Performance and Energy Consumption Analysis of a Delay-Tolerant Network for Censorship-Resistant Communication

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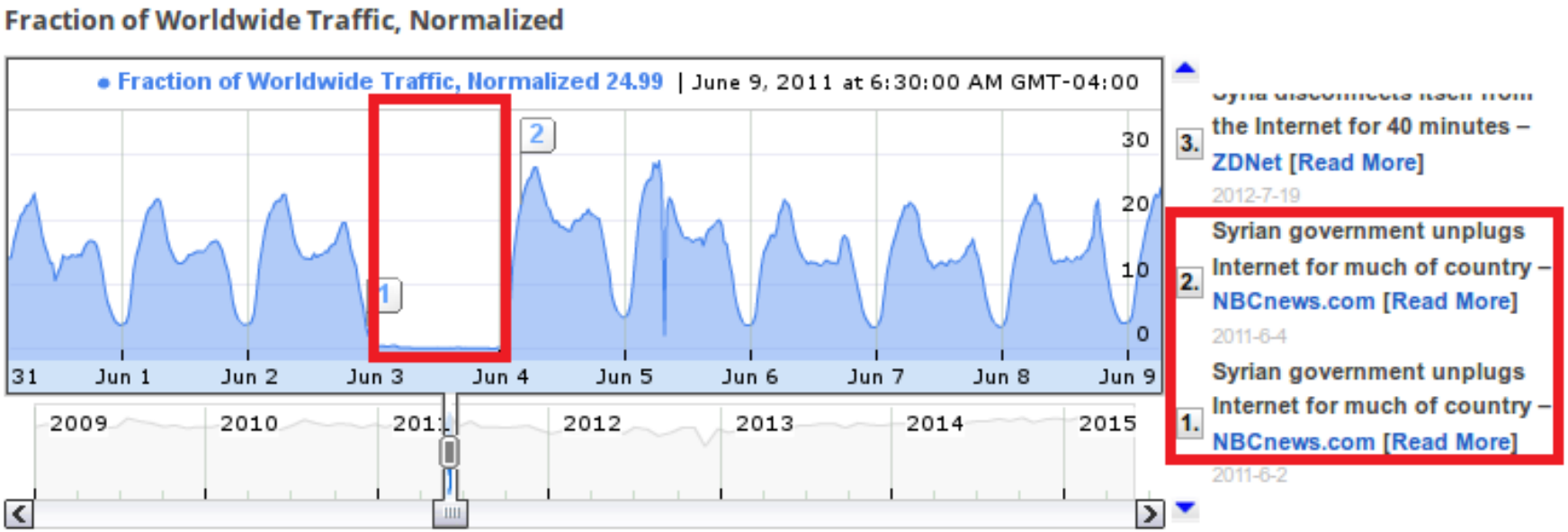
June 25, 2015

Outline

Surveillance and Censorship Threaten Privacy and Freedom of Speech on the Internet

Many countries are conducting active censorship at this moment...

Surveillance and Censorship Threaten Privacy and Freedom of Speech on the Internet



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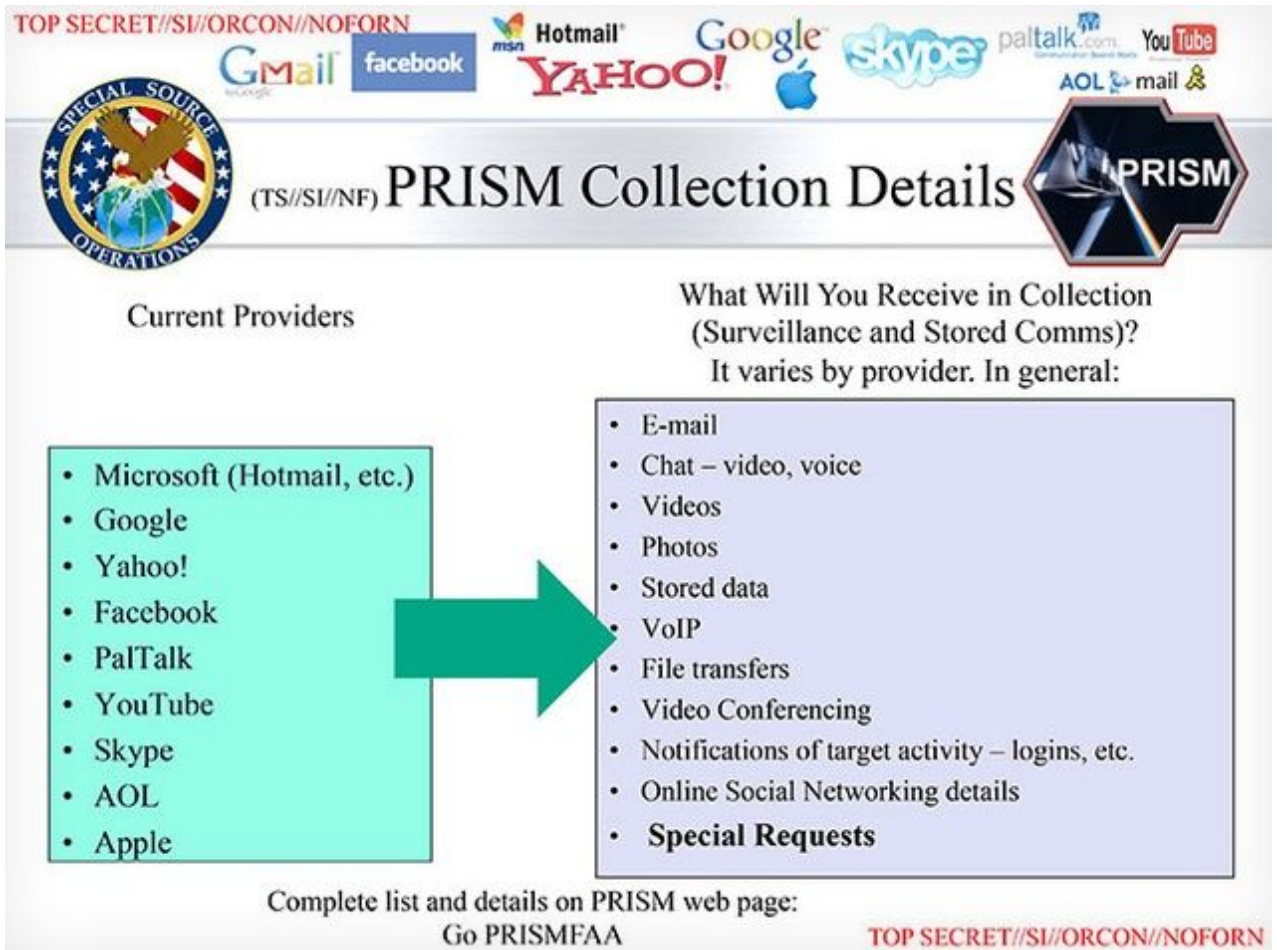
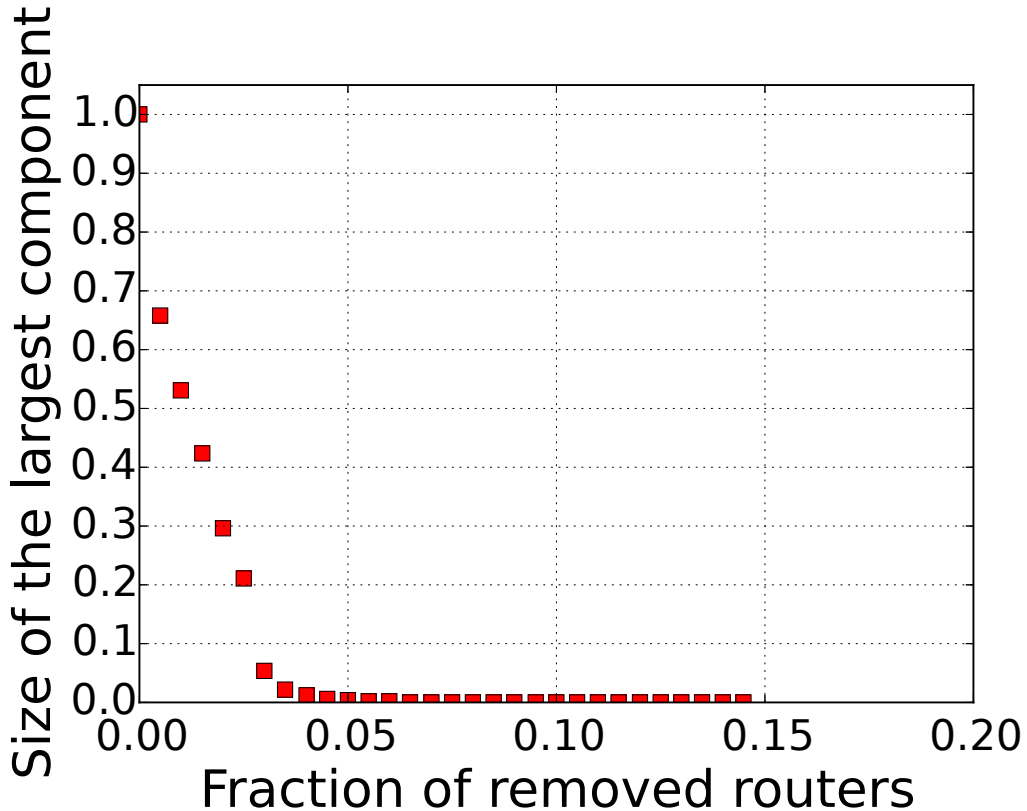


