The Future of 3G Wireless: Should the Cellular Incumbents be Worried?

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Outline
- The next generation cellular challenge
- Wireless LAN’s and ad hoc networks
- Energy aware routing

The Second Generation Model
- Radio Tower
- Radio Equipment
- Backhaul
- Switching
- Voice Circuits

The Third Generation Model
- Radio Tower
- Radio Equipment
- Backhaul
- Switching
- Voice, Video, Audio, and Data Circuits

The Economic Challenge
- What price for high-quality, on-demand, anywhere content?
  - $0.01/kbps per minute
- Examples:
  - 1.2Mbps MPEG video = $12.00/minute
  - 128kbps MP3 audio = $1.28/minute
  - www.nytimes.com (150kB) = $0.20/page
- Can anyone afford this?
  - NO!

What Can Be Done?

Price = BWxP
- Reducing Bandwidth Demand
- Increasing Bandwidth Supply
- Alternative Delivery Models
Reducing Bandwidth Demand

- 2G → 3G: 2x more efficient
- 2-way → 1-Way: 2x more efficient
- Better Source Coding: 2x more efficient

Result: Would you pay:
- $1.50/min video: $150 to see a movie? No!
- $0.16/min audio: $7 to hear an album? No!
- $0.025/page news: $0.25 to read a paper? Yes

Increasing Bandwidth Supply

- Adding Spectrum:
  - 2x spectrum = 2x capacity
  - 2x licensed spectrum cost = $85B
  (Assuming it was available)
- Adding Base Stations:
  - 2x BS = 2x capacity
  - 2x BS cost = $130B
- Either way cost is high
  - > $650/current subscriber

Alternative Delivery Models

- So far have considered:
  - high-quality
  - on-demand
  - anywhere

Quality

- Video:
  - Movie: 1.2Mbps, $3.00/min
  - Thumbnail: 28kbps, $0.07/min
- Audio:
  - CD: 128kbps, $0.32/min
  - Static AM: 12kbps, $0.03/min
- News:
  - Text/Figs: 160KB, $0.05/page
  - Plain text: 6KB, $0.002/page

Choice

Content Sharing Models

- On-demand Aggregated Requests
  - Broadcast: On-demand
  - Broadcasting

Where

- Wide Area Cellular
  - Good coverage
  - Good quality
  - Expensive
- WLAN Hot-Spots
  - Localized coverage
  - “Internet” quality
  - 50x Cheaper
Summary

- The cellular model is too expensive for high-quality, on-demand, anywhere content delivery.
- Content sharing models can be very efficient but require technology development and rollout.
- Restricting access to internet-like downloads in hot-spots can be cost effective and is happening today.

The 3G Challenge

- Spectrum Expensive/Unavailable
- Base Stations $1M each
- Performance ~2x 2G efficiency
- Handsets Expensive/Delayed
- 2G Entrenched/Voice is killer app

The business proposition is uncertain

The WiFi Challenger

- Spectrum Free/Available
- Base Stations $200 each
- Performance Proven multi-megabit rates
- Handsets You probably own one
- 2G Complementary service

The technology is already deployed

Preference for Wide Area

Customer's Application Preference

Preference for Wide Area

Complementary Services

<table>
<thead>
<tr>
<th>Bandwidth per subscriber in Mbps</th>
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<tbody>
<tr>
<td>WLAN 3G 2G</td>
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Ad Hoc Networks

- A cooperative network that emerges when wireless nodes are brought together.
- Dynamic
- Peer-to-peer
- Capacity and coverage increase with more users
Ad Hoc Networks

Where are these Networks?
- Free nets in 50+ cities
- Boingo, Joltage, ... for fee

Ad Hoc Network Challenges
- Non-technical
  - Economic—is growth sustainable?
  - Legal—FCC limits, service contracts
  - Business Models
- Technical
  - Security—who do you trust?
  - Reliability—mobility, poor links
- Resource Management
- QoS
- Battery

The Power Issue

Power and Distance
Orders of magnitude dependence on distance

Power and Routing
Up to 8 times less power
Routing in Ad Hoc Networks

- Routing:
  - Topology Discovery
  - Route Choice
  - Route Maintenance

- Example with Dynamic Source Routing (DSR)

Power Aware Routing

- Requirements:
  - Link Power Metrics
  - Power Based Routes
  - Assisted Route Discovery
  - Power Based Route Maintenance

- Experimental Results

Power Metrics

- Measuring Required Link Power

\[ P_{\text{cost}} = RS + (P_{\text{TX}} - P_{\text{RX}}) \]

RS = receiver sensitivity
Powers in dB

\[ P_{\text{rad}} = RS 	imes (P_{\text{TX}} - P_{\text{RX}}) \]

Power-Based Routes

- “Shortest” power path

- Not enough

Assisted Route Discovery

- Nodes observe other route discoveries
- Gratuitous reply if they can improve

Power Based Route Maintenance

- Two aspects
  - Route power changes
  - New opportunities
Current Status

- Power Aware DSR Design
- Implemented in ns-simulator
- Implementing in laptop test bed using Click

Simulation Experiments

- Nodes wander over a large area
- Generate traffic streams at random intervals
- Carefully measure where energy is spent
- Compare to “God Energy”

Experimental Results

![Baseline scenario](chart1)

Baseline scenario
- 10 nodes; speed 1m/s; packet rate 1packet/sec/node
- Protocols: DSR, DSR with transmit power control, Egod

![Baseline scenario with increased speed](chart2)

Baseline scenario with increased speed
- 10 nodes; speed 10m/s; packet rate 1packet/sec/node
- Protocols: DSR, DSR with transmit power control, Egod

Conclusion

- Wide area cellular networks are not well suited for high bandwidth services
- Wireless LAN networks complement wide area networks
- Ad hoc networks can expand coverage and capabilities of WLAN networks
- The routing layer has a role in conserving battery energy