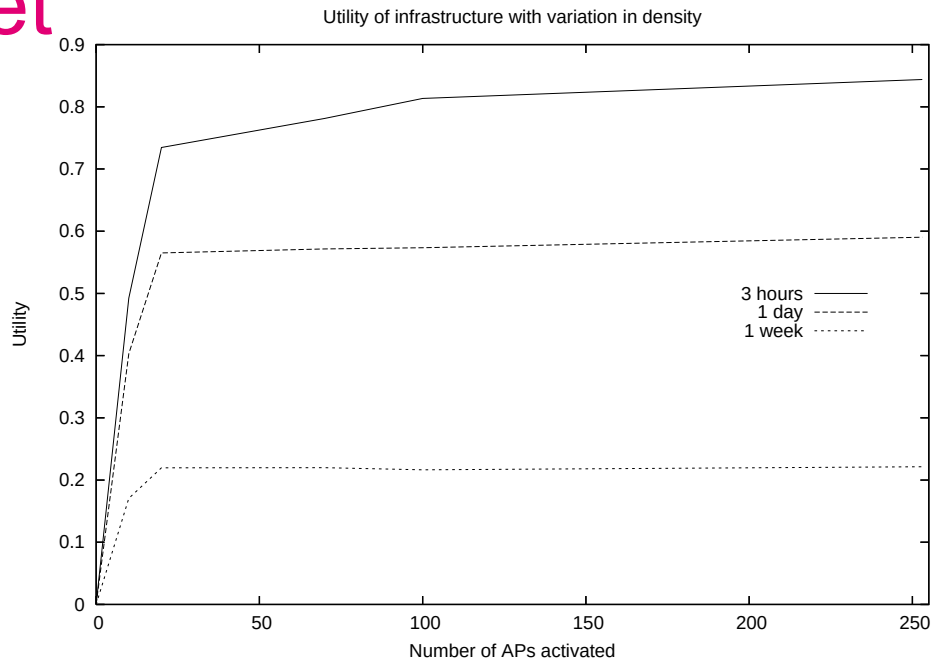
Network Utility:

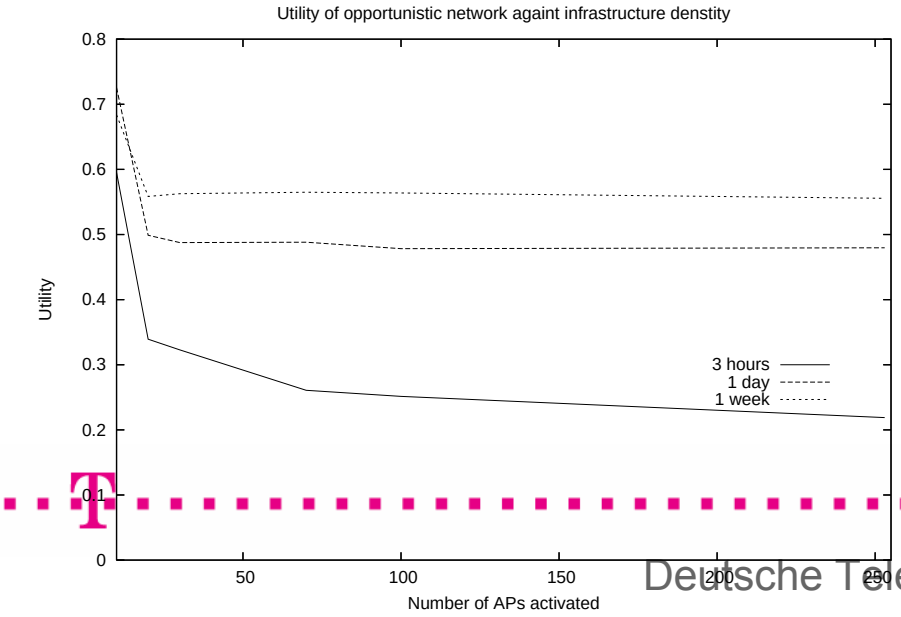
$$U(I) = \frac{T(O+I) - T(O)}{T(O+I)}$$

- Left-up : Utility of OppoNet (messaging)
- Left-down : Utility of OppoNet (data-push)
- Right : Utility of APs (messaging)