The Hierarchical Internet

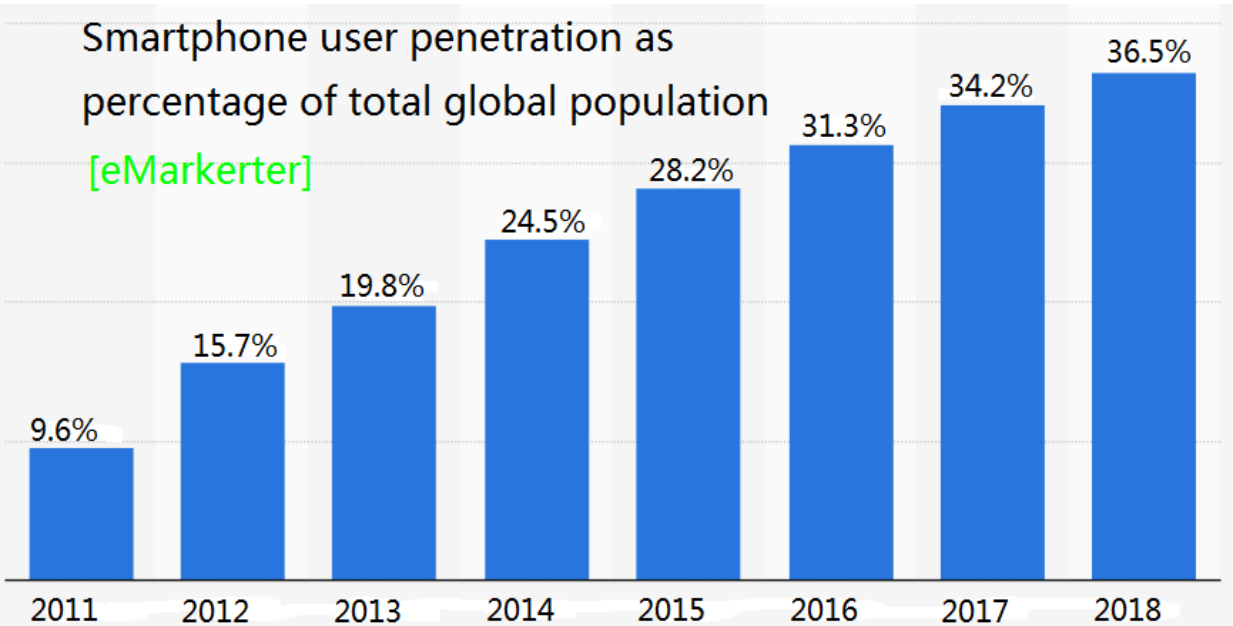


Fragmentation of the Internet as its most connected routers are removed.[Albert'00]

