Augmenting Mobile 3G Using WiFi

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Mobile data is growing exponentially

CISCO VNI 2010
Demand projected to outstrip capacity

![Graph showing demand versus capacity from 2010 to 2016. The demand line is consistently higher than the capacity line, indicating an increasing gap.](chart.png)
Is more spectrum the answer?

“In light of the limited natural resource of spectrum, we have to look at the ways of conserving spectrum” -- Mark Siegel (AT&T)

<table>
<thead>
<tr>
<th>Current allocation</th>
<th>409.5 MHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Available but unallocated</td>
<td>50 MHz</td>
</tr>
<tr>
<td>Projected demand by 2016</td>
<td>800-1000 MHz</td>
</tr>
</tbody>
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Getting What You Pay For on the Mobile Internet

BERLIN — When TeliaSonera, the Nordic telecommunications operator, switched on the world’s fastest wireless network last December, customers quickly ratcheted up their consumption of mobile data tenfold.

http://www.nyt.com
The BET of spectrum scarcity

**Behavioral**

*AT&T wants to 'educate' you about data usage*

Any time a business announces that it needs to "educate" its customers about their behavior, you'd best check your wallet, because someone's going to be reaching for it.

**Economic**

*Metered Mobile Data Is Coming and Here's How*

Contributor Stacey Higginbotham | Monday, December 28.

**Technical**

*Shannon's specter*

By Kevin Fitchard

Increase efficiency
Reduce usage
Augmenting Mobile 3G using WiFi

Offload data to WiFi when possible

We look at vehicular mobility
Our work

First joint study of 3G and WiFi connectivity

• Can WiFi usefully augment 3G capacity?
• Conducted across three cities

Wiffler: A system to offload data to WiFi

• Increase offloaded data but respect app constraints
• Deployed on 20 vehicles
Measurement study

Vehicular nodes with 3G and WiFi (802.11b) radios

- Amherst: 20 buses
- Seattle: 1 car
- SFO: 1 car
WiFi availability is low
WiFi loss rate is higher

Cumulative fraction

Packet reception ratio
WiFi (802.11b) throughput is lower
Implications for offloading data to WiFi

Straightforward design: use WiFi when available
  Offloads only 10% of the data
  Hurts application performance
Key techniques in Wiffler

Prediction-based offloading
• Exploit the delay tolerance of apps to increase data offloaded to WiFi

Fast switching
• Combat poor WiFi connectivity
Prediction-based offloading

Delay data transfers only if that reduces 3G usage

Transfer requirements: $S$ bytes by $D$ seconds

- $W = \text{Predicted WiFi capacity over future} \ D \ \text{seconds}$
- Send data on 3G only when $(W < S \cdot c)$
- Send data on WiFi whenever available
Predicting WiFi capacity

Based on (# of APs) x (capacity per AP)

Observation: future AP encounters depend on recent past

Predict # of APs based on the last $\forall$ encounters
Error in predicting # of APs

Relative error

Prediction interval (secs)

N=1

N=4

N=8
Fast switching

Poor WiFi connectivity will hurt demanding apps such as VoIP and video streaming

Send the packet on 3G if WiFi does not succeed within a threshold

• Link-layer retransmissions take time
• Losses are bursty
Implementation of Wiffler
Evaluation

Deployment on 20 vehicular nodes

Trace-driven simulations
## Deployment results

<table>
<thead>
<tr>
<th></th>
<th>Data offloaded to WiFi</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prediction-based offloading</td>
<td>30%</td>
</tr>
<tr>
<td>WiFi when available</td>
<td>10%</td>
</tr>
</tbody>
</table>

Transfer size: 5MB; Delay tolerance: 60 secs; Inter-transfer gap: random with mean 100 secs

<table>
<thead>
<tr>
<th></th>
<th>Time w/ good voice quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fast switching</td>
<td>68%</td>
</tr>
<tr>
<td>WiFi when available</td>
<td>42%</td>
</tr>
</tbody>
</table>

VoIP-like traffic: 20-byte packet every 20 ms
Trace-driven evaluation

Yields results comparable to deployment

Vary workload, AP density, delay tolerance, switching threshold

Alternative strategies

**Impatient**: use WiFi when available

**Patient**: waits until the delay threshold

**Breadcrumbs**: mobility prediction + location history

**Oracle**: perfect future knowledge
Wiffler increases data offloaded to WiFi

Performance of Wiffler is comparable to optimal
More complicated predictions do not help
Prediction reduces completion time

![Graph showing completion time vs. delay tolerance for different models: Patient, Wiffler, Breadcrumbs, Oracle, and Impatient. The graph indicates that prediction reduces completion time.](graph.png)
More offloading in urban centers

Fraction of data offloaded to WiFi

24% WiFi availability

12% WiFi availability

Delay Tolerance (seconds)
Fast switching improves performance of demanding applications

% time with good voice quality

Switching delay threshold (ms)

Oracle
Only 3G
Wiffler
No switching
Possible extensions

Reduce energy cost of searching for usable WiFi

Predict what a user will access and prefetch

Recommend content to users based on what is cached (courtesy Romit Roy)
Conclusions

Offloading to WiFi can augment mobile data transfer capacity and reduce pressure on cellular spectrum

But must overcome the low WiFi availability and performance

Prediction-based offloading and fast switching can tackle these challenges

Offloads a third of the data if 1-min delays are tolerable