Utilities – Reality Dataset







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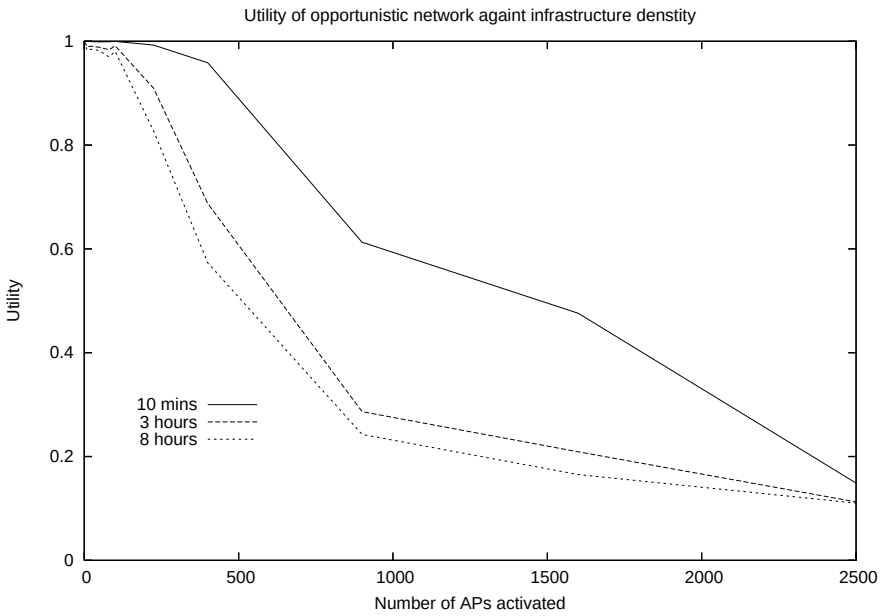
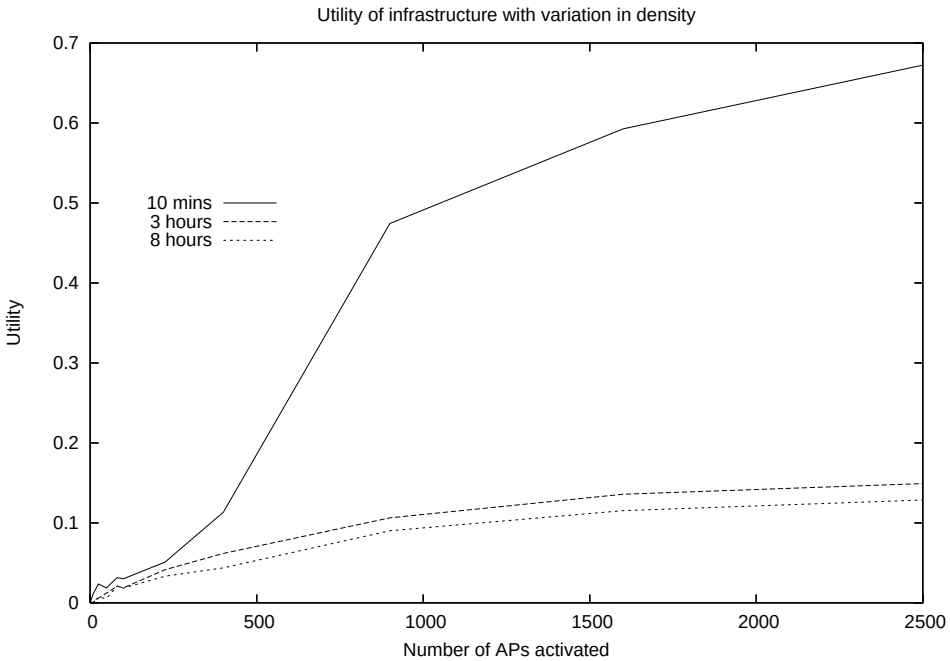
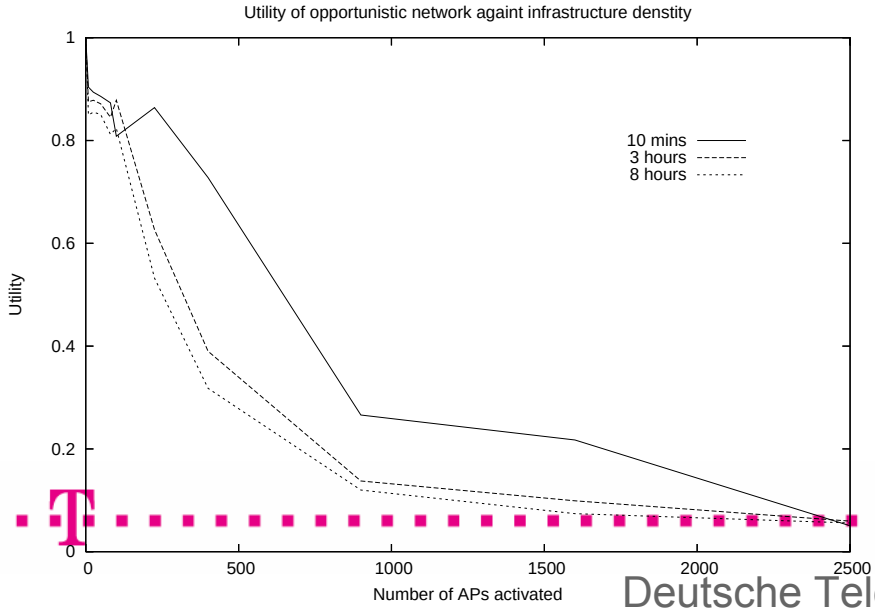
Utilities – Kaist Dataset