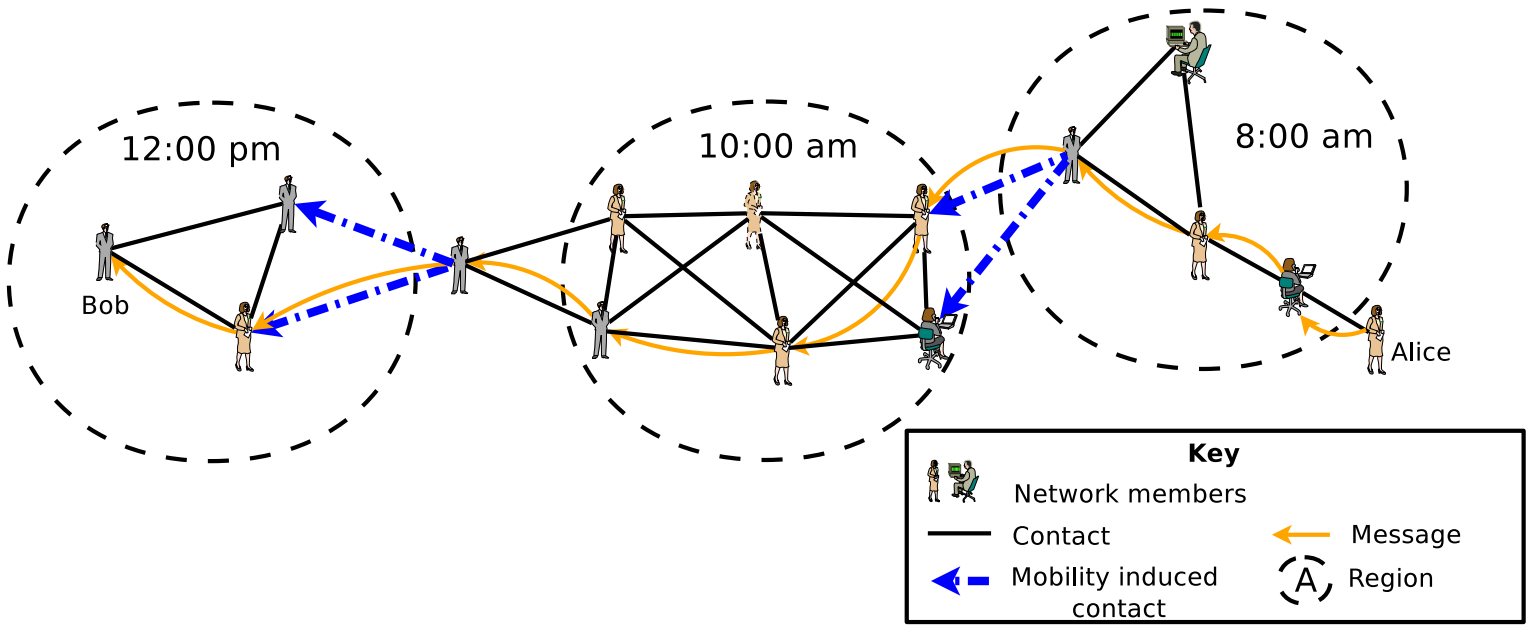
Infrastructureless Networks Composed of Commodity Mobile Devices

Advantages

- Very low technical/economical barrier to participation
- High availability



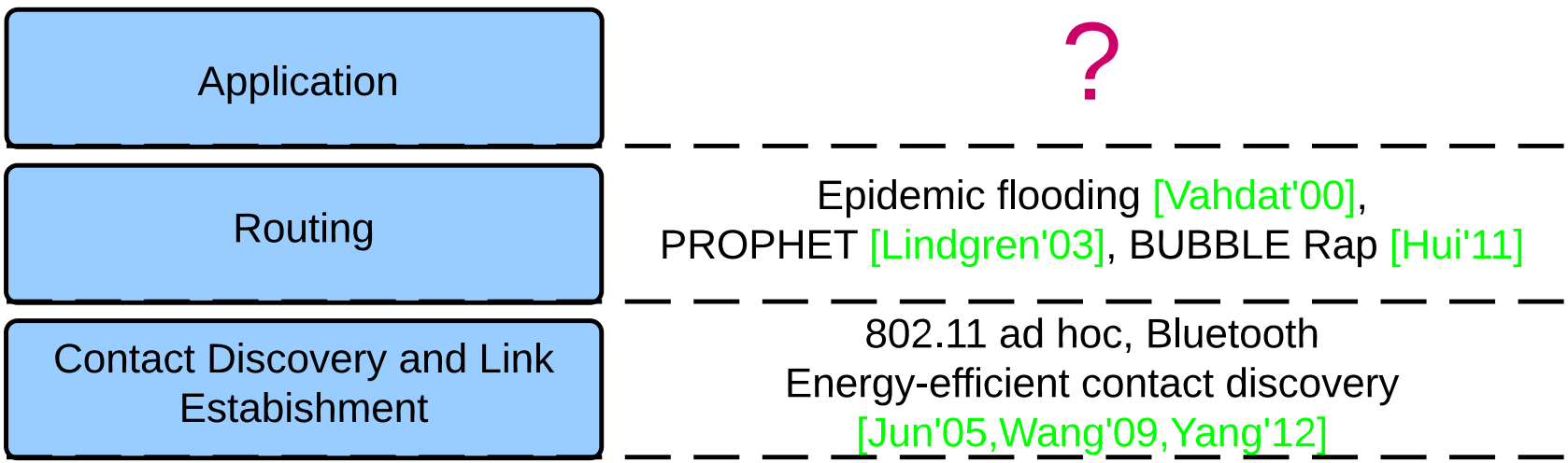
Infrastructureless Networks: DTNs Composed of Commodity Mobile Devices



Characteristics

- No end-to-end connectivity & long delay
- Resource-limited network nodes

DTNs Related Work



Our Contributions: Deployment-Based DTN Performance Characterization

Utility

Message delivery performance characterization

Robustness

Performance evaluation under blocking and censorship attacks

Overhead

Energy overhead modeling and evaluation

- measurement-based

Outline

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Why A New Deployment?

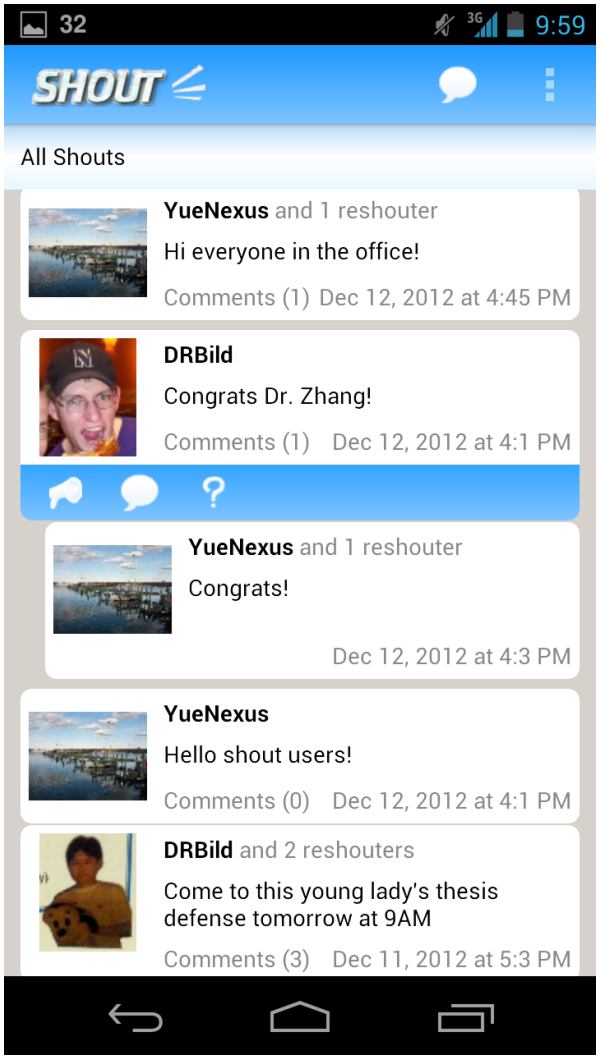
Existing traces are outdated...

