Mobile Social Networks: Challenges and Opportunities

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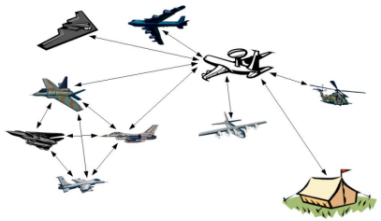
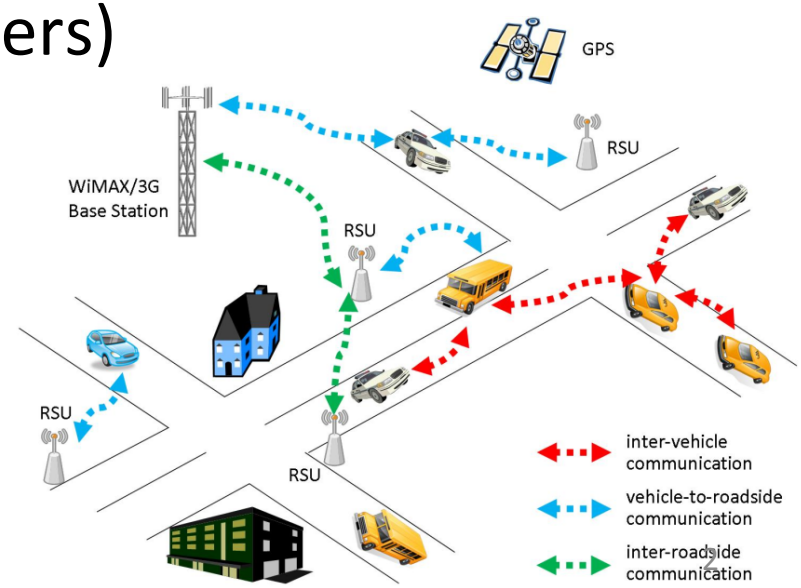
A new type of network…

- Delay Tolerant Networks (DTN)
- Opportunistic Networks (OpNet)
- Intermittently Connected Networks (ICN)
  - Vehicular Ad-hoc Networks (VANET)
  - Mobile Social Networks (MSN)
  - Military Networks (UAVs, Soldiers)

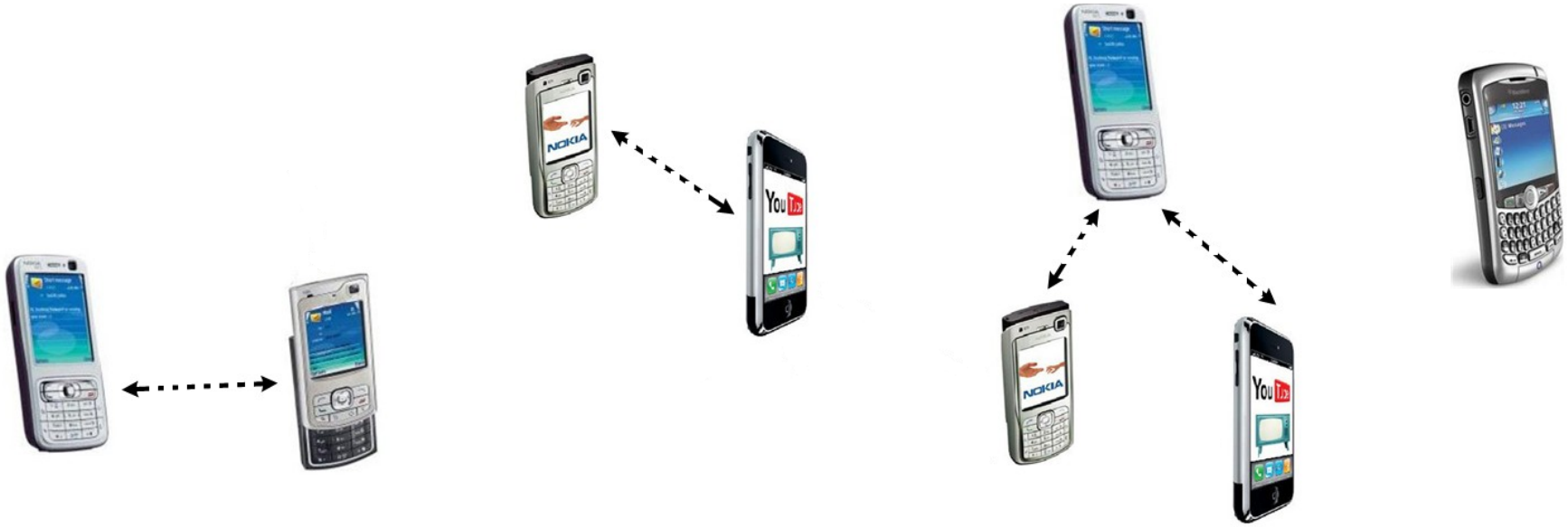




http://www.thebookmyproject.com/

Mobile Social Network (MSN)

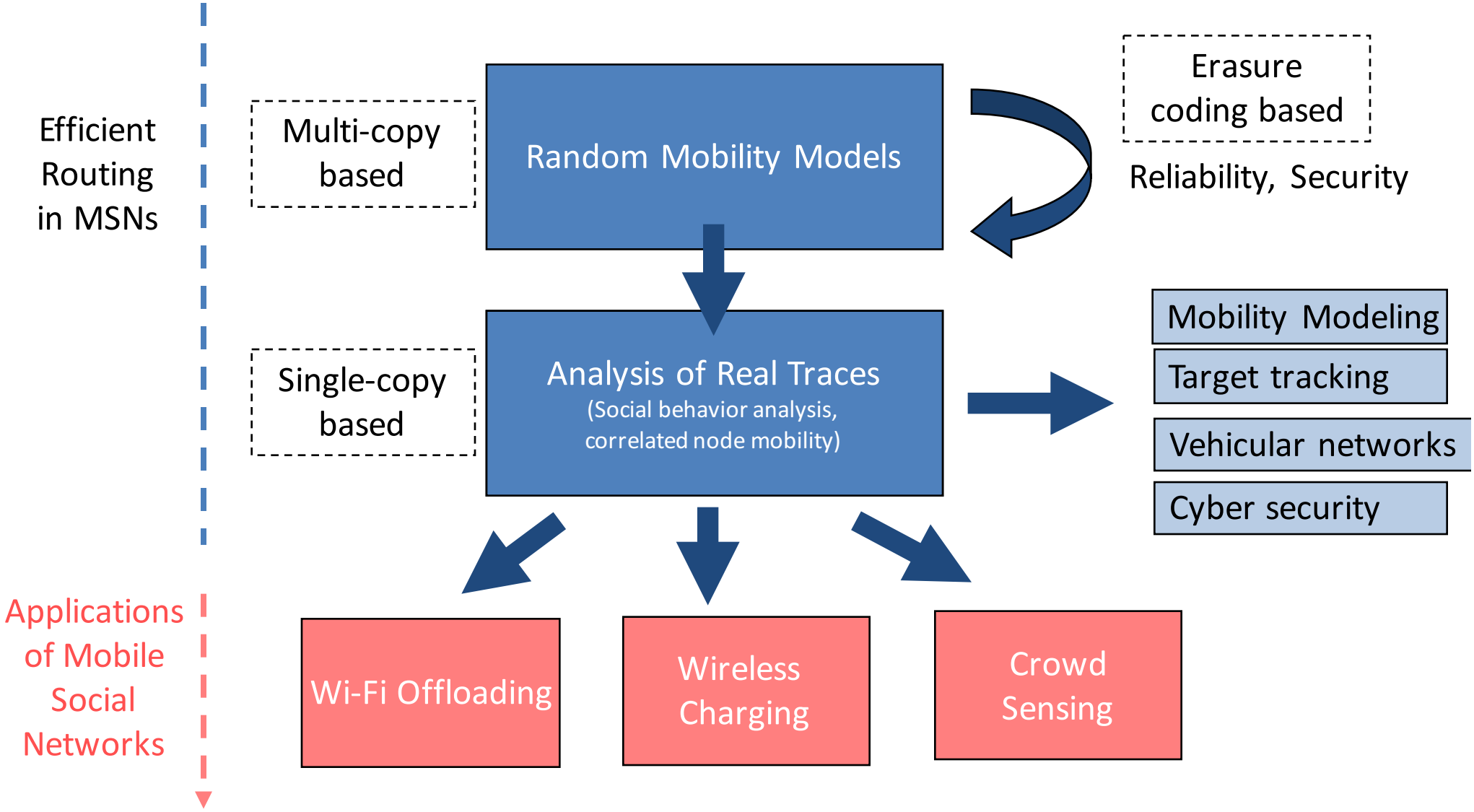
- Network of wireless devices (e.g., smartphones) carried by people.
  - Nodes can communicate with each other when they are in their radio range



Challenges in Routing in MSNs

- Dynamic and sparse topology
- Lack of continuous end-to-end connectivity
- Opportunistic message exchanges
  - How to decide whom to forward/copy a message?

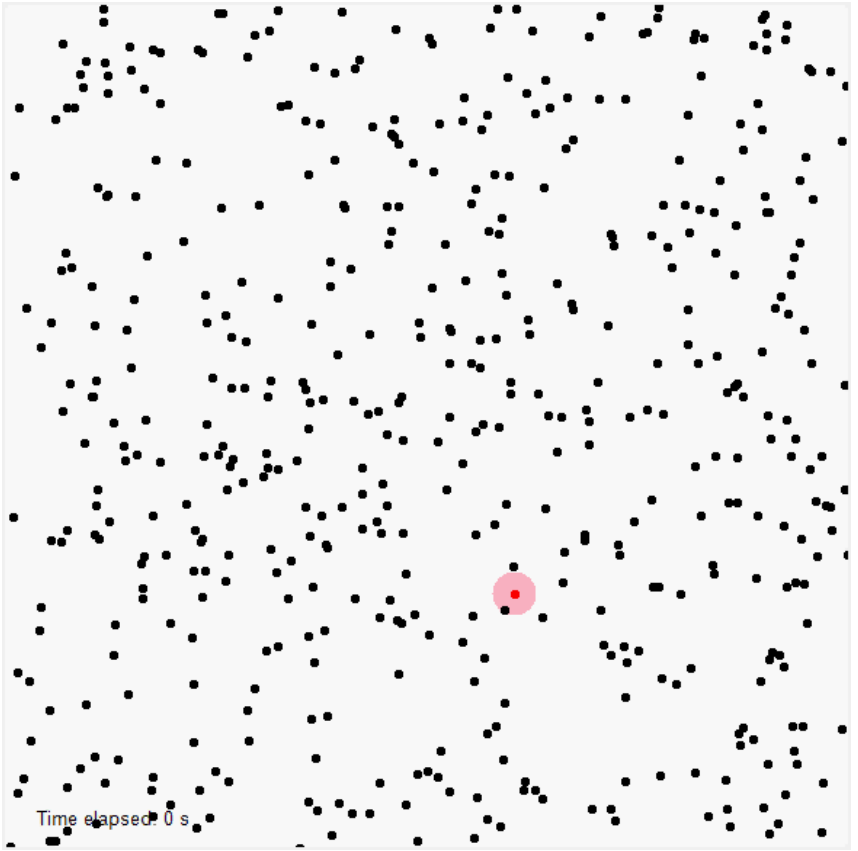
Outline


Efficient Routing in MSNs
Multi-copy based
Random Mobility Models
Erasure coding based
Reliability, Security
Single-copy based
Analysis of Real Traces
(Social behavior analysis, correlated node mobility)
Mobility Modeling
Target tracking
Vehicular networks
Cyber security
Applications of Mobile Social Networks
Wi-Fi Offloading
Wireless Charging
Crowd Sensing

