Deciphering a Commercial WiMAX Deployment using COTS Equipments

Kok-Kiong Yap

SING Group Meeting : August 10, 2010
Wireless Networks Today

- Mobile network
  - High latency (100 - 200 ms)
  - Low bandwidth
  - Good coverage
- WLAN/WiFi
  - Low latency (0.1 - 20 ms)
  - High bandwidth
  - Poor coverage
The Promise of 4G

- Low latency, high bandwidth & wide area coverage

- We study an incipient commercial WiMAX network to investigate
  - No rate limits on traffic
  - Result can be seen as informal upper bound on performance (because network is unloaded)
A 4G WiMAX Network

- Study of a commercial WiMAX network
- Clear’s innovation network in Mountain View and Stanford
- Production at the end of the year
Measurement Setup

- **COTS equipments**
  - GPS, laptop and modem
  - Custom Python scripts

- **Driving Tests**
  - Location, Time, CINR, RSSI

- **Static Tests**
  - Location, Time, CINR, RSSI, iPerf, RTT, Traceroute
Some numbers...

- **Driving test**
  - 1.33 to 12.72 s each
  - average 21.8 readings per min

- **Static test**
  - 66.93 s (st.dev. 13.27 s) per reading

- **Stanford**
  - 1837 driving readings
  - 75 static readings

- **Mountain View**
  - 2961 driving readings
Signal Strength

- **Average (± St.Dev.)**
  - CINR 17.6 (± 9.0) dB
  - RSSI -72.5 (± 11.39) dBm
- Deadspots are present but rare
  - 2.3% of locations surveyed
- Usable (i.e., CINR > 10 dB) in 82.7 % of area surveyed
Goodput in Stanford

- **TCP**
  - 0.81 Mbps up
  - 2.49 Mbps down
- **UDP**
  - 2.17 Mbps up
  - 7.45 Mbps down
Latency in Stanford

- **Jitter**
  - 19.14 ms up
  - 4.98 ms down

- **RTT**
  - 94.37 (± 77.90) ms

- Occasional spikes
Wide area measurements?

- Static tests is tedious
  - too slow for repetition during driving
  - end-user performance probed

- Driving tests is simple
  - fast and easy
  - not measuring end-user performance
Goodput & CINR/RSSI

- Correlation coeff : 0.876

<table>
<thead>
<tr>
<th></th>
<th>TCP Uplink</th>
<th>TCP Downlink</th>
<th>UDP Uplink</th>
<th>UDP Downlink</th>
</tr>
</thead>
<tbody>
<tr>
<td>CINR</td>
<td>0.037</td>
<td>0.938</td>
<td>0.823</td>
<td>0.933</td>
</tr>
<tr>
<td>RSSI</td>
<td>0.045</td>
<td>0.902</td>
<td>0.729</td>
<td>0.896</td>
</tr>
</tbody>
</table>

UDP
Latency/Jitter & CINR

• Fairly correlated

• RTT/Jitter
  • Stable if CINR > 20 dB
  • Corr. coeff. -0.564 to -0.791 with CINR for CINR < 20 dB
Tiers of Performance

- CINR < 0 dB : Unusable
- 0 dB < CINR < 10 dB : difficult/intermittent
- 10 dB < CINR < 20 dB : restrictive web surfing
- 20 dB < CINR < 30 dB : good access with min. jitter
- CINR > 30 dB : wireless is not the bottleneck
## Coverage

<table>
<thead>
<tr>
<th>Metric</th>
<th>Location</th>
<th>Min</th>
<th>Avg ± Std Dev</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of Base stations</td>
<td>Stanford</td>
<td>0</td>
<td>2.01 ± 1.07</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Mtn View</td>
<td>0</td>
<td>3.56 ± 1.16</td>
<td>6</td>
</tr>
<tr>
<td>CINR (dB)</td>
<td>Stanford</td>
<td>-11.0</td>
<td>18.61 ± 8.15</td>
<td>38.0</td>
</tr>
<tr>
<td></td>
<td>Mtn View</td>
<td>-13.0</td>
<td>16.90 ± 9.41</td>
<td>35.0</td>
</tr>
<tr>
<td>RSSI (dBm)</td>
<td>Stanford</td>
<td>-100.0</td>
<td>-73.91 ± 10.25</td>
<td>-37.0</td>
</tr>
<tr>
<td></td>
<td>Mtn View</td>
<td>-106.0</td>
<td>-71.62 ± 11.97</td>
<td>-34.0</td>
</tr>
</tbody>
</table>
Variations of CINR

- Predicts variation of performance
- Temporal (Stable)
  - avg. CINR of 21.7 dB has std. dev. 0.59 dB
  - 0.18 dB per s change
- Spatial
  - 0.18 dB per m with std. dev. 0.24 db per m
  - Expect changes in seconds when moving
Handover

- Jumps in CINR/RSSI
- Not detectable in TCP iperf with 1s interval
Footprint of Base-station

- Simple average path loss? \( L = 10^n \log_{10}(d) + C \)

Mountain View

Stanford
Footprint of Base-station

- Complex function of terrain, frequency, power, etc.
Lesson Learnt

• COTS equipments

• CINR vs RSSI

• Applications for mobile networks
Summary of Survey

- The good...
  - Good bandwidth
  - Wide area coverage
- The not-so-good...
  - Dead spots and variations
  - High latency (at least compared to WiFi)
Questions and Comments?