Optimal Cellular Traffic Offloading Through Data Partitioning in Opportunistic Mobile Networks

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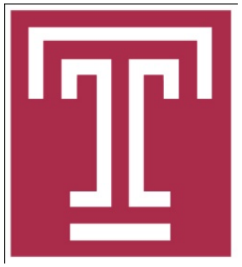


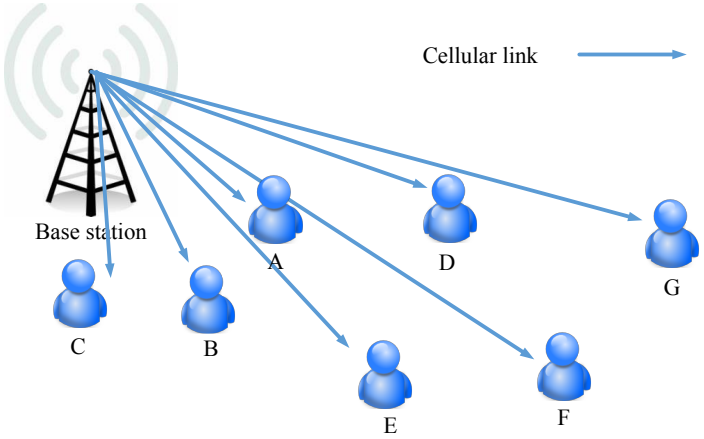
Road Map

- Introduction
- Related Work
- New Observation
- Partition Model
- Experiments
- Conclusions

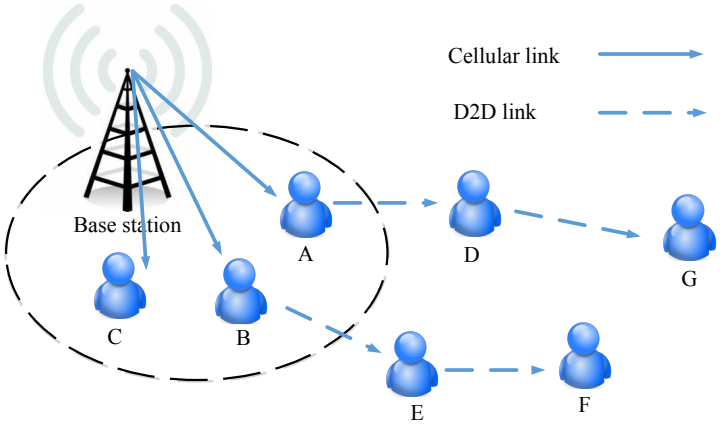
Introduction

Cellular Data Offloading

- Limited cellular network capacity cannot match with increasing user demand (Cisco VNI 2016-2021).
- Offloading through opportunistic mobile networks is a potential solution.