Random Mobility Case

- Optimal Routing:

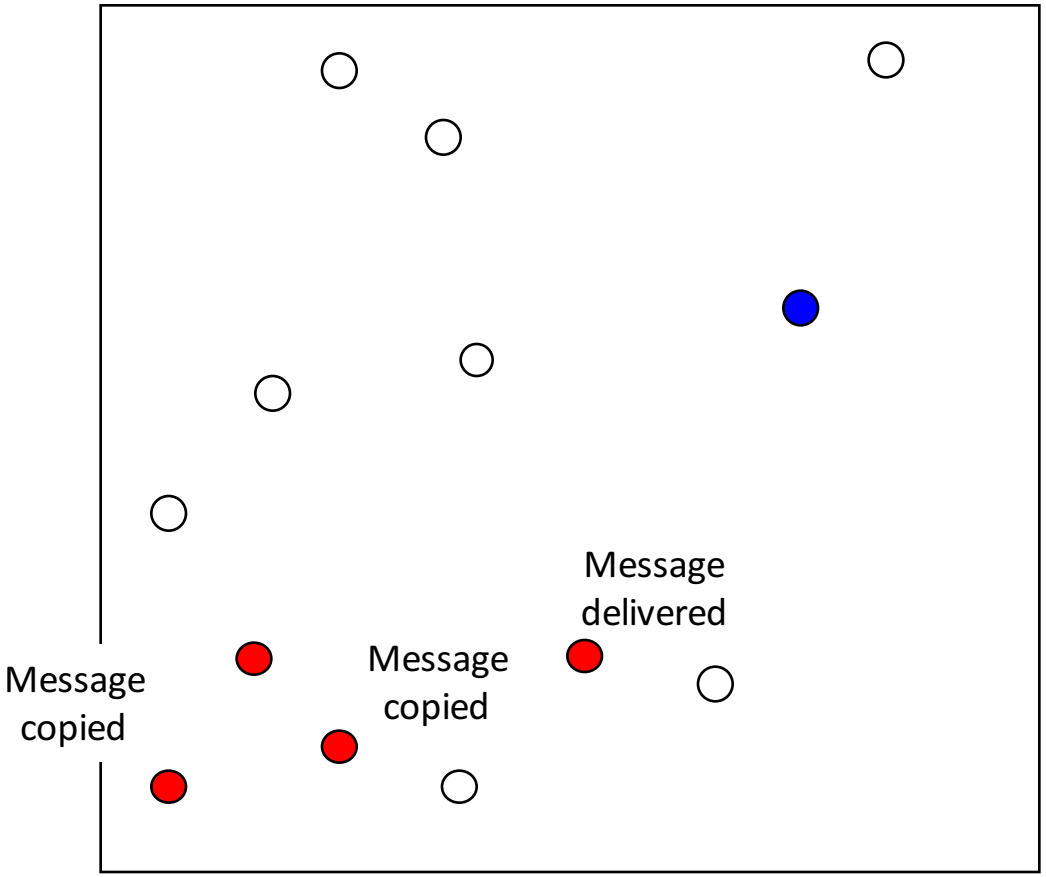
  Epidemic Routing:
  - Minimum delay
  - High Cost

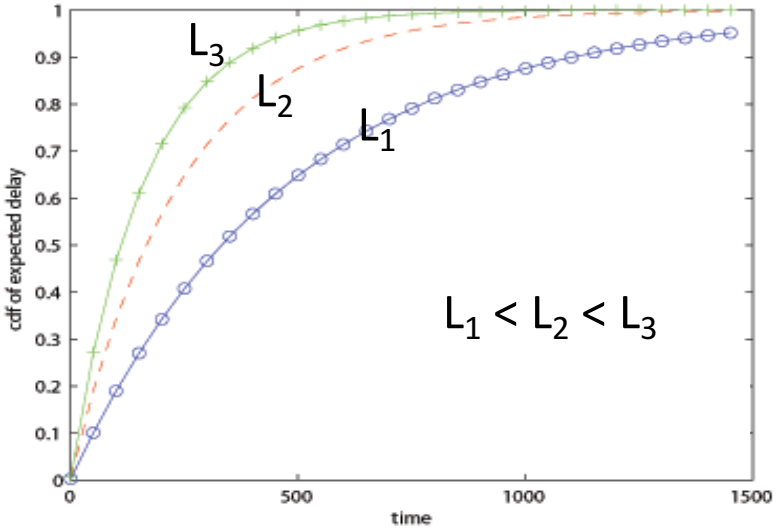


Source: http://zijie.net/

Spray and Wait

- Random mobility model
  - Exponentially distributed intermeeting times





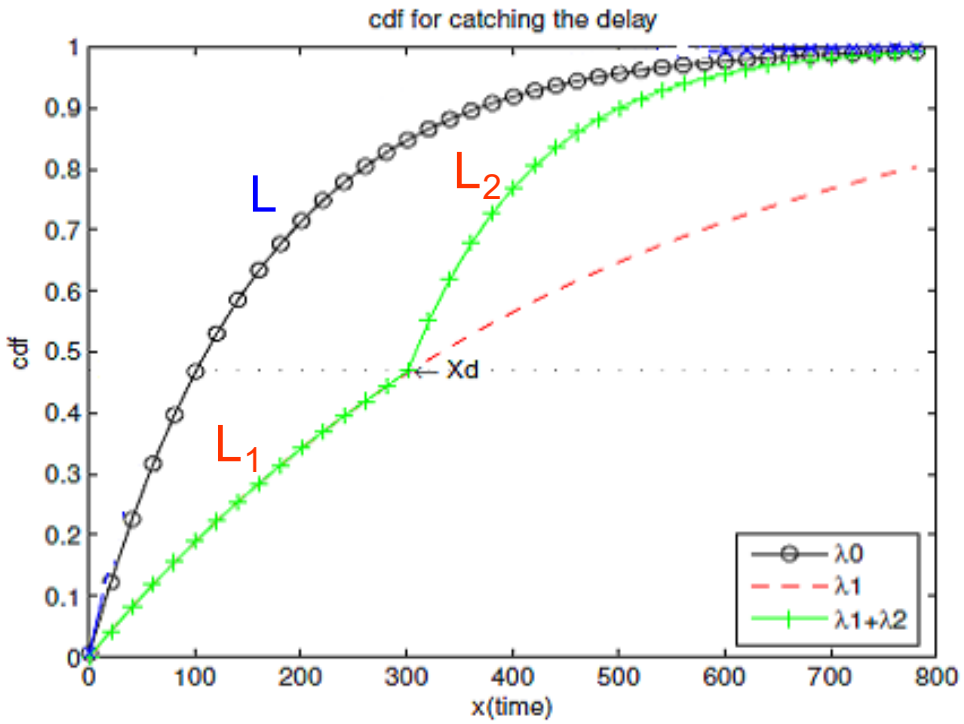
Destination

Node with message copy

Node without message copy

Haste Makes Waste: Multi-Period Spray & Wait

- Spray L_1 copies at the beginning
- Spray additional L_2 - L_1 copies at the start of second period (x_d)



GOALS:

1) Maintain the same delivery rate by deadline (td)

2) Lower the average cost

$$L_1(P) + L_2(1-P) < L$$

↓

Delivery probability in first period

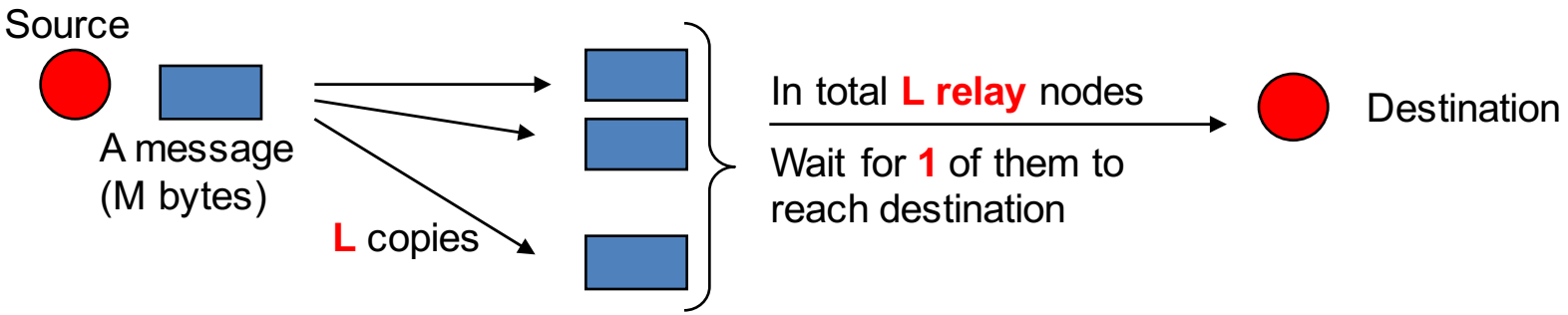
[IEEE Tran. on Networking, 2010]

Example Optimum Copy Counts (L_i)

Average Target Delivery rate	Deadline	Minimum Copy Count (L) 1 period	2 period- Optimum Copy counts (L1, L2)	3 period- Optimum Copy counts (L1, L2, L3)
99%	400 sec	6	4, 11	3,6,14
Average cost		~6	4.64 (23% saving) second period starts at 285th sec	4.28 (30% saving)