	UCSD	Dartmouth
Year	2002	2003/2004
Device	PDA	Laptop/PDA
Duration (days)	77	114
# of devices	273	6,648

Likely cannot capture the mobility of modern smartphone users

- Dartmouth: mostly laptops
- UCSD: limited-functionality PDAs
  User engagement declined during study

1am: A Microblogging Service on DTN

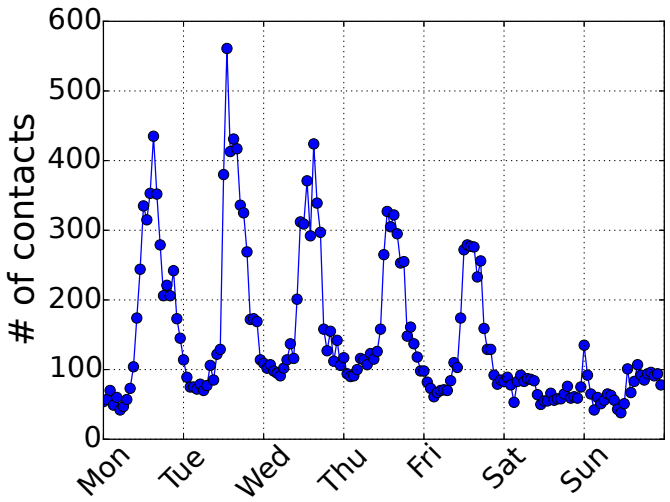


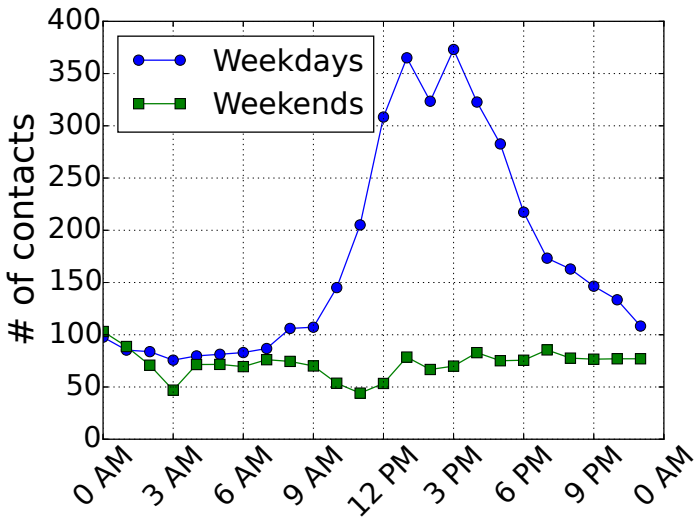
- A Twitter-like microblogging app
- Installed by UMich students and faculty members (291 in total)
- WiFi based contact estimation

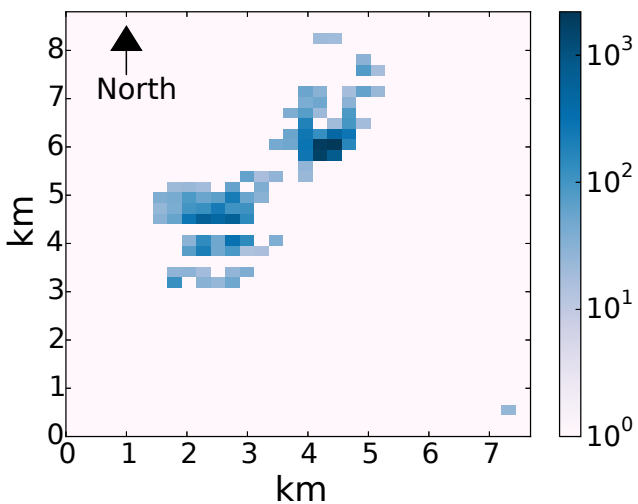
1am Trace Summary

	UCSD	Dartmouth	1am
Year	2002	2003/2004	2013
Device	PDA	Laptop/PDA	Smartphone
Duration (days)	77	114	31
Granularity (seconds)	120	300	114.5
Devices participating	273	6,648	111
# contacts/pair/hour	0.0028	0.000067	0.033

Temporal and Spatial Patterns of Contacts







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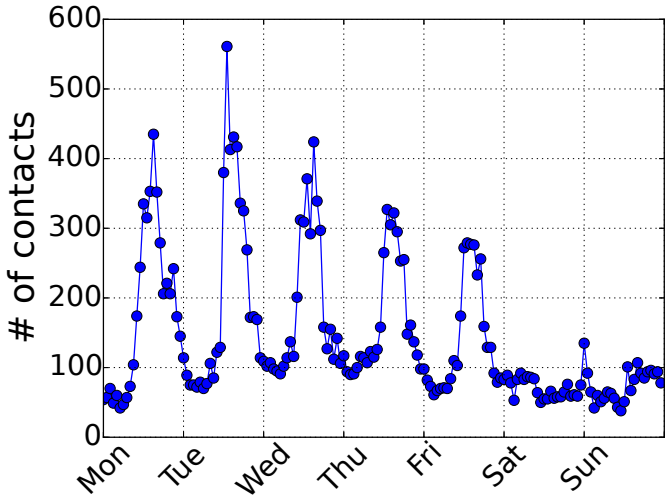

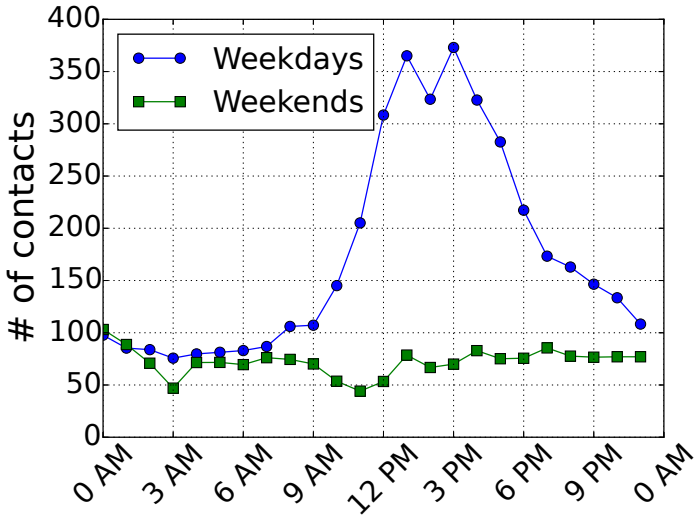

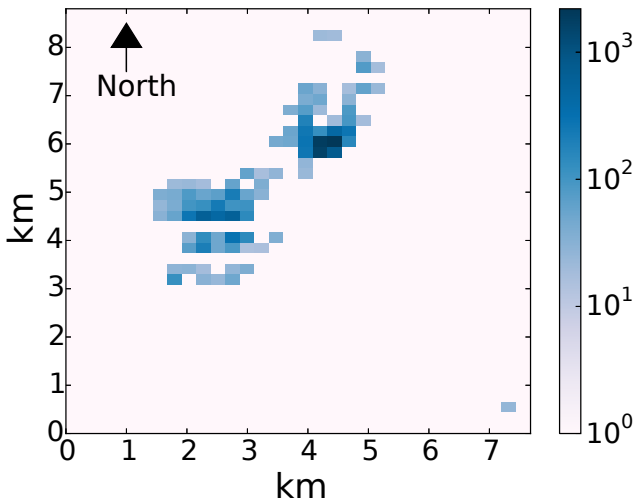

- Work- or study- related co-location
- Concentrated in very few buildings in the north campus

Outline

Evaluation Methodology: Trace-Based Simulation

Why simulation?