No offloading

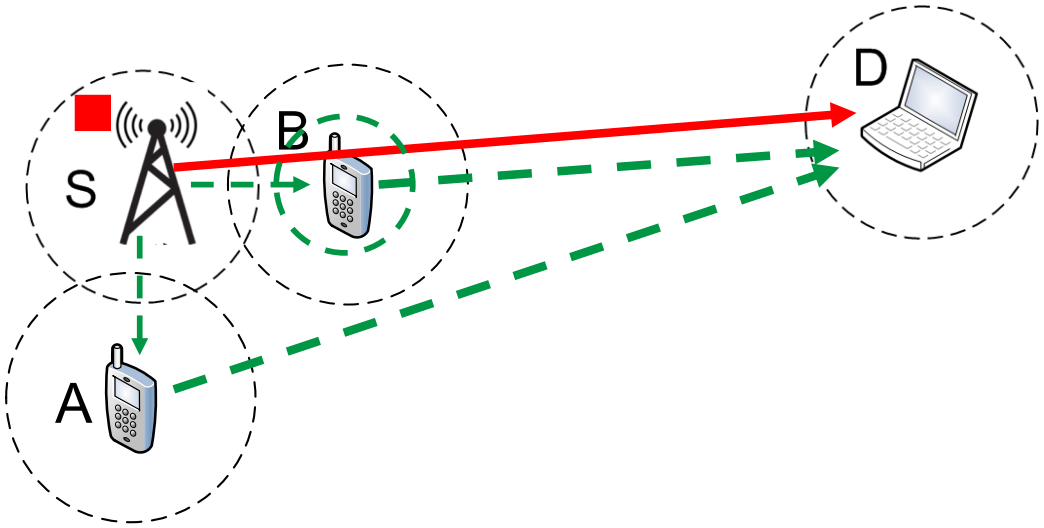


Offloading with mobile nodes

Introduction

Opportunistic contact (store-carry-forward)

- Mobile nodes physically carry data as relays
- No construction fee, wide availability

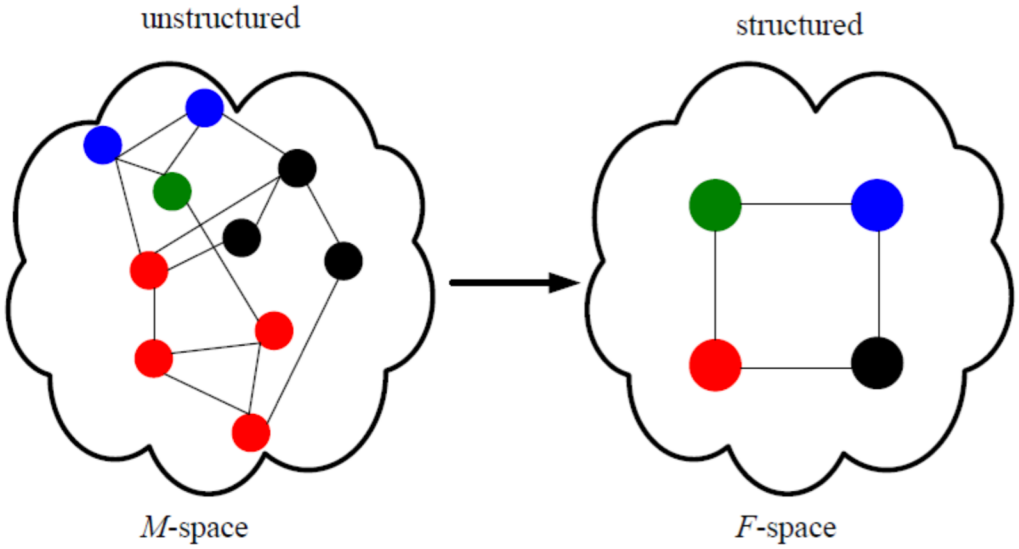


Commercial: Open Garden, M87, and VANET applications

Introduction

Social Features in Opportunistic Mobile Network

- Each individual with a social feature profile {F_1, F_2, …}
- Convert an unstructured and dynamic network to a structured and static network.

