Optimal Cellular Traffic Offloading Through Data Partitioning in Opportunistic Mobile Networks

Ning Wang and Jie Wu
Dept. of Computer and Info. Sciences
Temple University
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.

---

**Diagram:**

- **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, \ldots\}
- Convert an unstructured and dynamic network to a structured and static network.

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 -&gt; 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 \( \{F_1, F_2, \ldots\} \)
- Forwarding based on feature distance in the hypercube
- \( k \) parallel paths of equal length (\( k = \text{dist}(s, d) \)).
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
  \[ P = 0.67 \times 0.67 = 0.45 \text{ (Winner!) } \]

- Split to 3 data chunks
  \[ p = 0.74 \times 0.74 \times 0.74 = 0.41 \]
Partition Model

Path Probability Calculation and Data Partition

\[ P_1(s_1) = p_1 p_2 p_3 \beta(s_1) \]
\[ P_2(s_2) = p_4 p_5 p_6 \beta(s_2) \]
\[ P_3(s_3) = p_7 p_8 p_9 \beta(s_3) \]

\[ \prod_{i=1}^{3} P_i(s_i) \text{ reaches the maximum when } s_1 = s_2 = s_3. \]
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

<table>
<thead>
<tr>
<th>Name</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>size</td>
</tr>
<tr>
<td>INFOCOM06</td>
<td>61</td>
</tr>
<tr>
<td>SIGCOMM09</td>
<td>75</td>
</tr>
</tbody>
</table>
Experiments

Settings

<table>
<thead>
<tr>
<th></th>
<th>INFOCOM</th>
<th>SIGCOMM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Min Contact duration</td>
<td>1s</td>
<td>120s</td>
</tr>
<tr>
<td>Data Size</td>
<td>12 MB to 84 MB</td>
<td>12 MB to 84 MB</td>
</tr>
<tr>
<td>Contact bandwidth</td>
<td>100 KBs</td>
<td>100 KBs</td>
</tr>
<tr>
<td>Edge contact probability</td>
<td>0.097</td>
<td>0.081</td>
</tr>
</tbody>
</table>

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