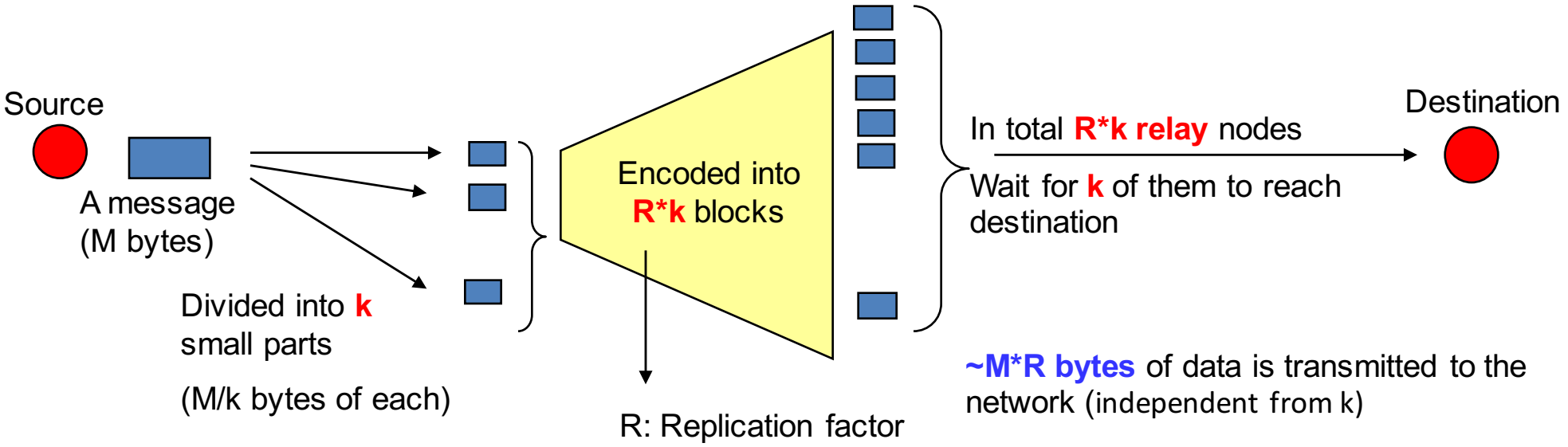
How to increase reliability?

- If a copy of the message is lost, delivery probability is affected dramatically.



M*L bytes of data is transmitted to the network

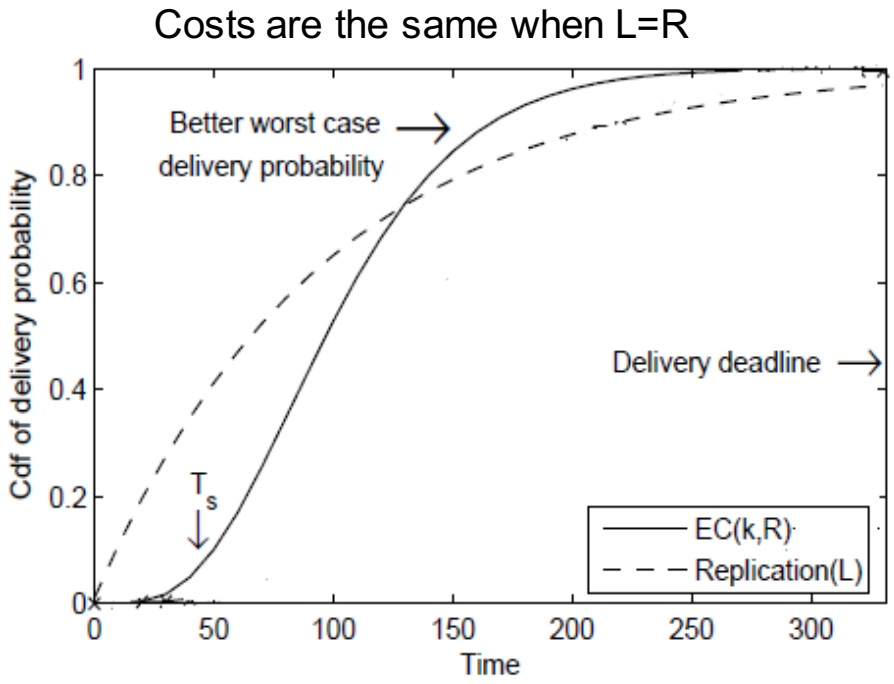
Erasure Coding based Routing



If L=R, then the cost (transmitted bytes over the radio) becomes equal to the cost of replication based routing (**M*L bytes**)

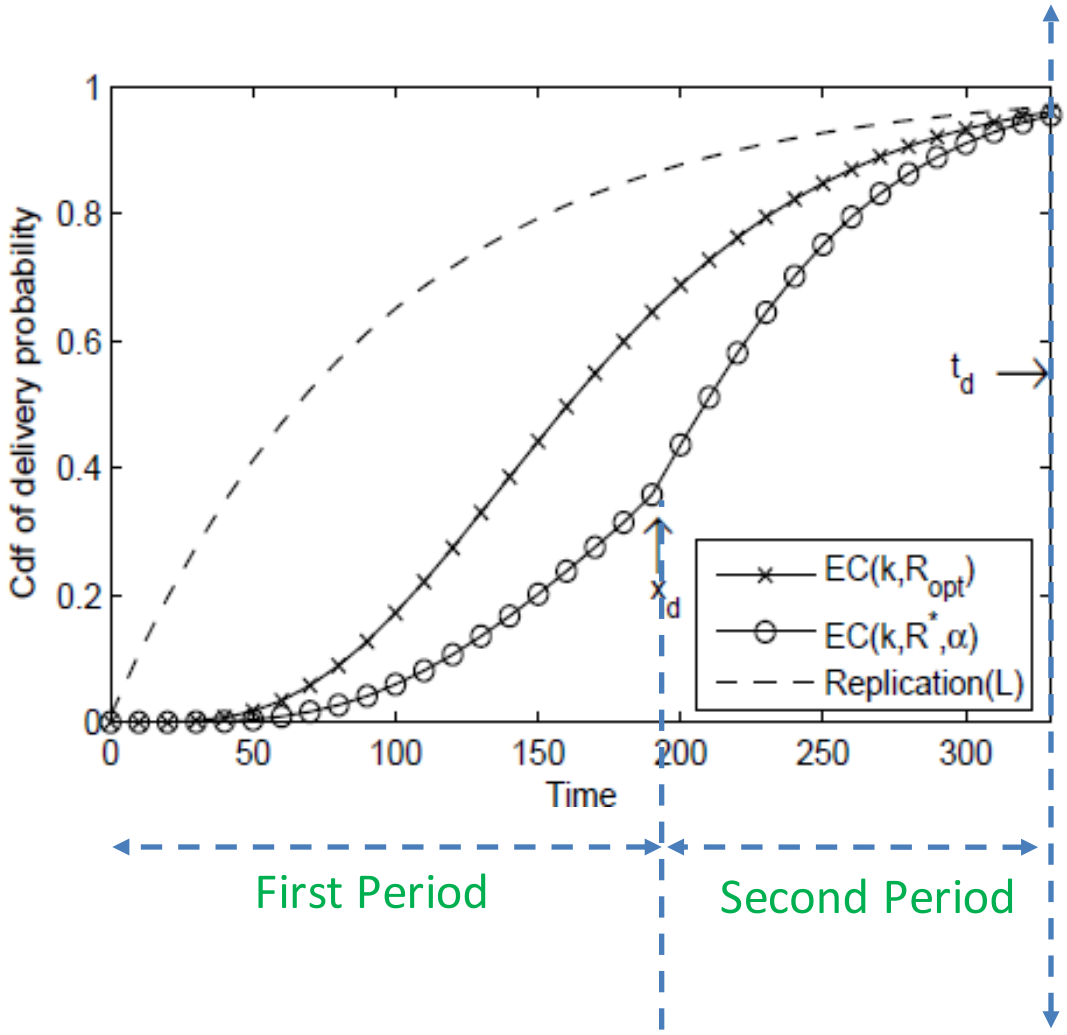
Replication vs. Erasure Coding

- Which one is better?
  1. Spraying L messages and waiting for 1 (to reach destination)?
     - Spraying duration is shorter
  2. Spraying R*k messages and waiting for k?



"EC" provides more reliable and secure routing

Application of Multi-Period Idea in Erasure Coding-based Routing

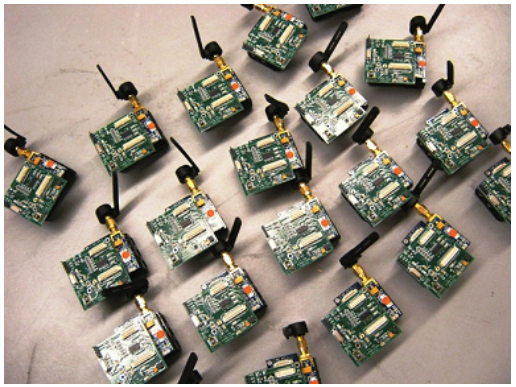


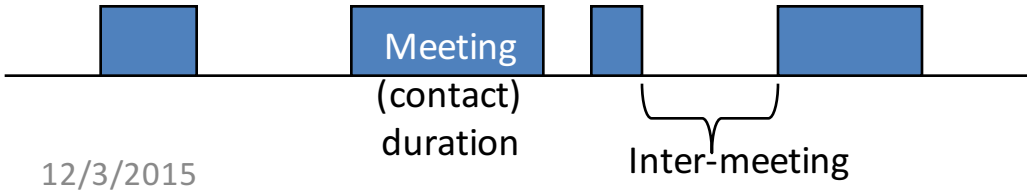
Maintain delivery rate
Achieve lower average cost

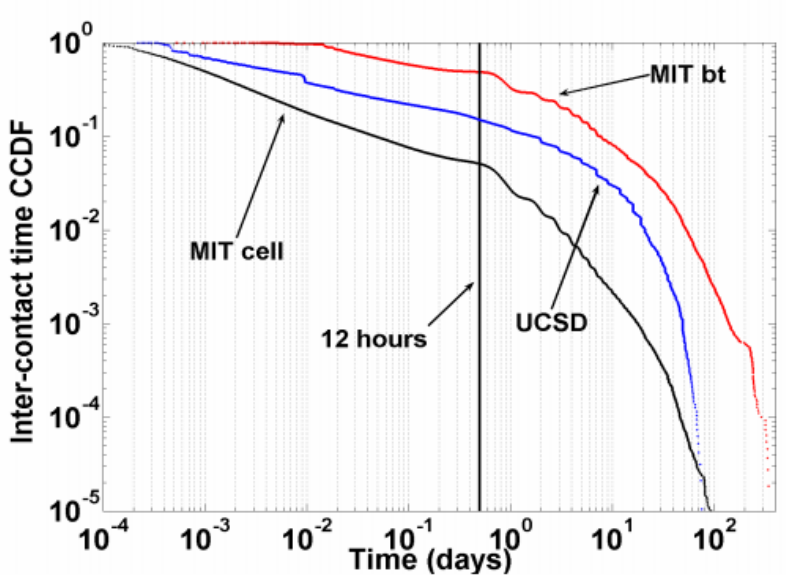
[IEEE ICC 2010]

How about Real Mobile Social Networks?