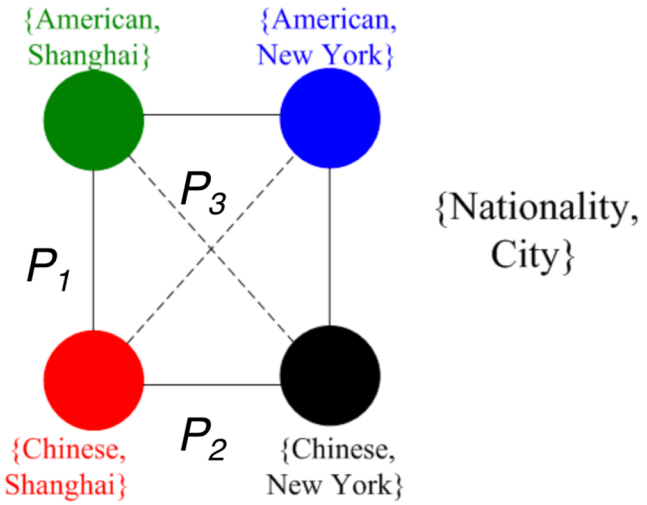


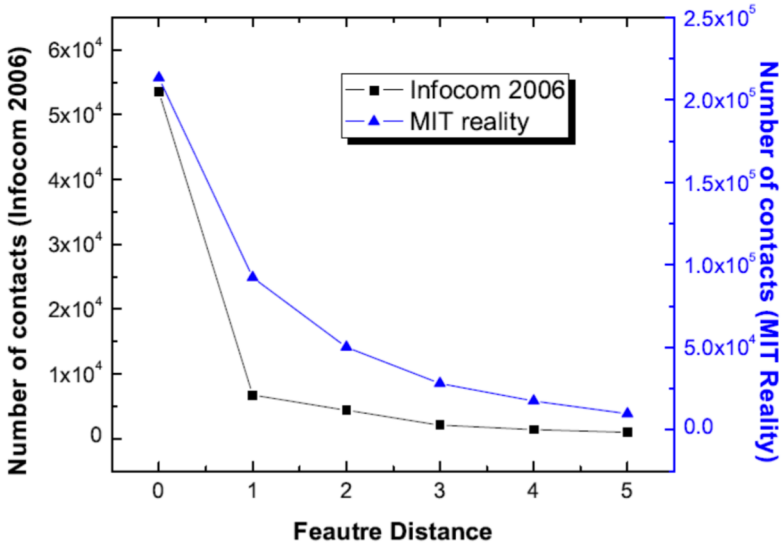
Jie Wu and Yunsheng Wang. "Social Feature-based Multi-path Routing in Delay Tolerant Networks", INFOCOM 2014.

Related Work

Feature-based Grouping Example

People come in contact with each other more frequently if they have more social features in common (P_1>P_3)

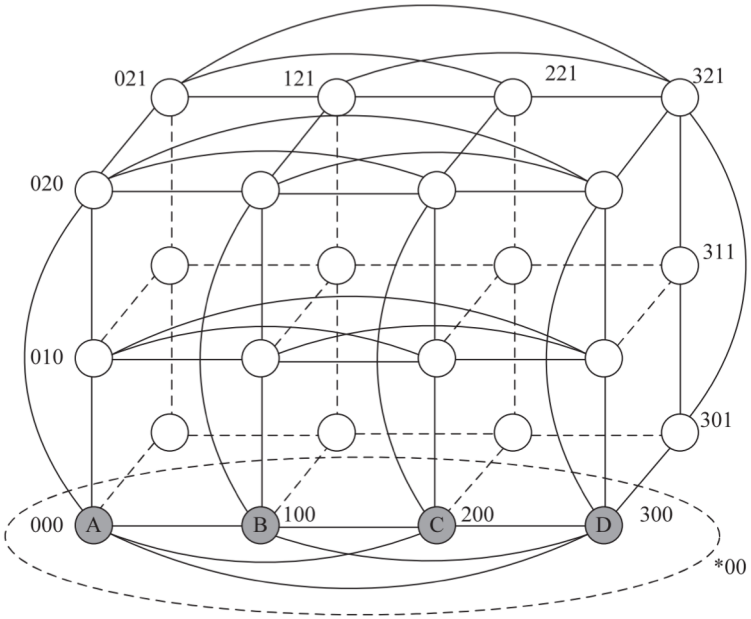




Related Work

Social Forwarding Path

Social-feature space -> social hypercube



Position (2): professor (0), researcher (1), student (2)

Gender (1): male (0), female (1)