- Not enough user initiated messages
- Based on users' contact traces

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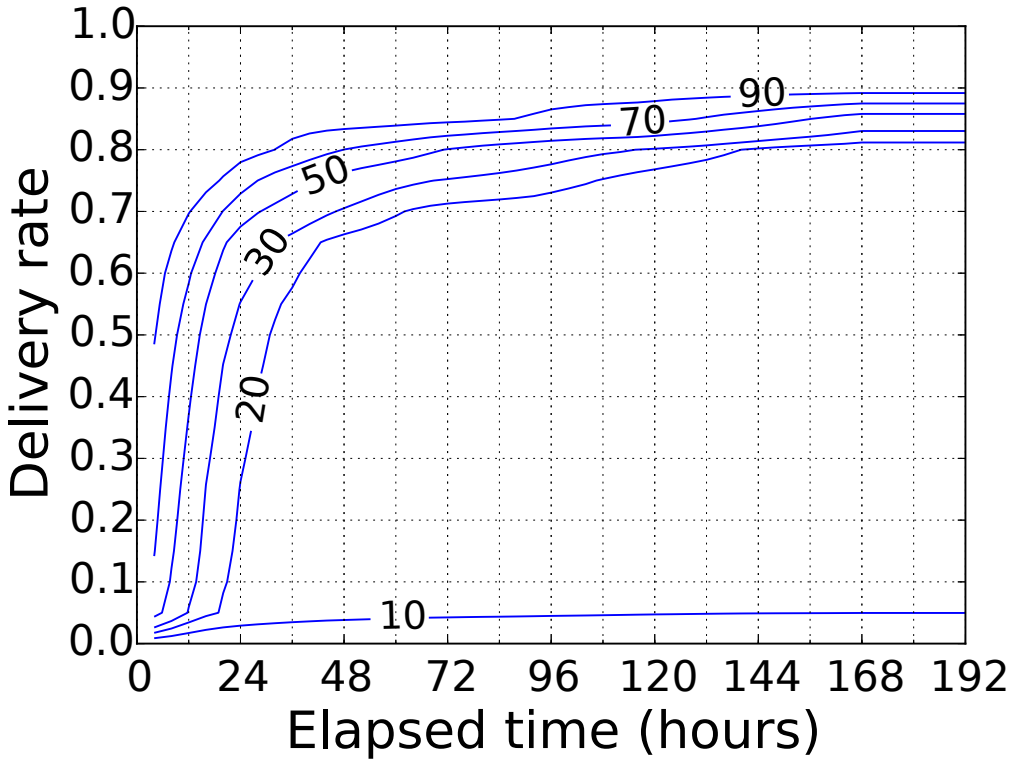
Setup

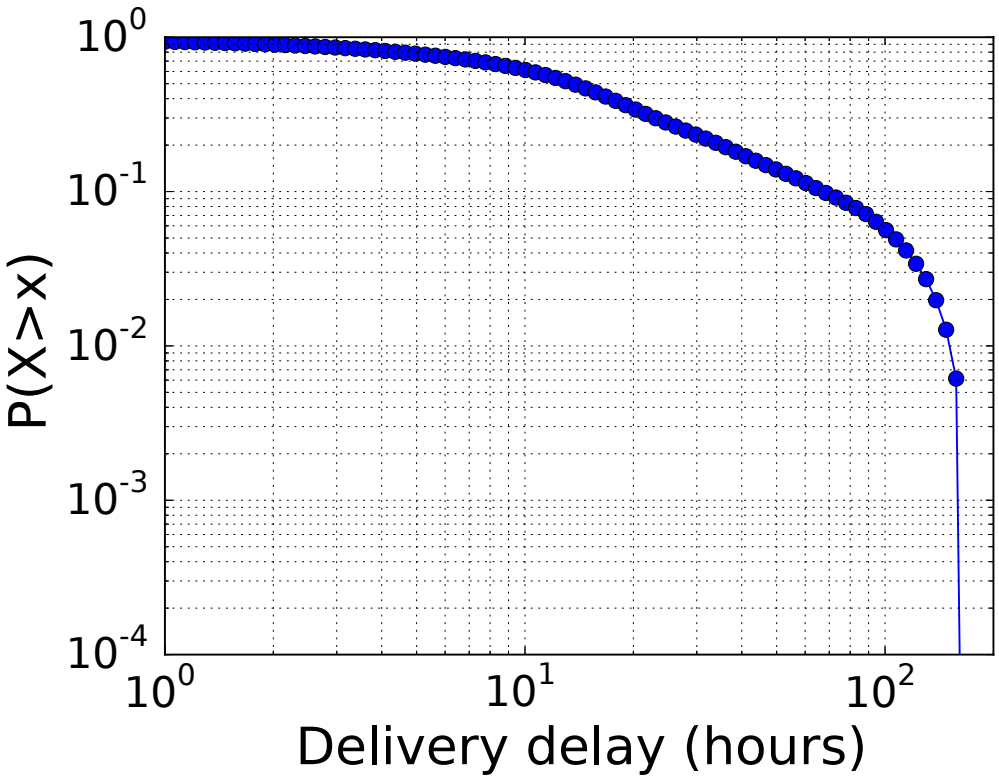
- 1 message per device per 6 minute
- Epidemic flooding