- Haggle Project (people, conference, Imote)
- MIT Reality Project (campus, phone)
- UMass Diesel-Net Project (bus meetings)
- RollerNet Traces (roller skate tour, Imote)

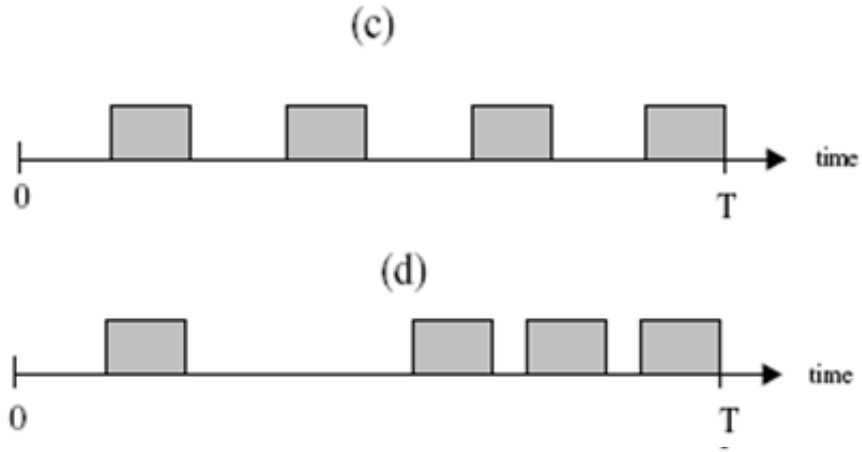






Analysis of “Message Exchange Opportunity” using Current Metrics

- Average Contact frequency
- Average Contact duration
- Average Separation Period

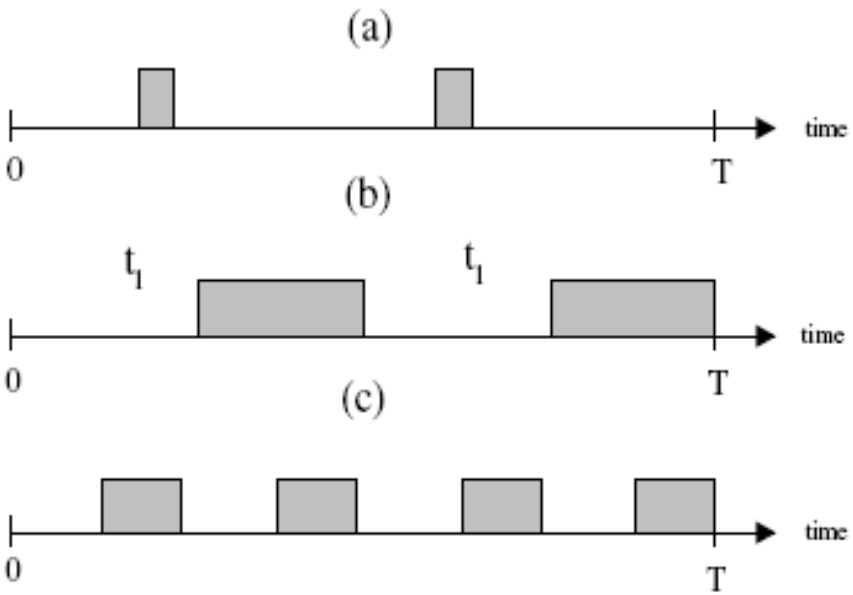


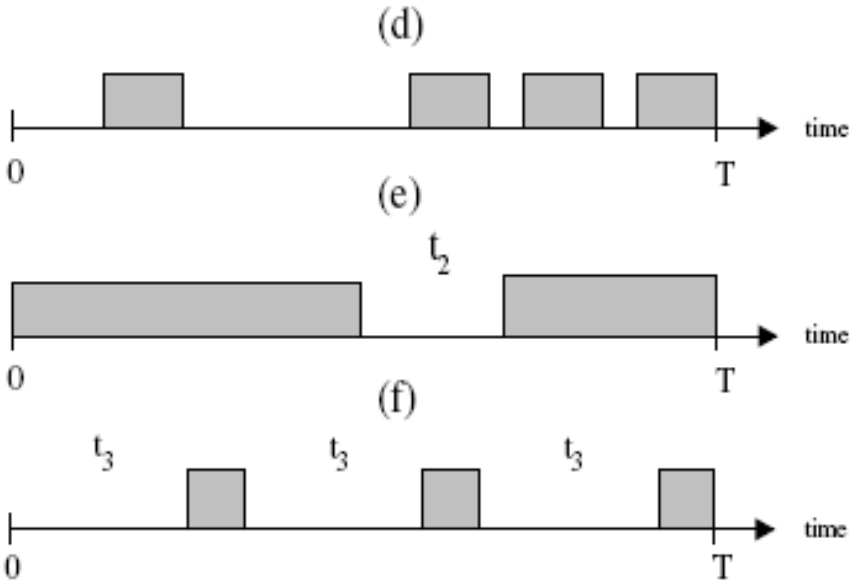
Social Pressure Metric (SPM)

"How actual is the knowledge of a person about his friend?"

- High Frequency
- Longer Contacts
- Regularity

Average delay of continuous messaging from i to j.

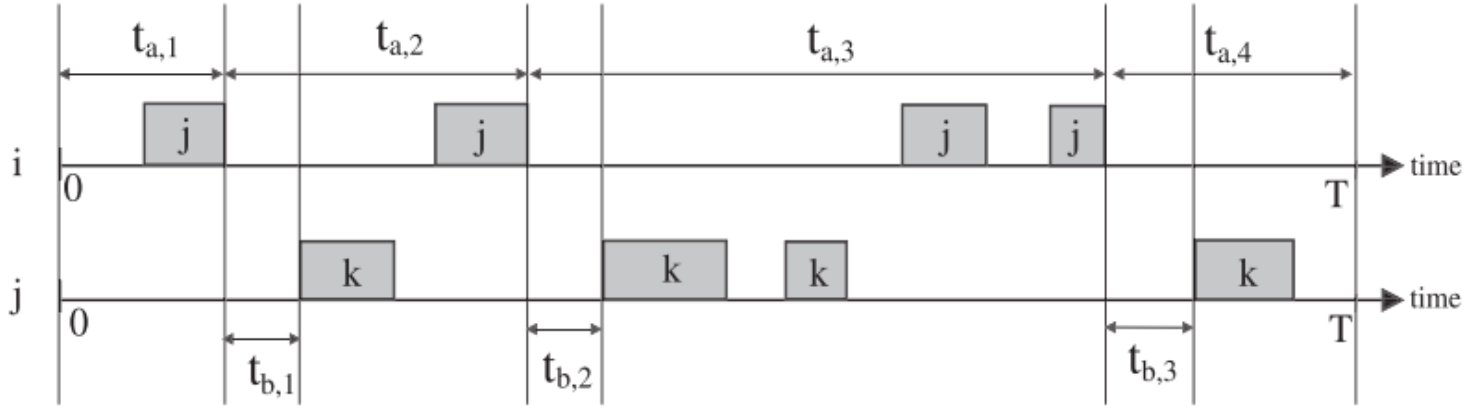




Indirect Relations

- Relative-SPM (RSPM)
  - Average delay of continuous messaging from i to k through j

    Better than ($SPM_{i,j}$ + $SPM_{j,k}$) due to the correlated node mobility



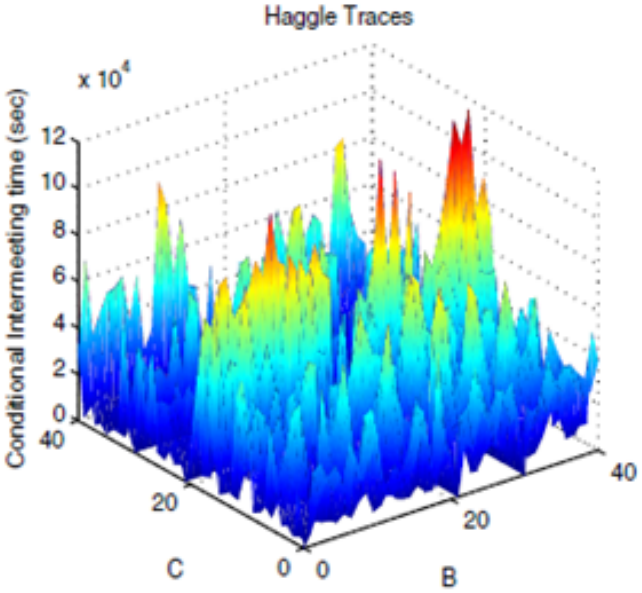
$$RSPM_{i,k|j} = \left(\sum_{x=1}^{n} \int_{0}^{t_{a,x}} (t_{b,x} + t_{a,x} - t)dt \right) \Big/ T$$

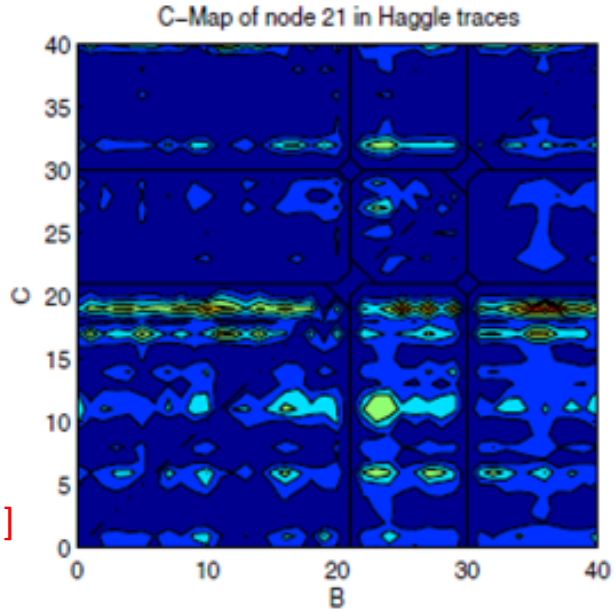
$$w_{i,j,k} = 1/RSPM_{i,k|j}$$

Node i's indirect delivery metric (weight) to k through j

Correlated Node Mobility

- A man's meeting with his office friends is correlated to his meeting with the security guard of his office building





[Elsevier Pervasive Mobile Computing, 2013]