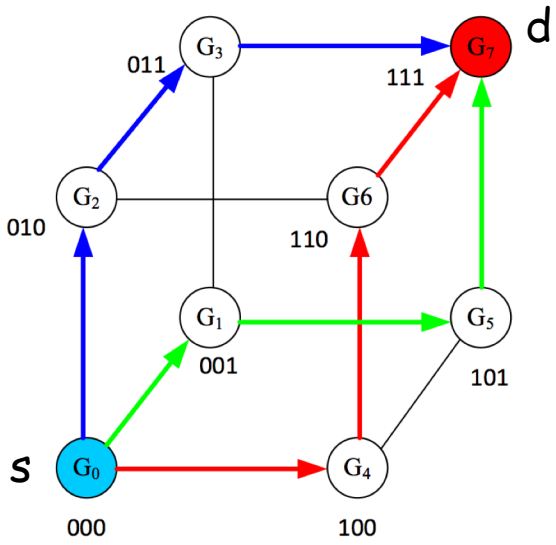
City (3): New York(0), London(1), Paris (2), Shanghai (3)

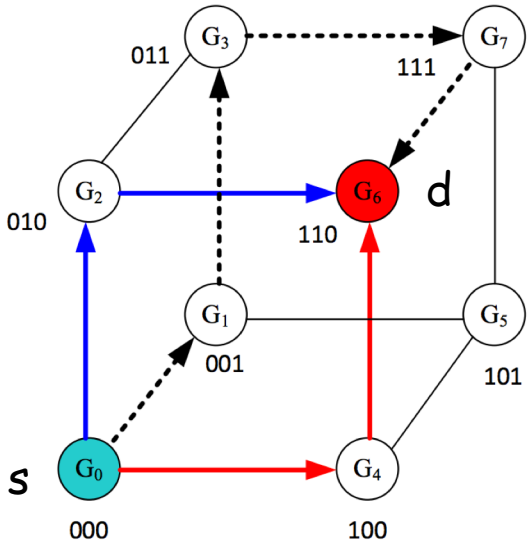
"311": a female researcher lives in Shanghai

Related Work

Hypercube-routing

- Each individual with a social feature profile {F_1, F_2, …}
- Forwarding based on feature distance in the hypercube
- k parallel paths of equal length (k = dist(s, d)).