Message Delivery Progress



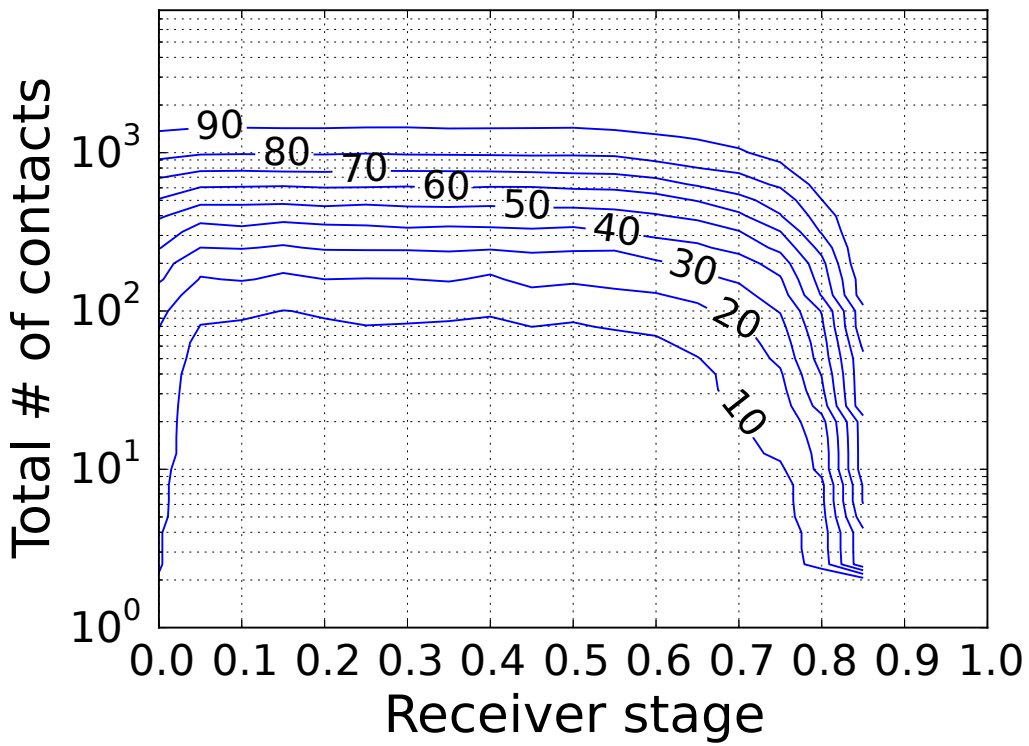
- Median delivery rate: 0.85
- Fast to reach first 60%-70% of nodes
- Extremely hard to reach the rest ?Why?

Delivery Delay Distribution



- Power-law distribution
- Median delay: 13 hours

Why So Hard to Reach The Last 30%?



- Contact heterogeneity causes the change in delivery speed
- The last 30% have diminishing contacts

Summary on Performance

111 users, 4 km×4 km campus (only 0.2% adoption rate)

- Median delivery rate after a day: 0.68
- Median delivery rate after a week: 0.85
- Median delay: 13 hours
- Extreme long delay for the last 20%-30% nodes

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Significant performance variations

- Significant performance variations caused by contact heterogeneity
- ATTN: Mobility models resulting in contact homogeneity are insufficient!

Outline

How the Network Reacts to Resource Removal Attacks?

Resource removal

- Blocking attacks = removing network resources
- Censorship = a selective form of blocking attacks

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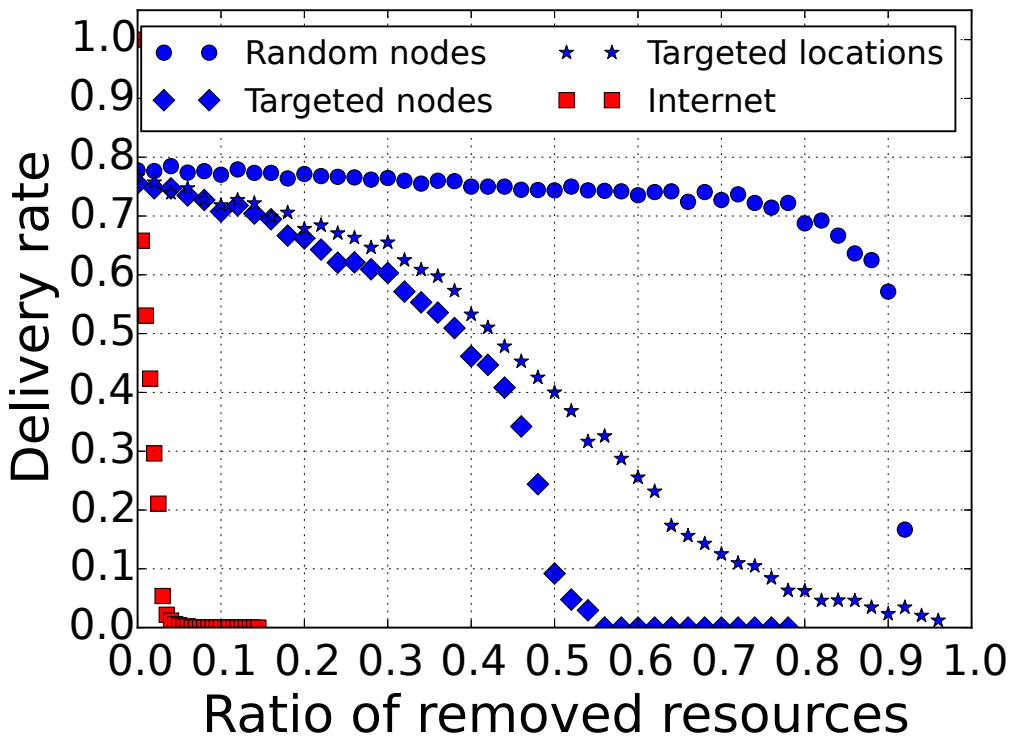
Attack strategies

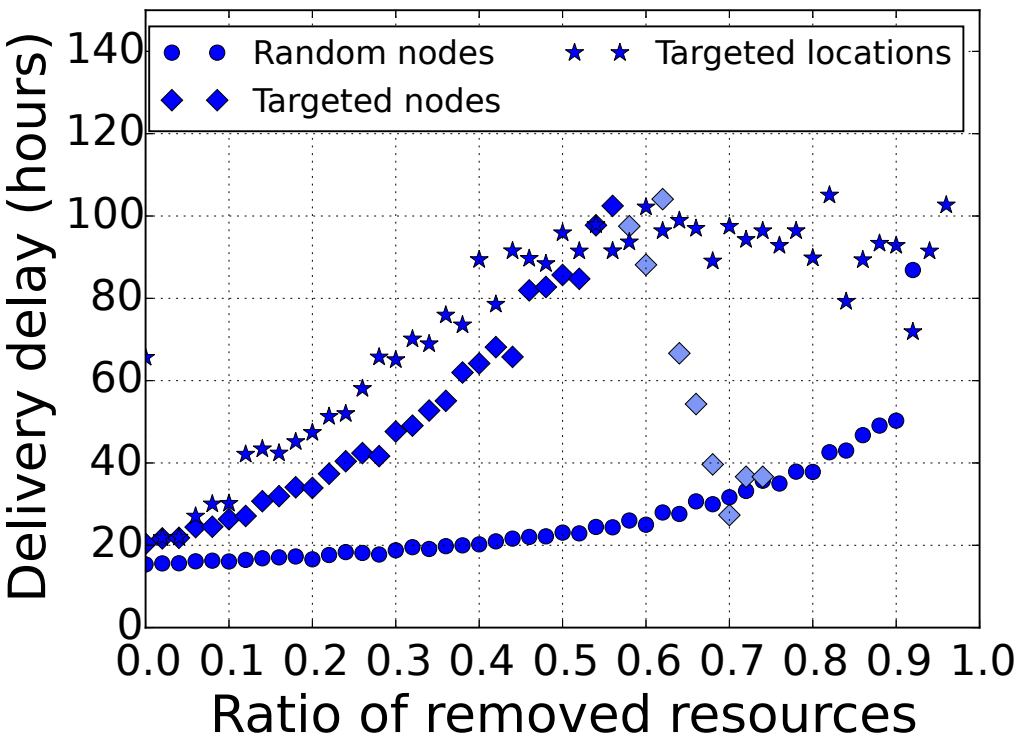
- **Random device removal**: Remove devices at random
- **Targeted device removal**: Remove devices appearing most frequently on shortest paths
- **Targeted location removal**: Remove locations appearing most frequently on shortest paths

