RoCNet: Robust Cellular Network for Disaster Communication and Traffic Offloading

Haruki Izumikawa
Suphakit Awiphan
Jiro Katto
Katto Laboratory, Waseda University

Outline

- **Research motivation**
  * “3.11” in 2011

- **Related study**

- **Proposed architecture RoCNet**
  * combines;
    - infrastructure-based networking
    - opportunistic networking
  for data-offloading and disaster controlling.

- **Preliminary evaluation using computer simulation**

- **Conclusion**
Severe natural disaster would make a cellular network unavailable due to the blackout that results in the stop of base stations.

Infrastructure-less communication technology, e.g., adhoc network, delay tolerant network (DTN) etc., could be considered as a promising idea for communication in challenged situations.
However, although the technology has been very popular for research engineers for years, it does not achieve business success. 

WHY??

→ Because such technology won’t be profitable.

→ Growing popularity of mobile data communication has been leading a growing lack of radio resource (capacity) in a cellular system.

→ A profitable infrastructure-less technology would be spreading!??
Related study tackling surge in mobile traffic

- Heterogeneous network (HetNet) in 3GPP
  - Offloading traffic to low-power local nodes (Pico cells)
  - Cell range expansion: balance the traffic load through a handover biasing and adaptive resource partitioning

- Self-organized network (SON) in 3GPP
  - Adjusting handover parameters to balance the traffic load

- Multi-RAT (Radio Access Technology) network
  - Offloading traffic by, for example, switching data path to Wireless LAN from cellular

→ These studies aim to *locally* offload traffic, which would result in nodes being wastefulness at off-peak times.
Related study about traffic offloading using the store-carry-forward manner

- Traffic offloading using the store-carry-forward manner is just a nascent study

- MADNet (Metro-politan Advanced Delivery Network) and others data-set is first sent to $k$ users from a server followed by being propagated to all subscribe users from the $k$ users.
  - Choosing $k$ is the research target.
  - Three algorithms: Random, Greedy, and Heuristic.

"Mobile Data Offloading in Metropolitan Area Networks," MobiCom 2010 (poster), Sep. 2010.
RoCNet: Robust Cellular Network for Disaster Communication and Traffic Offloading

- Combines infrastructure-based (e.g., cellular) and opportunistic networking for disaster controlling and spatial data offloading

- While the 3G network is used as both signaling (e.g., the end-to-end ACK in DTN) and bearer channel (e.g., contents), DTN is mainly used as bearer channel.

- Since the message switching mechanism has some drawbacks such as message delivery delay and delivery rate, the cellular network is normally used as a communication path as far as the network is not congested.
  → The degree of congestion decides a route of data forwarding.
Overview of RoCNet

1. Uplink traffic Offloading
   - User A in congested region
   - Physically move to suburbs
   - NOT congested

2. Downlink traffic Offloading
   -Popular content
   -RoCNet Mediator (middle box)
   -App. server

3. P2P communication
   -3G/LTE
   -App. server

4. Disaster controlling
   -Outside coverage

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Preliminary evaluation

- Performance evaluation of the RoCNet uplink transmission scenario using the Opportunistic Network Environment (ONE) simulator
- Focusing on the effect of the traffic offloading by smoothing out traffic imbalances the store-carry-forward fashion gives
- Use of a realistic scenario: Working day movement model on Pittsburgh map
- Mainly two scenarios: cellular scenario and RoCNet scenario
  * Cellular scenario: user terminals had one communication interface and only attached to a cellular BS to transmit messages
  * RoCNet scenario:
    - User terminals were equipped with two interfaces --cellular and Bluetooth interfaces
    - A messenger who had a role in carrying messages was introduced. (The messenger followed Shortest Path Map Based Movement.)
    - The user terminals directly transmitted a message to a BS whenever the BS was not congested.
    - A BS that had more than 30 connections was considered to be under congestion. If there were a Bluetooth connection with a messenger, the terminal forwarded a message to the messenger.
## Simulation parameters

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area size [km]</td>
<td>18.2 x 11.7</td>
<td>Around Pittsburgh (PA, USA)</td>
</tr>
<tr>
<td>The number of user terminals</td>
<td>250</td>
<td></td>
</tr>
<tr>
<td>The number of messengers</td>
<td>30, 50, 100</td>
<td>Data carrier</td>
</tr>
<tr>
<td>Radio coverage of cellular [m]</td>
<td>1000</td>
<td></td>
</tr>
<tr>
<td>Radio coverage of Bluetooth [m]</td>
<td>100</td>
<td>Assuming class 1</td>
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<tr>
<td>Maximal transmission speed of cellular [Mbps]</td>
<td>21.6</td>
<td>Assuming LTE</td>
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<tr>
<td>Maximal transmission speed of Bluetooth [Mbps]</td>
<td>24</td>
<td>Assuming Bluetooth 3.0 + HS</td>
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<tr>
<td>Movement model</td>
<td>Working day movement (users)</td>
<td></td>
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<tr>
<td></td>
<td>Shortest Path Map Based Movement (messengers)</td>
<td></td>
</tr>
<tr>
<td>Moving speed [m/s]</td>
<td>2 - 5</td>
<td>Users</td>
</tr>
<tr>
<td></td>
<td>4 - 10</td>
<td>Messengers</td>
</tr>
<tr>
<td>Wait time of messengers after reaching destination s</td>
<td>60 - 120</td>
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</tr>
<tr>
<td>Messages size [KB]</td>
<td>1 - 500</td>
<td>Randomly selected</td>
</tr>
<tr>
<td>Message generation interval [s]</td>
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<tr>
<td>Storage capacity in each terminal [GB]</td>
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<td></td>
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<tr>
<td>Simulation time [sec]</td>
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<td>2 hours</td>
</tr>
<tr>
<td># of simulations</td>
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<td></td>
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</tbody>
</table>
Simulation environment overlaid on a real map

Users stay in their homes

Downtown area (business district)
Simulation environment overlaid on a real map

Cellular coverage

Cellular BS

Road

Downtown area (business district)

User
Simulation environment overlaid on a real map

Users still stay in their homes

Downtown area (business district)
Simulation environment overlaid on a real map

Two hours later: some went to work and are still working

Downtown area (business district)
Pick up three BSs in specific areas

- **Downtown area (business district)**
- **On commute route**
- **Residential district**
Transition of traffic in the BS-A in a residential district

The amount of traffic treated in the BS-A decreased with time since some users went to work.
Transition of traffic in the BS-B on a commute route

The amount of traffic treated by the BS-B increased only while users commuted.
In RoCNet, traffic load drastically reduced owing to the store-carry-forward message switching mechanism in the high traffic demand time zones (i.e., 40 minutes after the start of the simulation and later).
In the RoCNet scenarios, average message delivery latencies became larger compared to the cellular scenario due to the store-carry-forward manner.
Conclusion

- We proposed a robust cellular network (RoCNet) that combines infrastructure-based and opportunistic networking for disaster controlling and data offloading.

- The result of the simulation indicated that RoCNet can alleviate the traffic congestion through the store-carry-forward message switching mechanism, i.e., RoCNet could suppress peak traffic in a traffic-congested base station by distributing traffic to vicinity base stations.

- As our future study, we will further consider the RoCNet mechanism, especially downlink traffic offloading mechanism, in more detail.