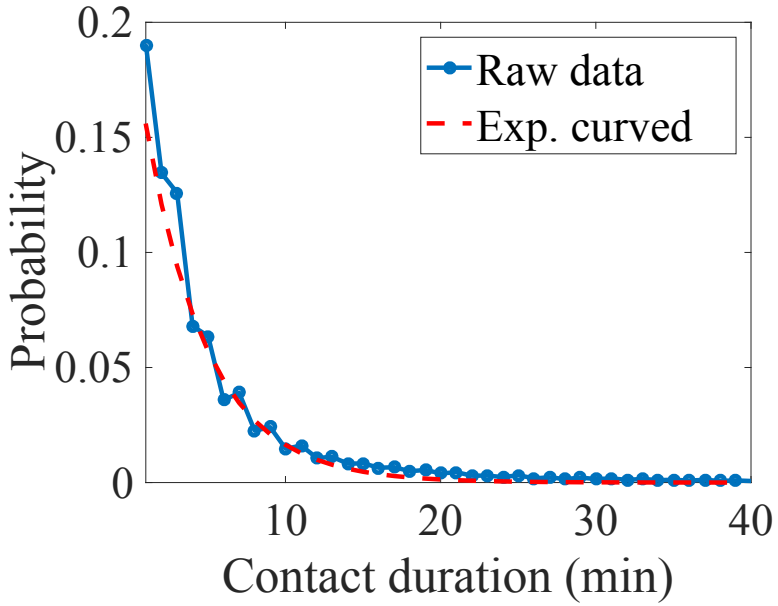


New Observation

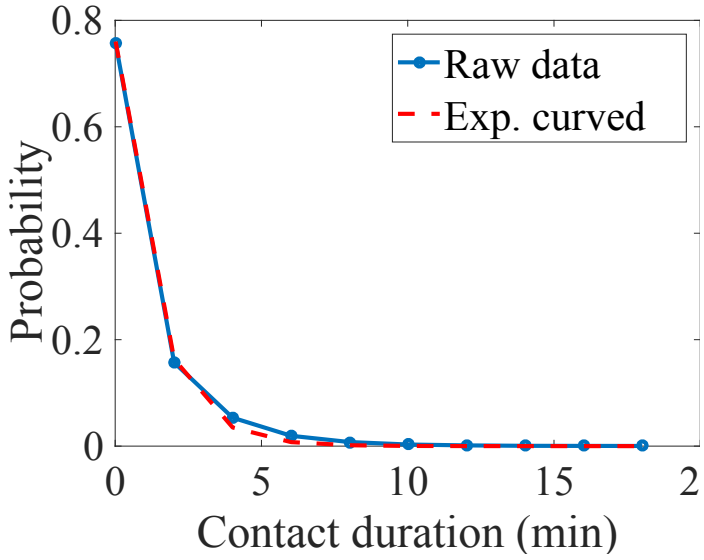
Can data always be fully transferred in one contact?

Not always!

There is a decay function $\beta(s)$, s: data size



INFOCOM trace



SIGCOMM trace

Partition Model

The Expected Delivery:

- Single path routing

  P = 0.22

- With one replication

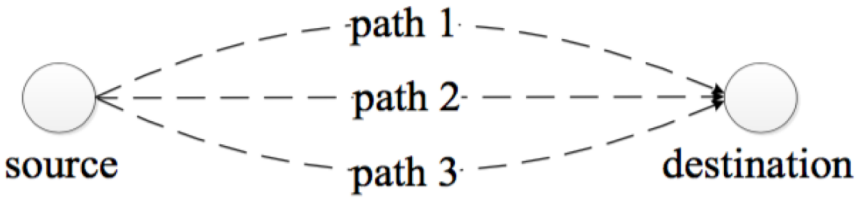
  P = 1 – (1 – 0.22) (1 – 0.22) = 0.39

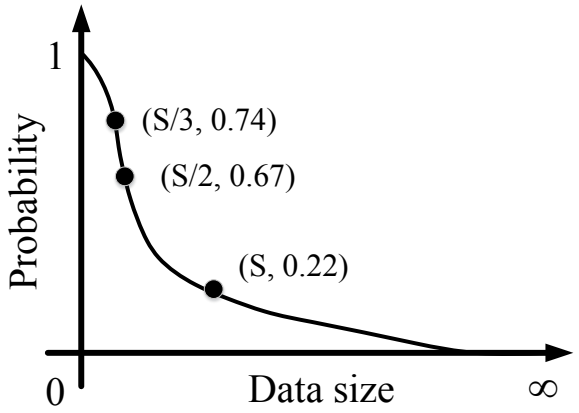
- Split to 2 data chunks

  P = 0.67*0.67 = 0.45 (Winner!)