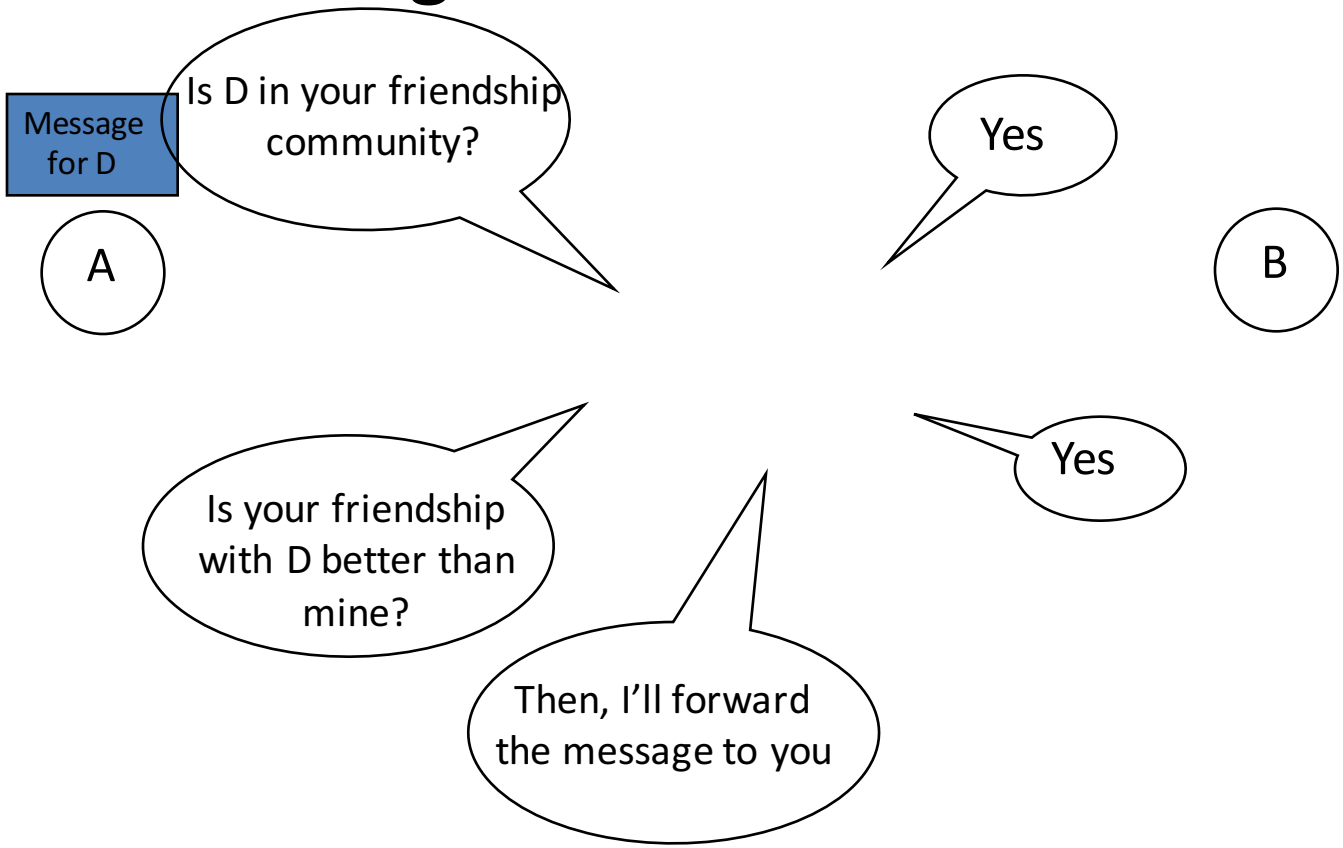
Friendship based Routing

Friendship Detection System

[IEEE Trans. on Parallel and Distributing Systems, 2012]
Best Paper of the issue

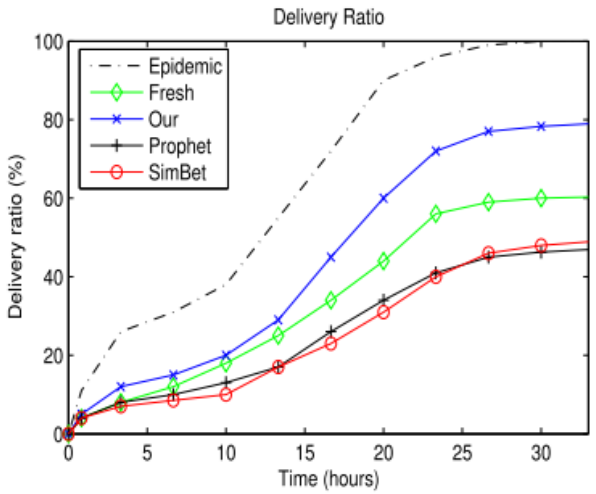
Forwarding Algorithm

- When two nodes meet, message is forwarded if the following case occurs:

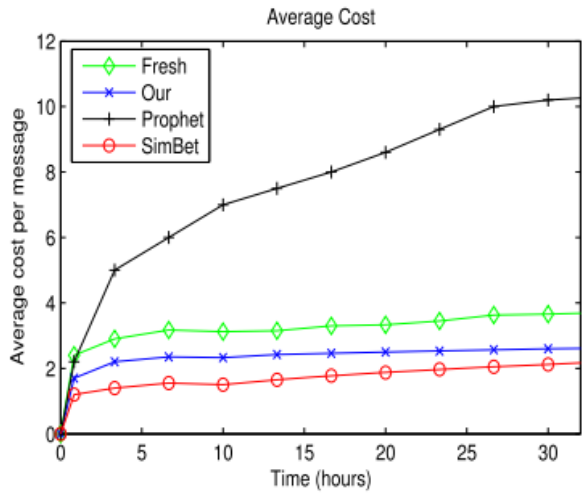


Simulation Results

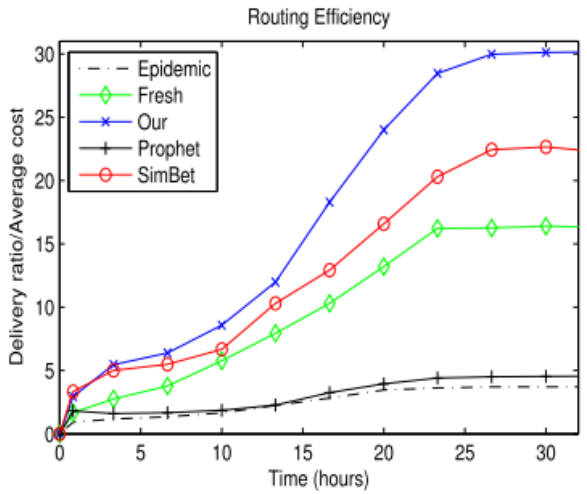
- Higher delivery ratio, lower delay
- Lowest cost, best routing efficiency (delivery rate/cost)



(a) Delivery ratio vs. time



(b) Average cost vs. time



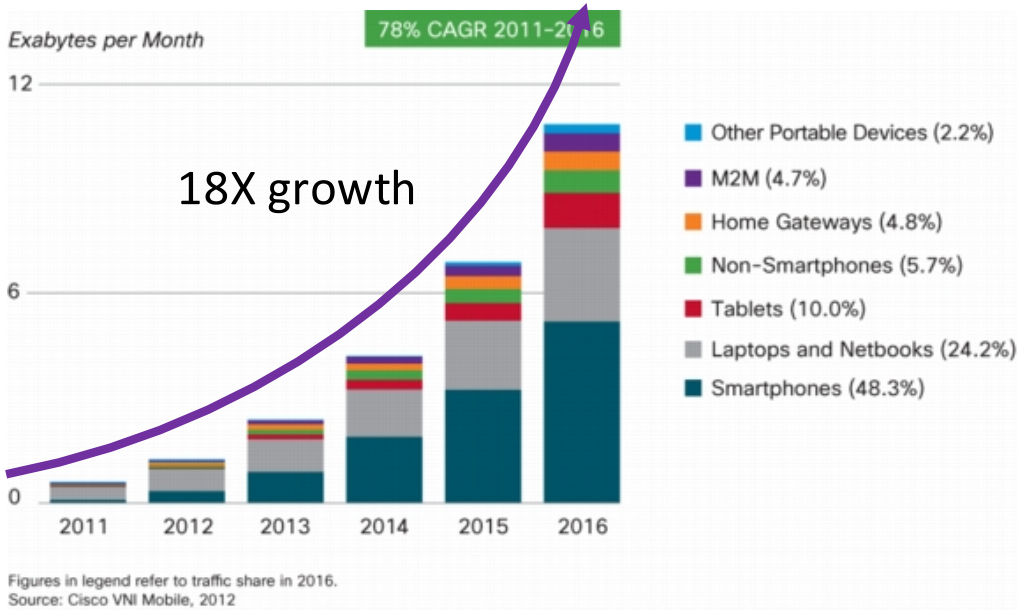
(c) Routing Efficiency vs. time

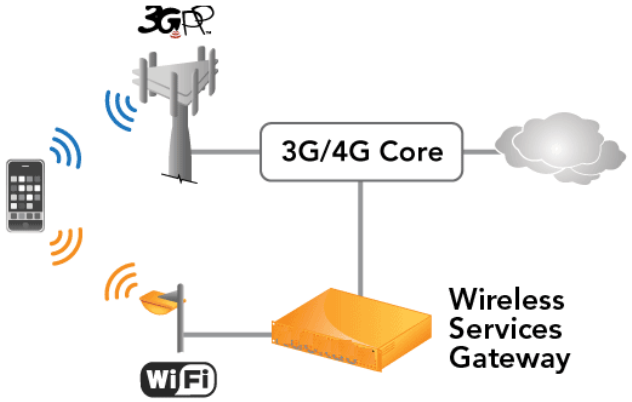
How to benefit from Mobile Social Networks?

