Network Coding for Wireless Grids

Frank H.P. Fitzek
Mobile Device Group
www.fitzek.net
frank@fitzek.net
wireless grids

Cellular link (C)

base station

Cellular link (C)

Cooperation
wireless grids

• Based on user cooperation, but why should users cooperate?
  – Create cooperation enabling services
  – Create trust and pay off tolerance
  – „emoney“ bad idea

• Which kind of services can be supported
  – All (unicast/multicast/etc)
  – Some examples
nice idea, but ...

• Analytical and simulative investigation
• A large number of testbeds to verify our ideas and the get real feedback for our further investigations (it is a two way street)
cooperative localization
cooperative video service
cooperative download

- Using GPRS and Bluetooth for cooperation among two terminals for file sharing
- N70 Mobile Phones
- Symbian/C++ implementation
- Tit for Tat Strategy
- Benefit in the download time (reduced by a factor of two), the energy (going down to 56%) and (perhaps) reduced service costs
- Fit with analytical results
cooperative web browsing
problem

• Interference in the cooperation (local) cluster is high and can cause long delays and high energy consumption

• Improve the local communication
network coding

end2end, network layer or higher
network coding for wireless grids
Scenario: Wheel++
- 12 mobile devices in total
- Four flows (one per cluster)
- Each device receives cellular input
- Just relaying to exchange

### Activity Matrix

<table>
<thead>
<tr>
<th>Mobile Device Number</th>
<th>Sending</th>
<th>Receiving</th>
<th>Idle</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>1</td>
<td>12</td>
</tr>
<tr>
<td>2</td>
<td>s</td>
<td>i</td>
<td>r</td>
</tr>
<tr>
<td>3</td>
<td>i</td>
<td>r</td>
<td>s</td>
</tr>
<tr>
<td>4</td>
<td>i</td>
<td>r</td>
<td>s</td>
</tr>
<tr>
<td>5</td>
<td>s</td>
<td>i</td>
<td>r</td>
</tr>
<tr>
<td>6</td>
<td>i</td>
<td>r</td>
<td>s</td>
</tr>
<tr>
<td>7</td>
<td>i</td>
<td>r</td>
<td>s</td>
</tr>
<tr>
<td>8</td>
<td>i</td>
<td>r</td>
<td>s</td>
</tr>
<tr>
<td>9</td>
<td>i</td>
<td>r</td>
<td>s</td>
</tr>
<tr>
<td>10</td>
<td>i</td>
<td>r</td>
<td>s</td>
</tr>
<tr>
<td>11</td>
<td>i</td>
<td>r</td>
<td>s</td>
</tr>
<tr>
<td>12</td>
<td>i</td>
<td>r</td>
<td>s</td>
</tr>
</tbody>
</table>

### Idle Matrix

<table>
<thead>
<tr>
<th>Sending</th>
<th>Receiving</th>
<th>Idle</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>24</td>
<td>16</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>180</td>
</tr>
</tbody>
</table>

**SUM**: 20 24 196
### Scenario: Wheel++

- 12 mobile devices in total
- Four flows (one per cluster)
- Each device receives cellular input
- Network coding within each cluster

#### Activity Matrixes

<table>
<thead>
<tr>
<th>Mobile Device Number</th>
<th>Sending</th>
<th>Receiving</th>
<th>Idle</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SUM</td>
<td>16</td>
<td>24</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Activity Matrixes</th>
<th>Sending</th>
<th>Receiving</th>
<th>Idle</th>
</tr>
</thead>
<tbody>
<tr>
<td>One activity matrix</td>
<td>4</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>All activity matrixes</td>
<td>16</td>
<td>24</td>
<td>8</td>
</tr>
<tr>
<td>All idle matrixes</td>
<td>0</td>
<td>0</td>
<td>144</td>
</tr>
</tbody>
</table>
Scenario: Wheel++
• 12 mobile devices in total
• Four flows (one per cluster)
• Each device receives cellular input
• Network coding over all cluster
• Device 2 is doing the most work

<table>
<thead>
<tr>
<th>mobile device number</th>
<th>sending</th>
<th>receiving</th>
<th>idle</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4</td>
<td>8</td>
<td>36</td>
</tr>
<tr>
<td>2</td>
<td>8</td>
<td>62</td>
<td>26</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td>SUM</td>
<td>13</td>
<td>78</td>
<td>65</td>
</tr>
</tbody>
</table>

Legend:
- i: idle slot
- r: receiving slot
- s: sending unicast slot
- b: broadcasting slot
- bc: broadcasting coded slot
Results

Energy usage Wheel++ 2 clusters

Normalized energy

- Pure relaying
- Coding in teams
- Pure coding

sending
receiving
idle
network coding

N810 testbed

S60 testbed

opensensor testbed
channel measurement
channel measurement
mac measurement

Not used
PictureViewer

- Convey pictures of your mobile phone to your neighbors
- How to do this?
RLNC on Mobile Phones

- Implementation with larger finite field
Results of Preanalysis (g=64)

Fig. 4: Expected number of transmission per packet, $p = 0.3$. 
Systematic Coding
Coding throughput on Nokia N95

Nokia N95-8GB, ARM 11 332 MHz CPU, 128 MB ram, Symbian OS 9.2

![Graph showing coding throughput for different generation sizes]
Energy Consumption

- Source pure
- Sink pure
- Source systematic
- Sink systematic

Normalized energy consumption

<table>
<thead>
<tr>
<th>Generation size [Packets]</th>
<th>No coding</th>
<th>16</th>
<th>32</th>
<th>64</th>
<th>128</th>
<th>256</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source pure</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sink pure</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Source systematic</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sink systematic</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
network coding and cooperation

Cooperation w & w/o nc
nc
SoA

Throughput [kB/s]

PEP [%]
Books

