Empirical Evaluation of Hybrid Opportunistic Networks

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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 other?
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

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

- 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

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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
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

- Left-up: Utility of OppoNet (messaging)
- Left-down: Utility of OppoNet (data-push)
- Right: Utility of APs (messaging)
Utilities – Kaist Dataset

- Left-up : Utility of OppoNet (messaging)
- Left-down : Utility of OppoNet (data-push)
- Right : Utility of APs (messaging)
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 infrastructure, i.e. 900 APs cost US$4,500,000.
- Compare our observation with previous theoretical 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