- Applications:
  - Enhancing WiFi Offloading via MSN Routing
  - Opportunistic Wireless Charging
  - Participatory or Crowd Sensing

Mobile Data Growth

- Possible Remedies:
  - Building new base stations, or femtocells
  - Improving radio technology and bandwidth (ex: LTE or 4G)
  - Applying tiered price plans on data usage
  - WiFi offloading: Cheaper and more practical

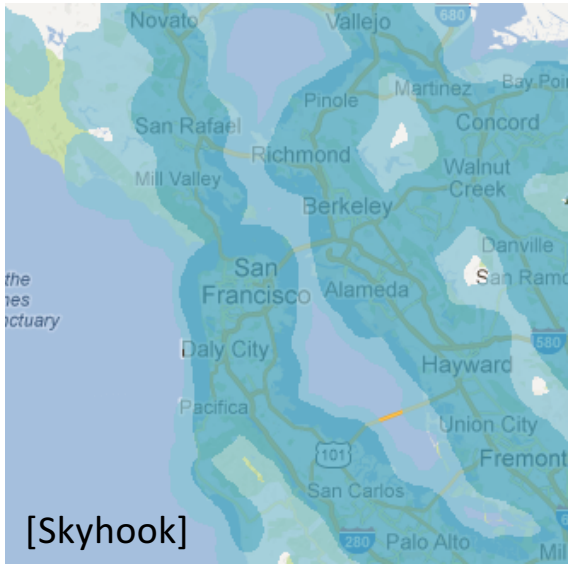


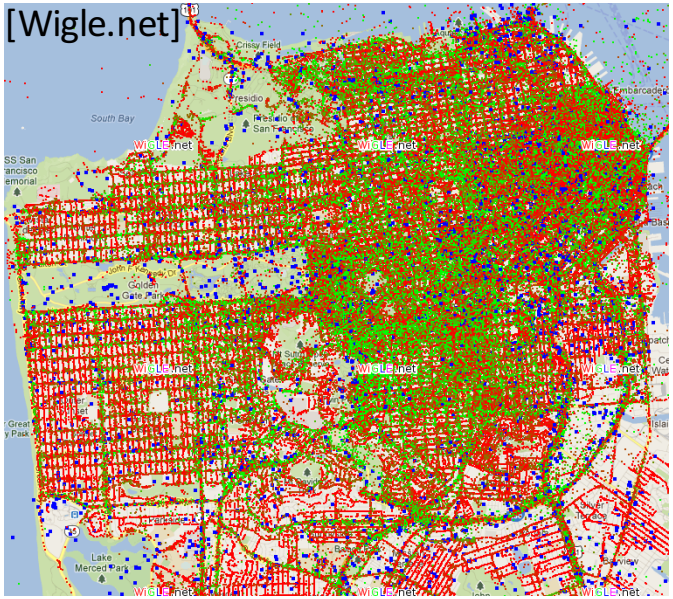


WiFi Offloading

- Deploying new APs to dense areas
- Recruiting available third-party APs
  - Incentive mechanisms

red= encrypted, green = free WiFi APs.
blue = AT&T cellular network + femtoCells

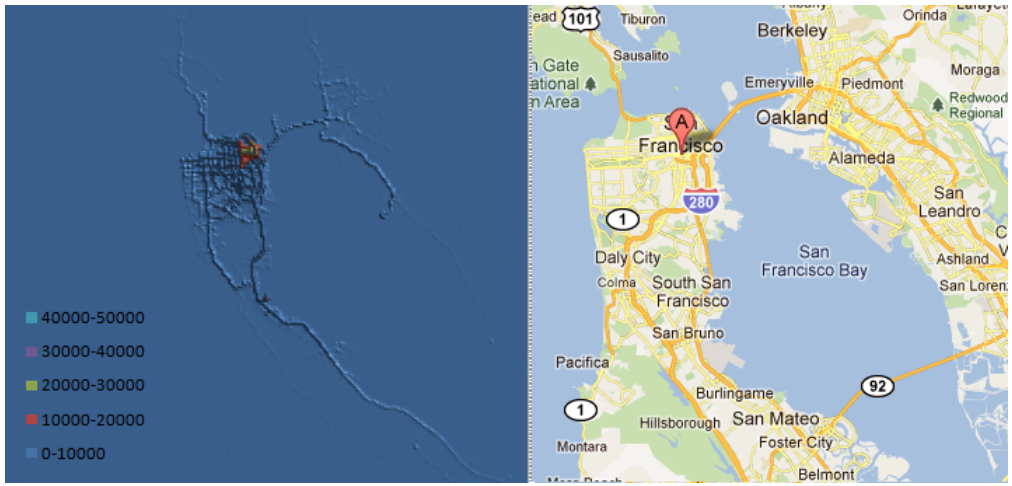




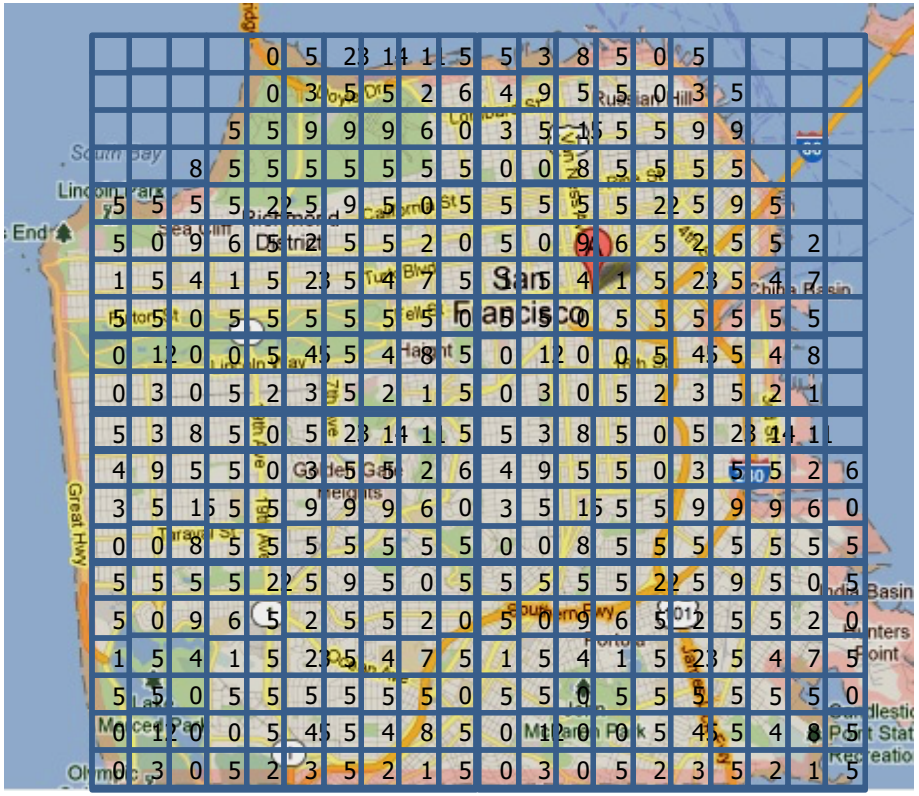
WiFi AP coverage in San Francisco

Optimal WiFi AP deployment

- How to deploy a given number of APs in an area to achieve maximum benefit (i.e., offloading ratio) from them?



San Francisco Taxi traces

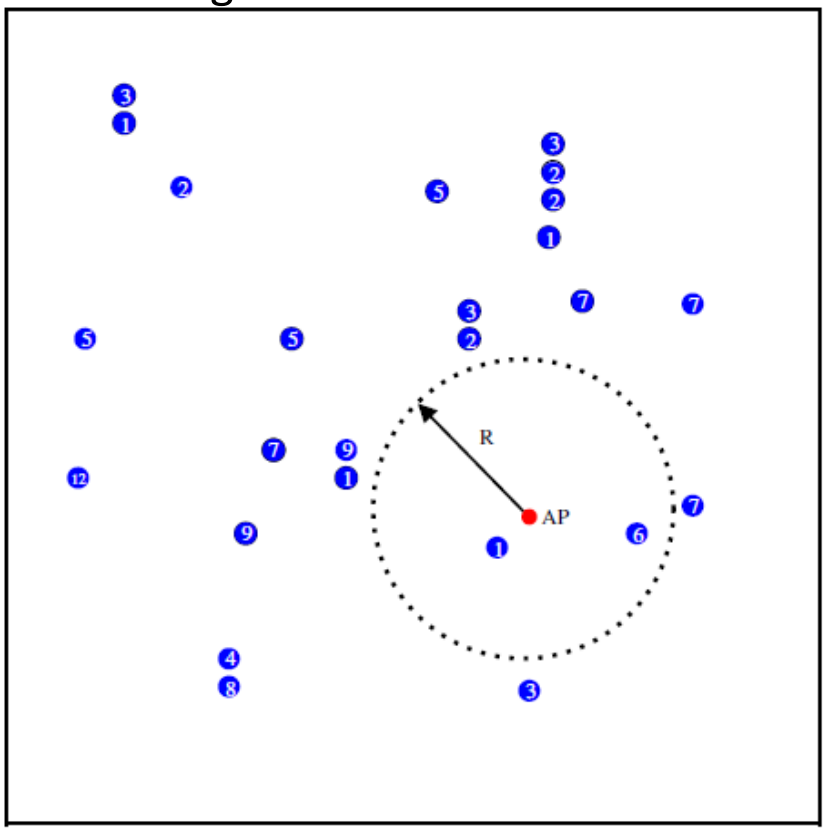


[Mobicom workshop 2012]