Message Delivery Rate Degradation Under Attacks



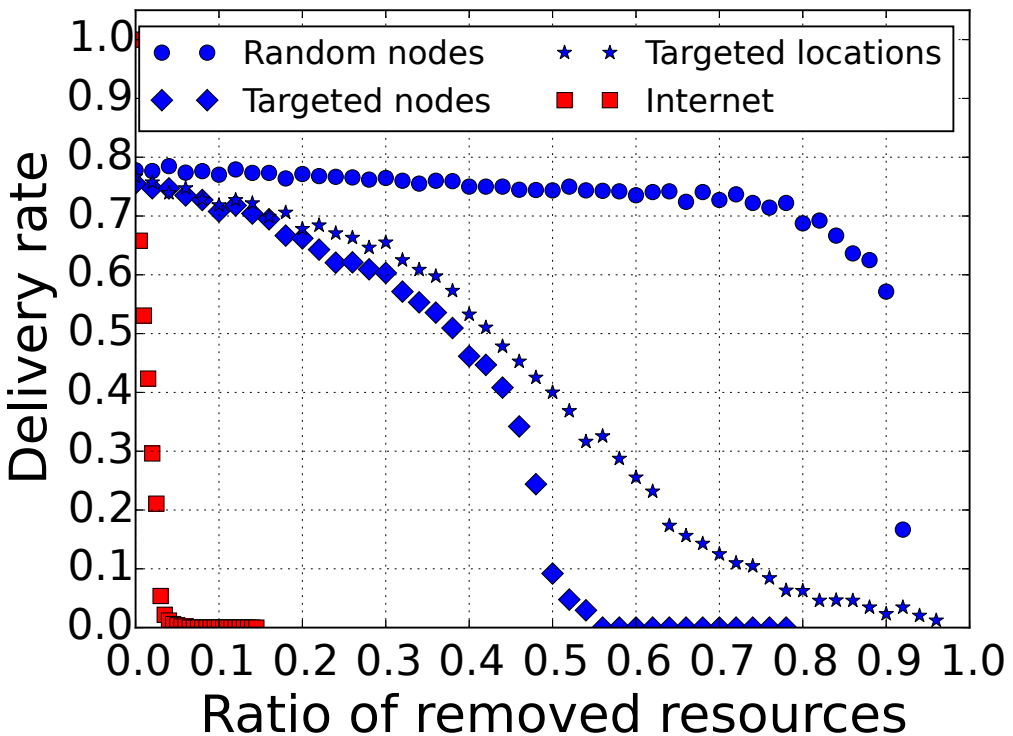
- Random device removal: almost no effect until more than 80% removed
- Targeted removal: fast degradation after more than 30%-40% removed
- The Internet: quick fragmentation after 3% removed [Albert'00]

Message Delivery Delay Degradation Under Attacks



- Random device removal: almost no effect until more than 60% removed
- Targeted removal: faster, gradual degradation
- Shaded points: dropped messages are not included

Summary on Robustness



- Non-hierarchical networks are much more robust
- Caveat: high-hierarchy Internet routers may be hard to attack...

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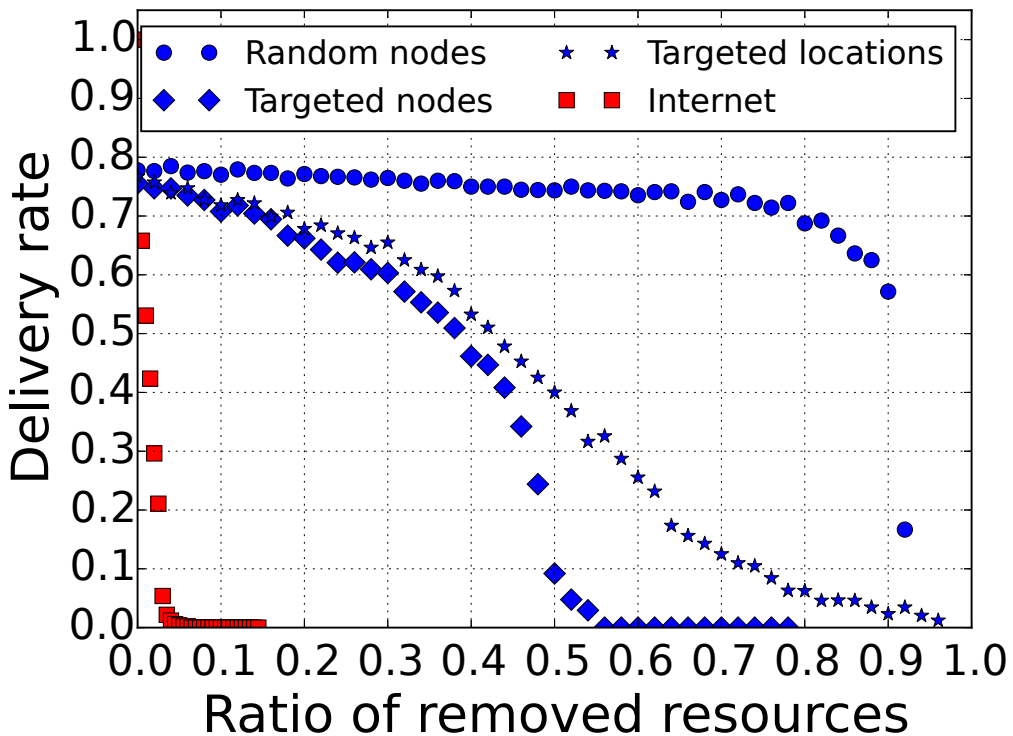


- Non-hierarchical networks are much more robust
- Caveat: high-hierarchy Internet routers may be hard to attack...
- Question: Will the same properties hold when the network scales up, e.g. with 1,000, or 10,000 users?