- Split to 3 data chunks

  p = 0.74*0.74*0.74 = 0.41

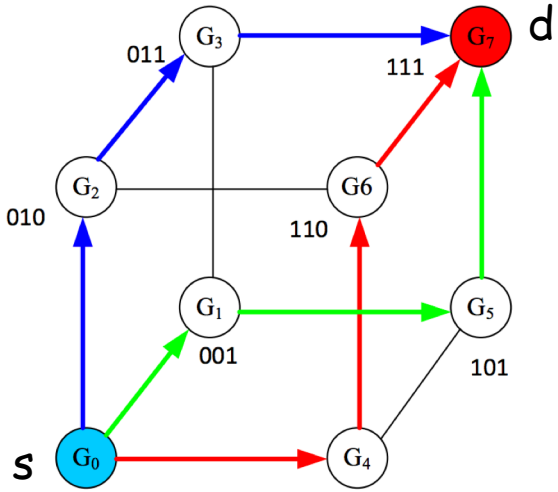


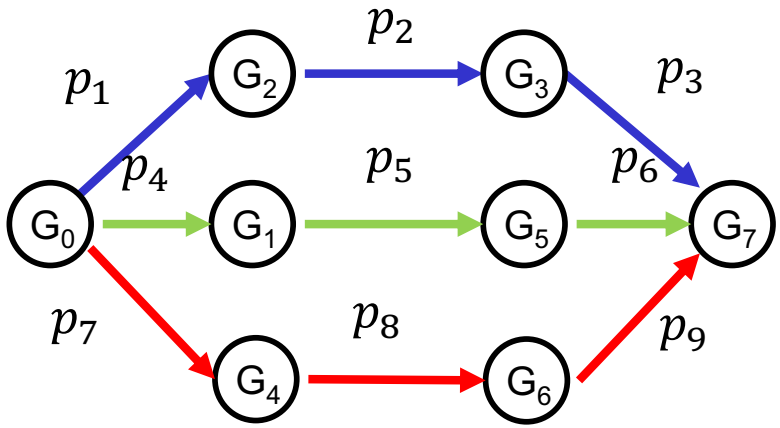


Data size	S/3	S/2	S
Probability	0.74	0.67	0.22

Partition Model

Path Probability Calculation and Data Partition





$$P_1(s_1) = p_1 p_2 p_3 \beta(s_1)$$

$$P_2(s_2) = p_4 p_5 p_6 \beta(s_2)$$

$$P_3(s_3) = p_7 p_8 p_9 \beta(s_3)$$

$\prod_{i=1}^{3} P_i(si)$ reaches the maximum when $s_1 = s_2 = s_3$.

Experiments

INFOCOM and SIGCOMM traces

Bluetooth sightings by groups of attendees carrying small devices (iMotes) in IEEE INFOCOM 2006 and ACM SIGCOMM 2009.

Trace information

Removing nodes without social information

Name	Summary		
	size	contact	social feature
INFOCOM06	61	337,418	6
SIGCOMM09	75	285,879	3