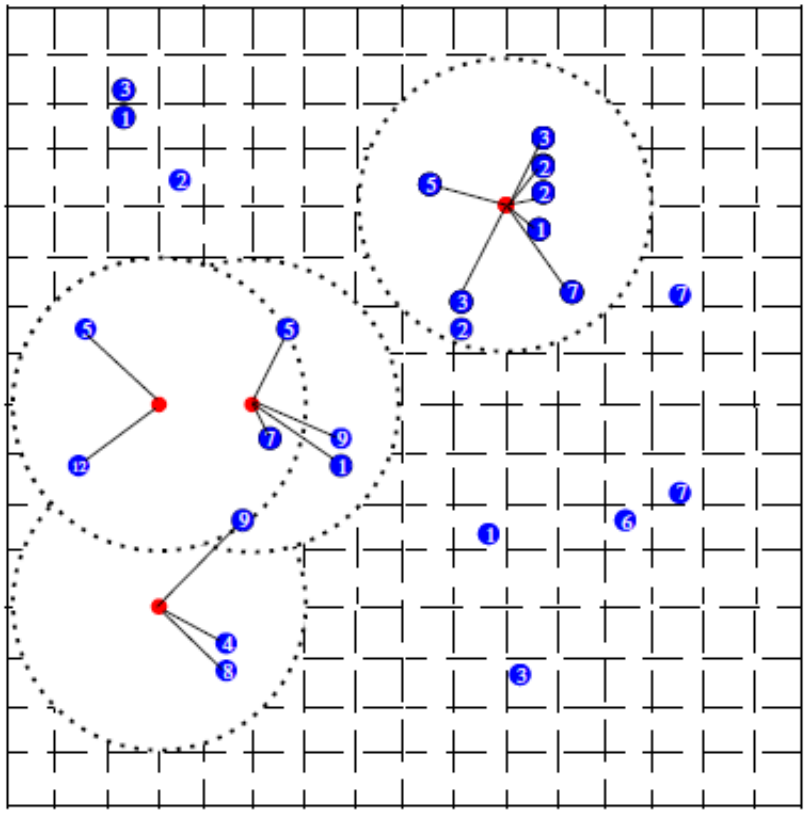
Optimal WiFi AP deployment

- Example Problem and Optimal Deployment

Problem (25 requests, 4 AP)
Total weight = 115

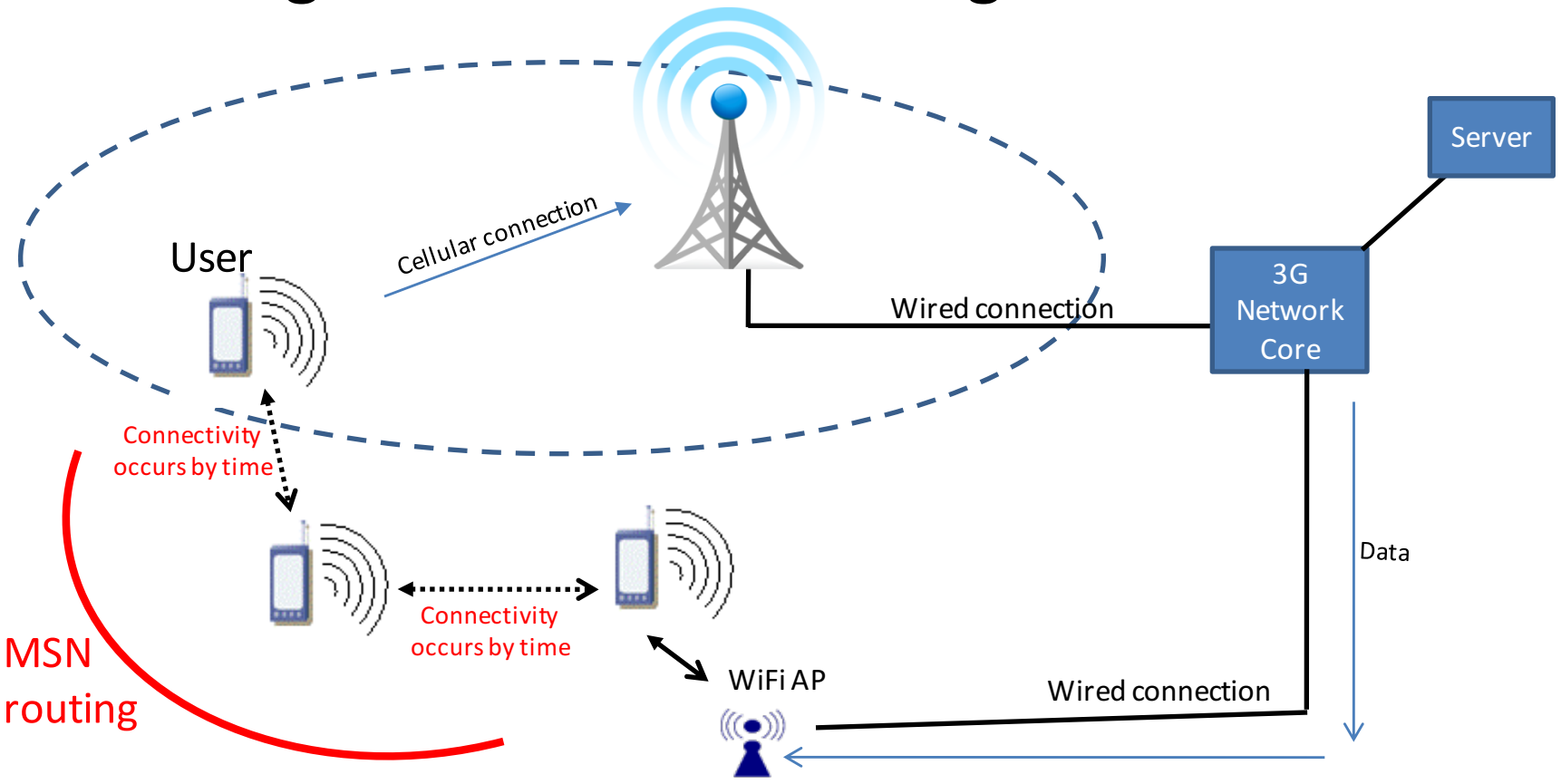


Optimal result
(Covered weight = 83)



Enhancing WiFi Offloading via MSNs

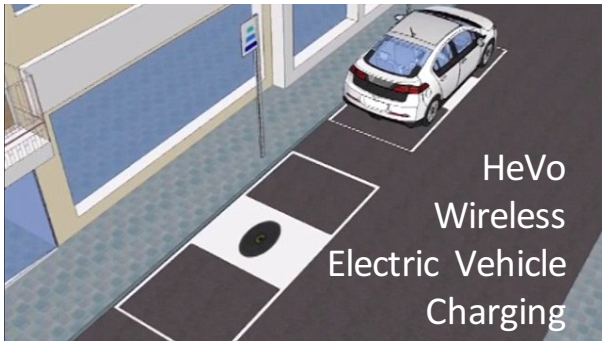
- Delay tolerant traffic can be offloaded via WiFi APs
- MSN routing could extend AP ranges



Wireless Charging

- Recent breakthroughs in
  - wireless energy transfer (i.e., 90% efficiency over 2m)
  - rechargeable lithium-ion batteries