Outline

Energy Model of All-to-All Content Sharing

Contact discovery

- Constant

Communication*

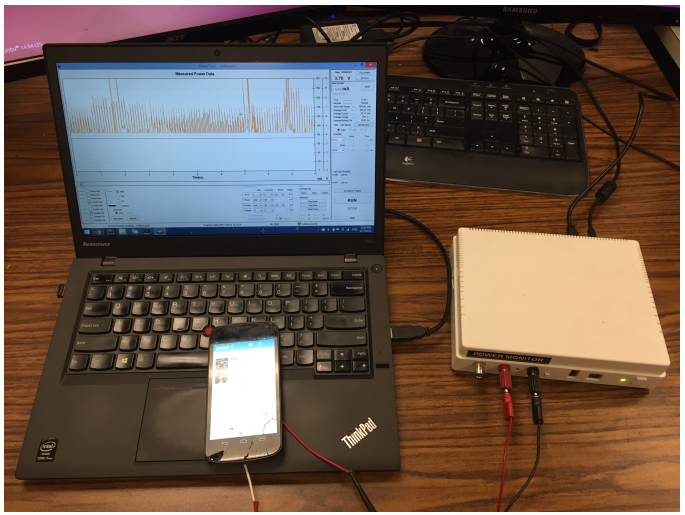
- Message delivery: $\mathcal{O}(N)$
- Metadata exchange: $\mathcal{O}(N^2)$

Computation

- $\mathcal{O}(N)$

*The epidemic flooding protocol is used

Energy Model of the Wireless Component in 802.11 Ad Hoc Mode



P_{idle} (idle state)	210 mW
P_{high} (send/receive state)	341 mW
E_{sw} (one power state switch from low-high-low)	242 mJ
E_{ping} (send+receive one 802.11b frame (ping))	2.16 mJ
E_{send} (send one 802.11b frame (UDP))	19.6 mJ
E_{recv} (receive one 802.11b frame (UDP))	6.8 mJ

Different Application Message Types

Message Sizes (F_m) and Initiation Frequencies (f_m)

Type	Typical Message size	F_m (frames/msg.)	f_m (msg./hour)
Text	514 characters	1	0.16667*
Image	100 KB	44	0.02536**
Video clip	$1\,\mathrm{Mbps} \times 240\,\mathrm{seconds}$	12000	0.00054***

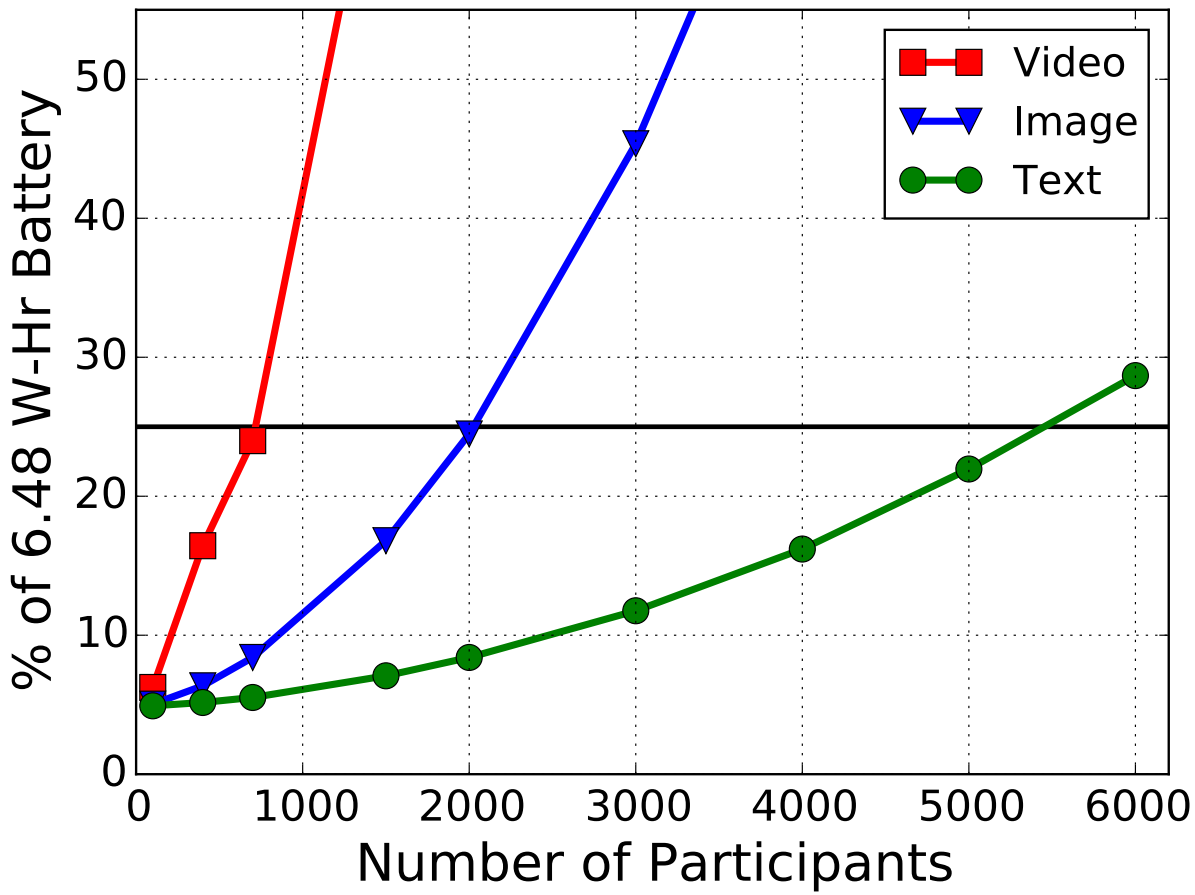
*This is Twitter's average rate

**This is Facebook's average photo posting rate

***This is YouTube's average rate

Results

12 Hour Energy Consumption against Network Size



- Text & Image: 1,500 nodes
- All Three: 400 nodes

Discussions on Energy Overhead

Battery energy severely limits network scale

- If everyone in our university joins to text, battery runs out in less than 1 hour!
- If everyone in our university joins to send photos, battery runs out in less than 10 minutes!

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Discussions

- Dominating contributor: metadata exchange
- How to reduce the cost of metadata exchange?

Conclusion and Future Work

Promising performance with only 0.2% adoption rate

- $\sim$70% delivery rate within 24 hours
- Median delay 13 hours

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Battery energy severely limits scale

- Cannot support the entire university population