Experiments

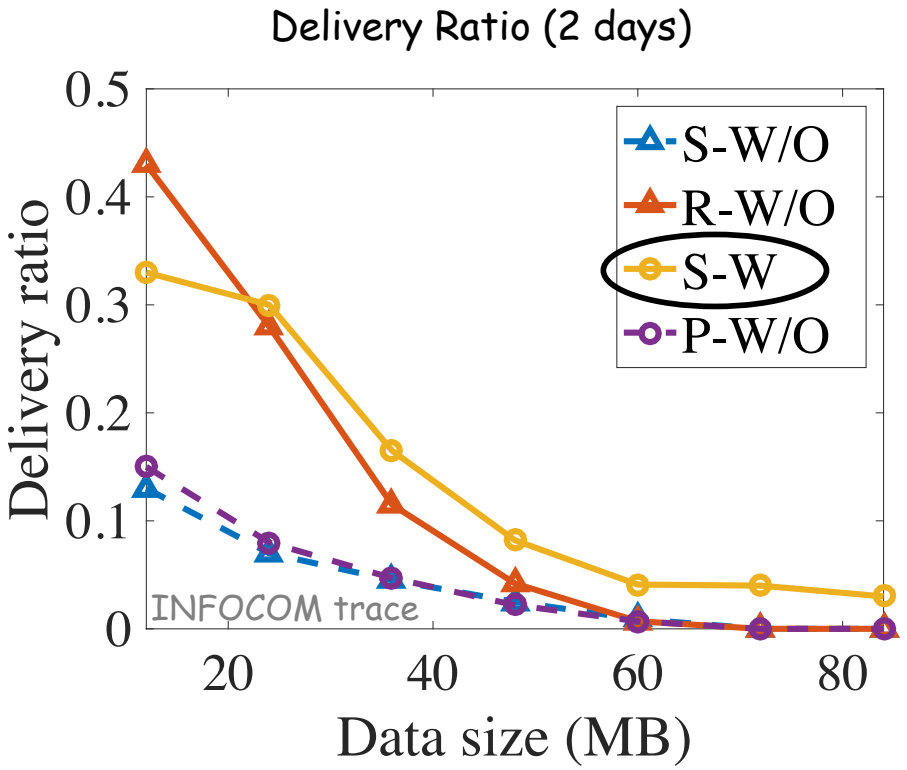
Settings

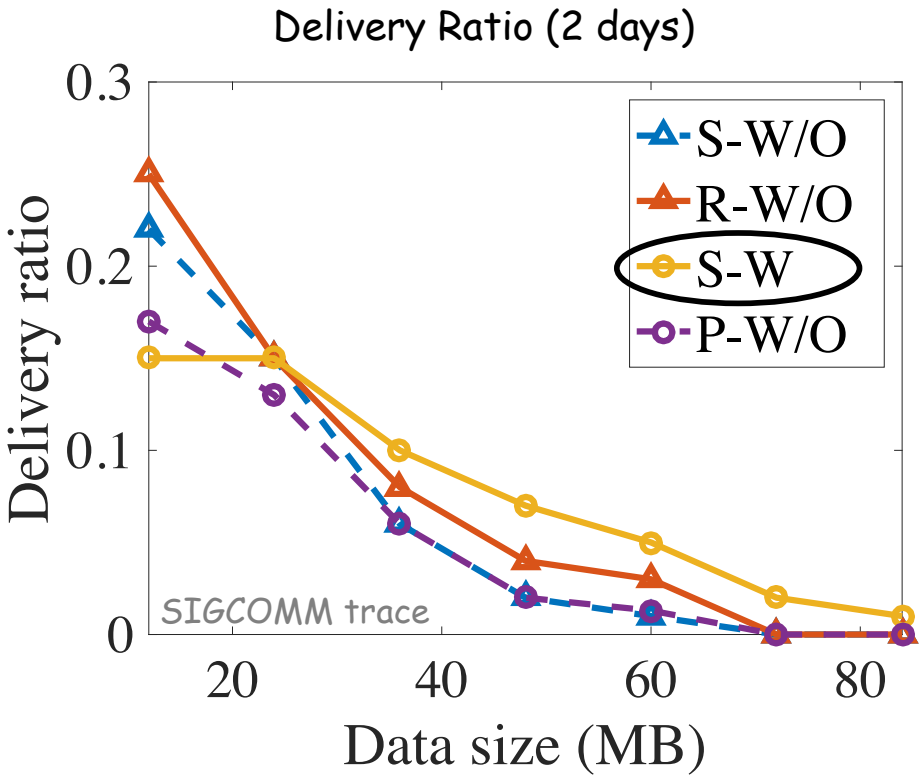
	INFOCOM	SIGCOMM
Min Contact duration	1s	120s
Data Size	12 MB to 84 MB	12MB to 84 MB
Contact bandwidth	100 KBs	100 KBs
Edge contact probability	0.097	0.081

Algorithms

- Hypercube-routing
  - Single data without partition algorithm (S-W/O) (1 path)
  - Single data with partition algorithm (S-W) (m paths, m: 2.4 on average)
  - Replication hypercube algorithm (R-W/O) (m paths)
- Single data probability-based algorithm (P-W/O)
  - Forward data based on the contact probability with destination

Experiments





Data size is small -> Replication-based algorithm is the best.
Data size is large -> Partition-based algorithm is the best.

Conclusions

Cellular traffic expansion is a challenging issue

- Traffic offloading with widely available devices

Social hypercube-based routing

- Opportunistic mobile network

Contact duration decides delivery probability

- Data partition v.s. data replication

Future work

- Comparison with coding, i.e., partition and replication