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Conclusions and Future Work

- Opportunistic communication can yield a significant increase in network performance, even if infrastructure is present
  - Supported by three experimental datasets
- Can save a lot of money from building a lot of expensive infrastracture, i.e. 900 APs cost US$4,500,000.
- Compare our oberservation with previous theoritical works.
- Look for more cost-effective way of infrastructure deployment strategies, e.g. consider human mobility and city topology.

Thank you!

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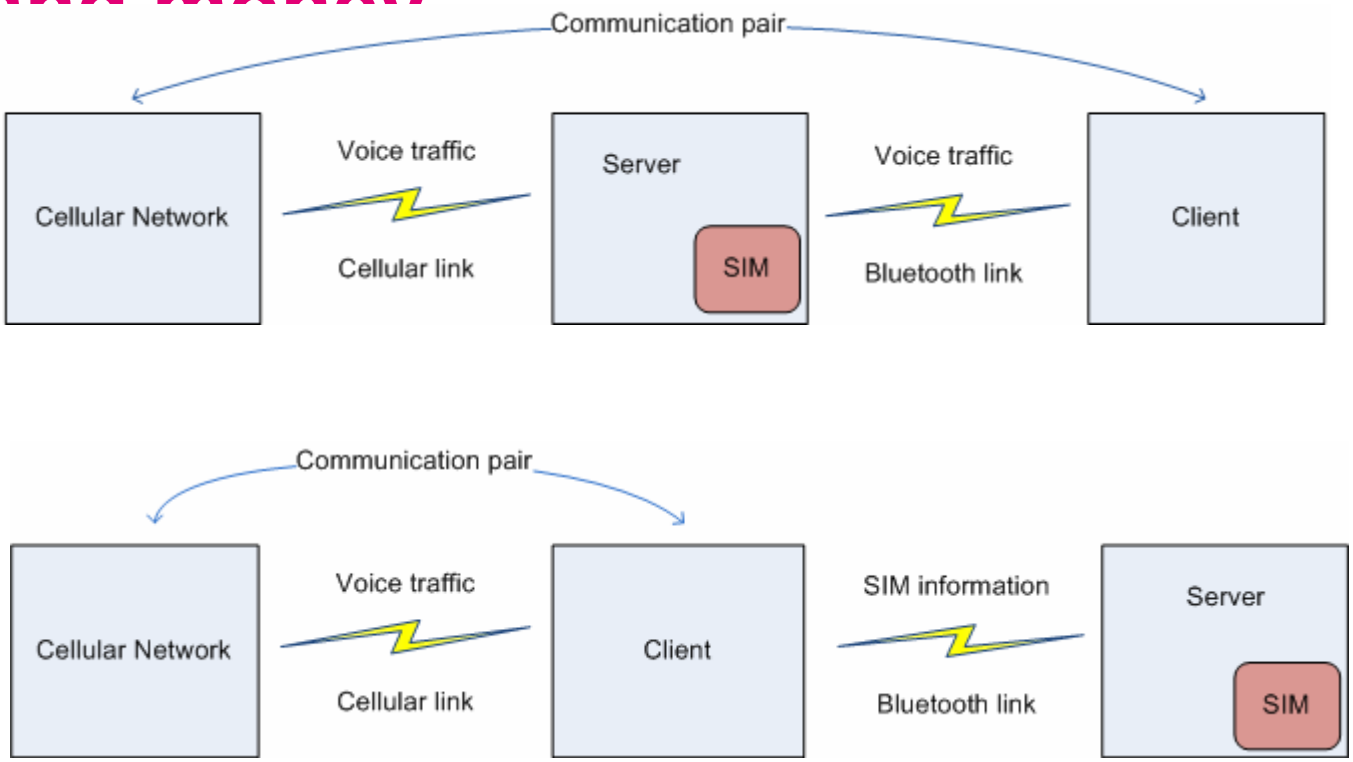
Additional slides

Sharing airtime with Shair avoids wasting time and money



Hui et al. HotMobile 2009