Nokia Lumia – Wireless charging pad

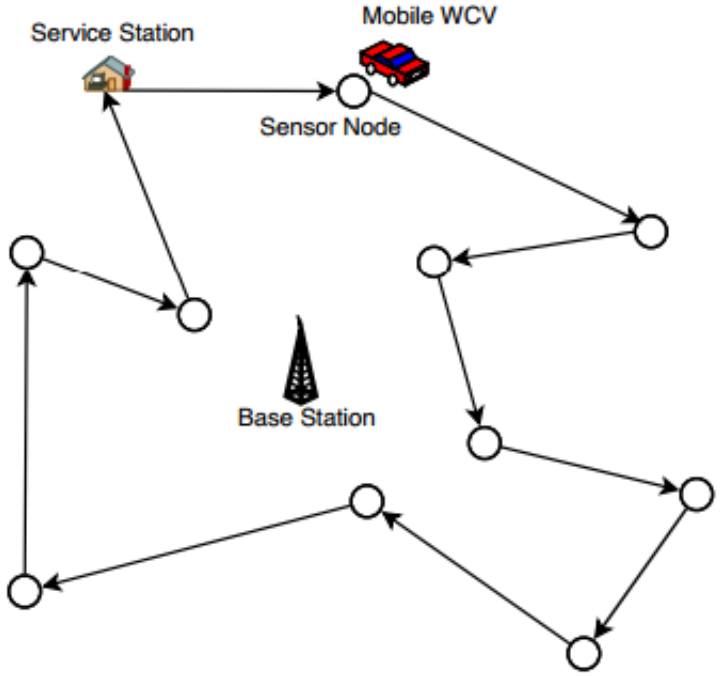


Wireless Charging in Sensor Networks

- Prolonging the lifetime of a sensor network lifetime via mobile chargers

  UAV energy transfer

- Extensive approach: Collaborative mobile charging

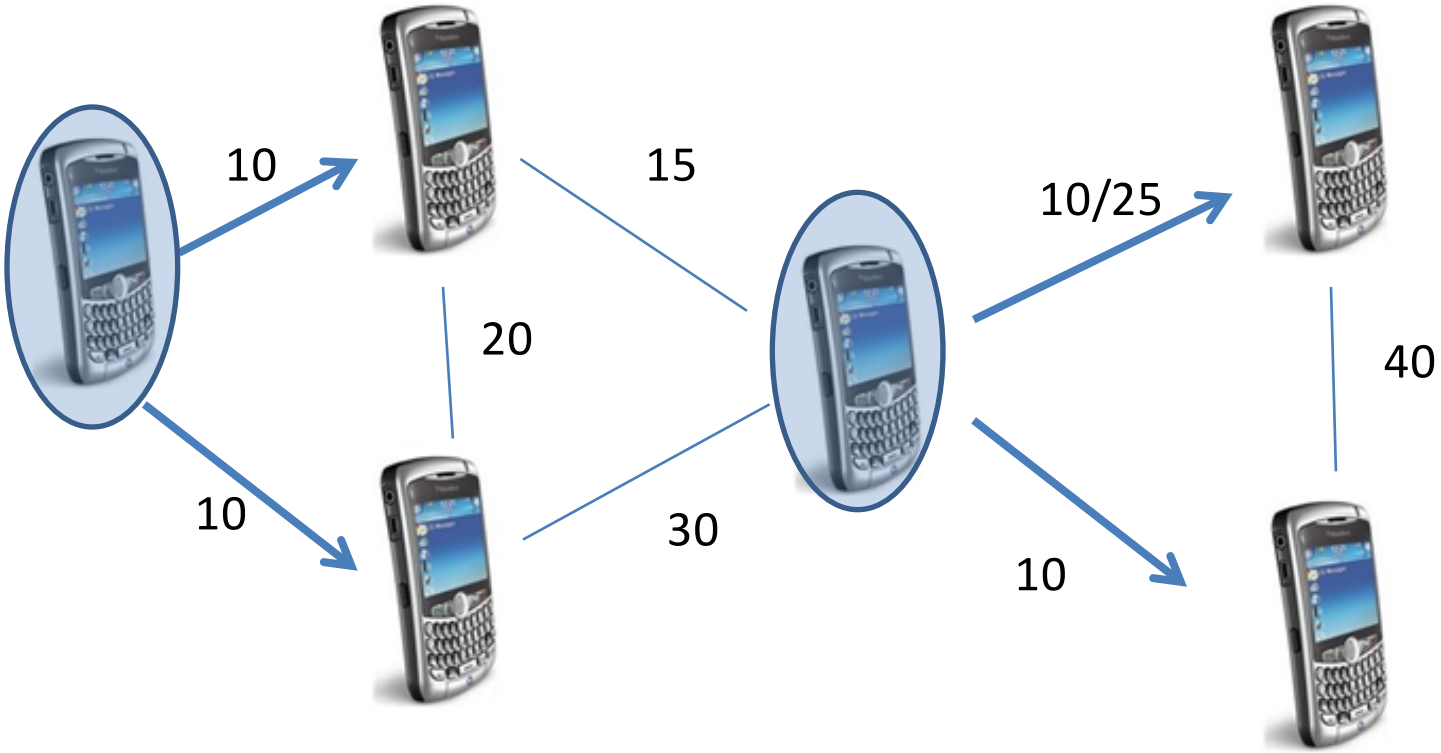


Stable Sensor node

Mobile charger

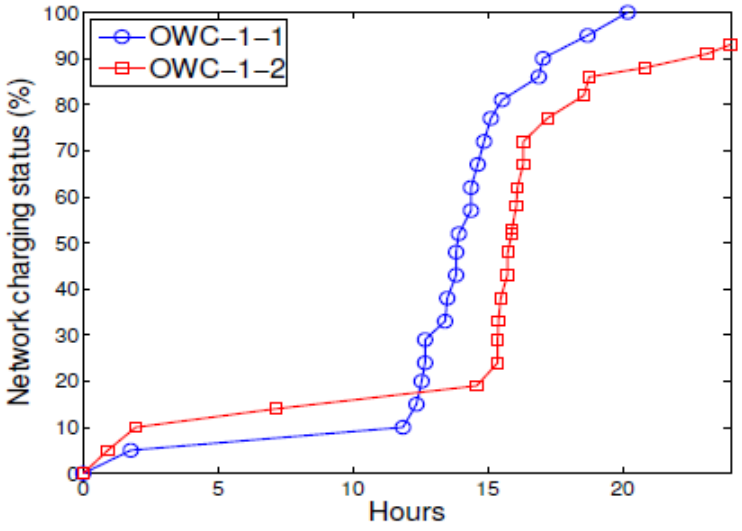
Opportunistic Wireless Charging

- Social relations could be analyzed to find the target set of mobile chargers

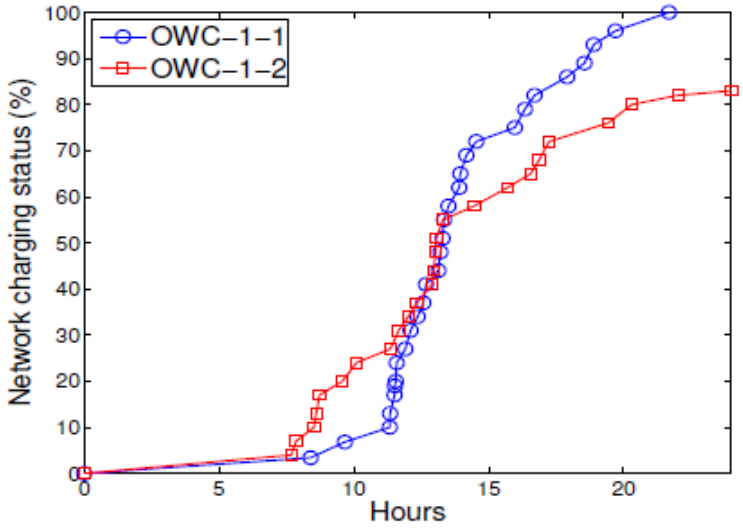


Opportunistic Wireless Charging

- OWC shows better efficiency with predictable (similar) node relations in different time frames



(e) Cambridge Dataset

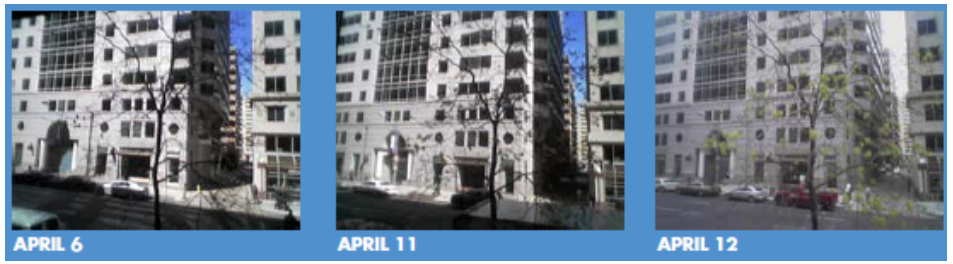


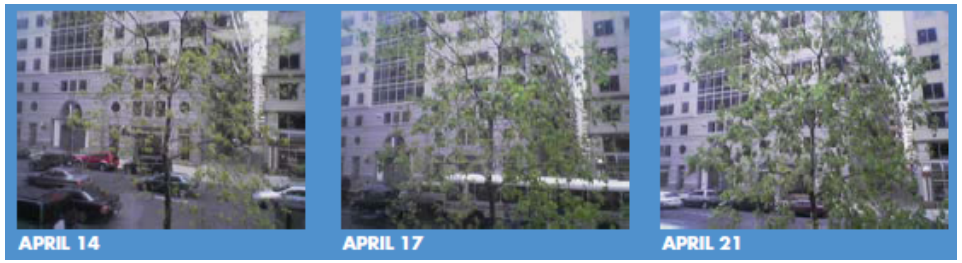
(f) MIT Dataset

[Globecom workshop 2014]

Participatory or Crowd Sensing

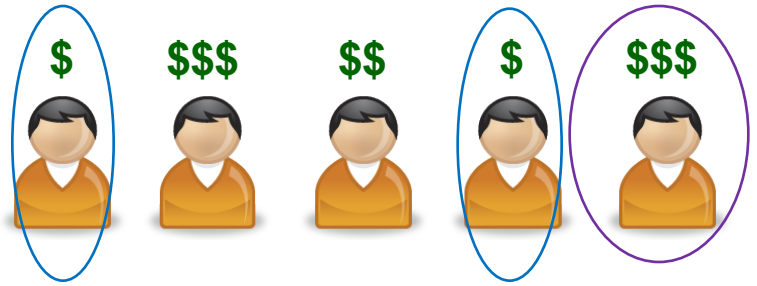
- Collection of sensor data in a repository
- Applications: Climate Change, Pollution, Health monitoring

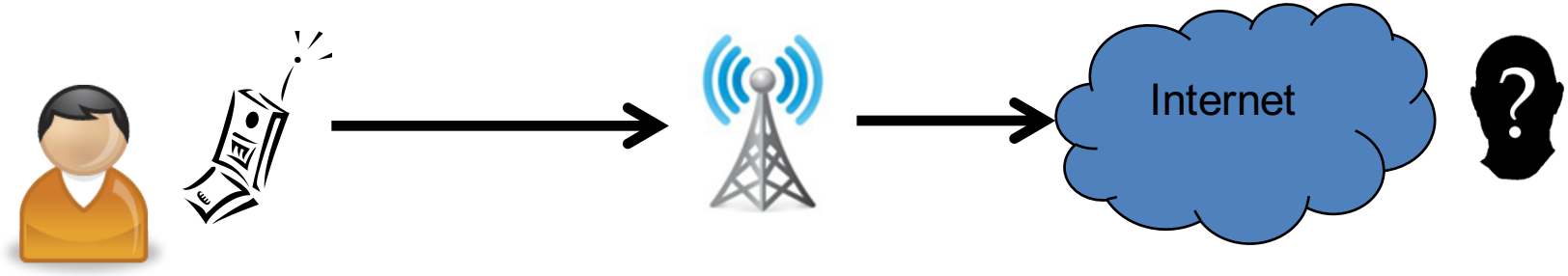




Participatory or Crowd Sensing

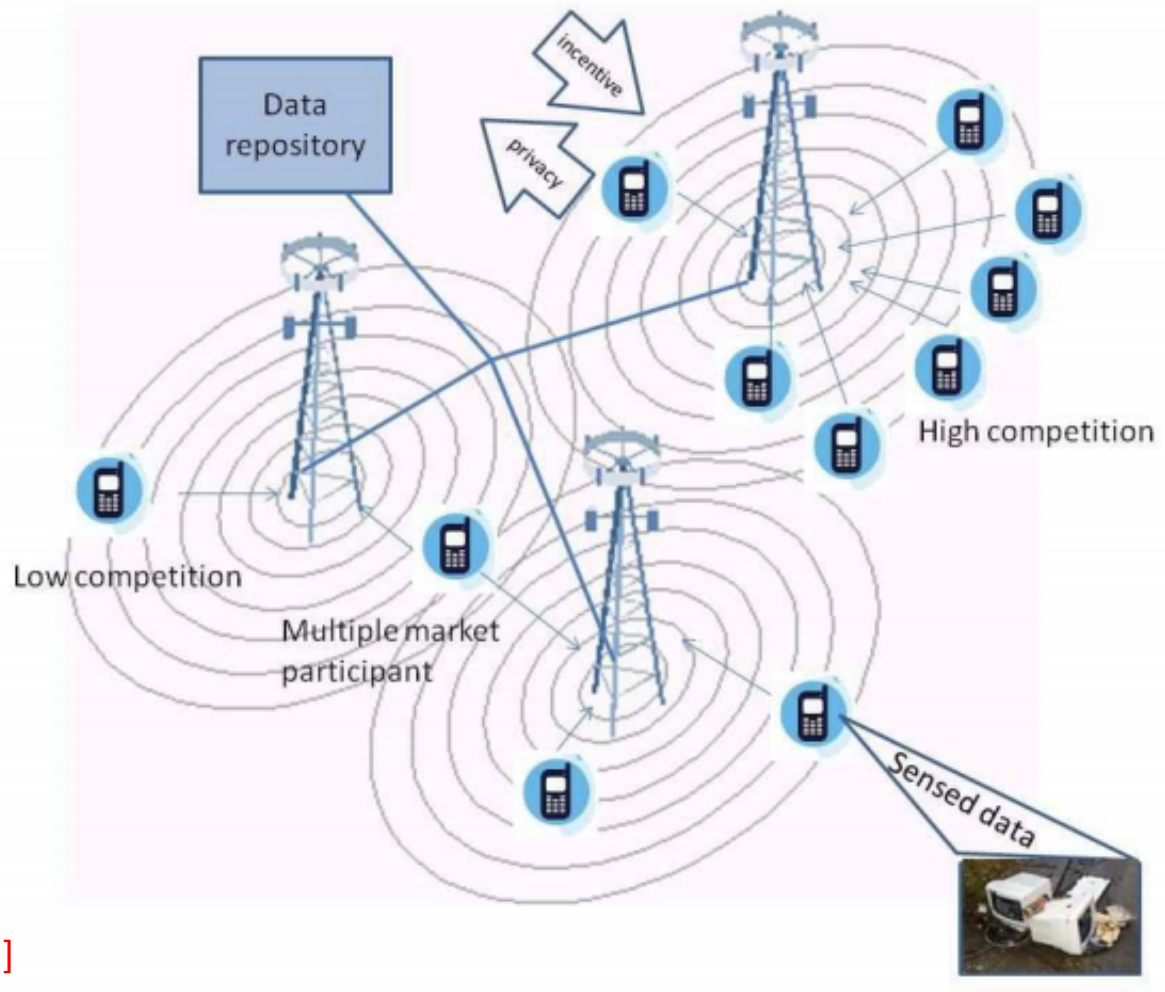
- Challenges:
  - Recruitment of Sensors
  - Incentive mechanism
  - Feature extraction
  - Anonymizing data





Reverse Auction based Crowd Sensing

- Promoting Participation
- Dynamic pricing
- Social concerns:
  - Privacy preservation
  - Power consideration



[Mobicom workshop]

Summary

Mobile Social Networks

Challenges:

Efficient Routing

Reliability

Security

Opportunities:

WiFi Offloading

Wireless Charging

Crowd Sensing

Target Tracking

Cyber Security

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