

# 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



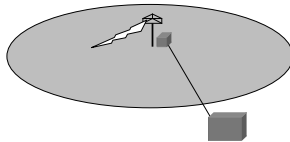
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## The Second Generation Model

- Radio Tower
- Radio Equipment
- Backhaul
- Switching
- Voice Circuits



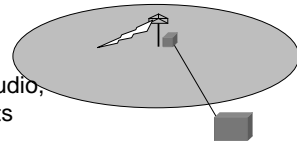
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## The Third Generation Model

- Radio Tower
- Radio Equipment
- Backhaul
- Switching
- Voice, Video, Audio,  
and Data Circuits



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## 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!



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## What Can Be Done?

$$\text{Price} = \text{BW} \times \text{P}$$

- Reducing Bandwidth Demand
- Increasing Bandwidth Supply
- Alternative Delivery Models



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## 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 paper?      Yes

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## 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

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## Alternative Delivery Models

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



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## Quality

- Video:
 

Movie	←	Thumbnail
1.2Mbps		28kbps
\$3.00/min		\$0.07/min
- Audio:
 

CD	←	Static AM
128kbps		12kbps
\$0.32/min		\$0.03/min
- News:
 

Text+Figs	←	Plain text
150KB		6KB
\$0.05/page		\$0.002/page

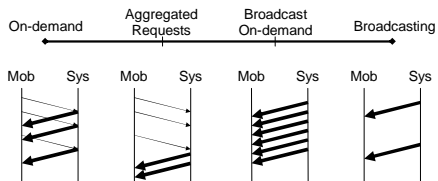
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## Choice

### Content Sharing Models



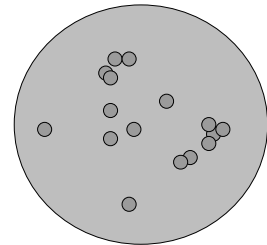
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## Where

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



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## 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.

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## 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

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## The WiFi Challenger

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



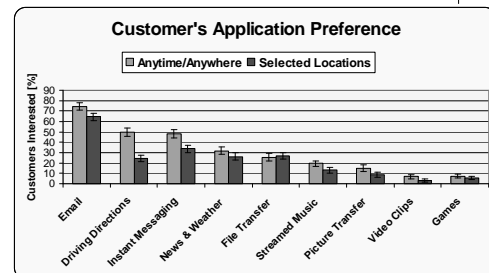
The technology is already deployed

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## Preference for Wide Area

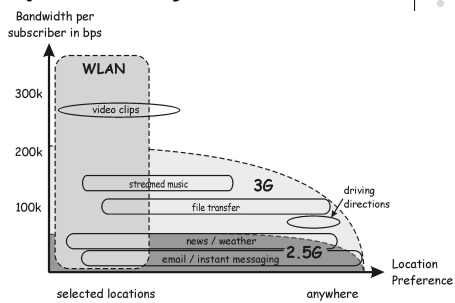


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## Complementary Services



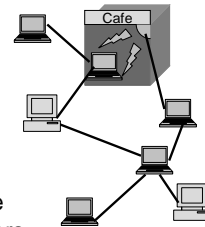
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## Ad Hoc Networks

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

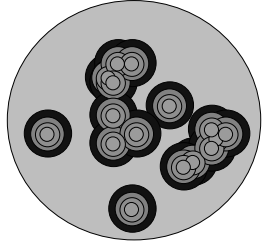


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## Ad Hoc Networks



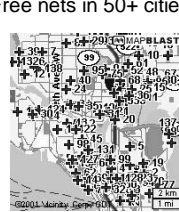
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## Where are these Networks?

- Free nets in 50+ cities



[www.seattlewireless.net](http://www.seattlewireless.net)

- Boingo, Joltage, ... for fee

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## Ad Hoc Network Challenges

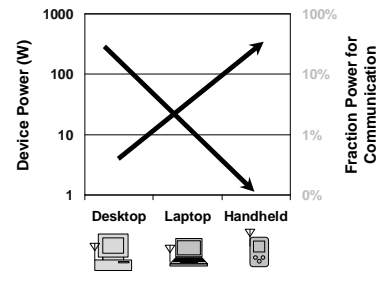
- Non-technical
  - Economic—is growth sustainable?
  - Legal—FCC limits, service contracts
  - Business Models
- Technical
  - Security—who do you trust?
  - Reliability—mobility, poor links
  - Resource Management
    - QoS
    - Battery

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## The Power Issue

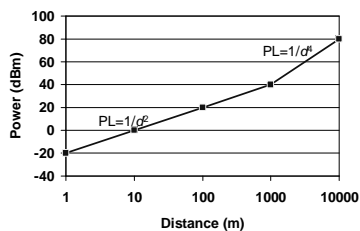


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## Power and Distance



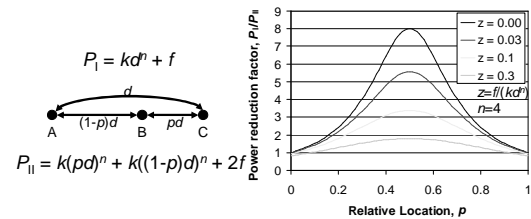
Orders of magnitude dependence on distance

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## Power and Routing



Up to 8 times less power

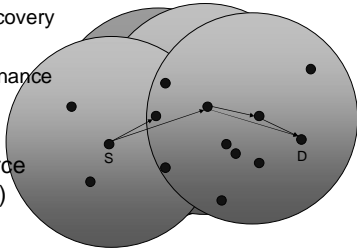
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## Routing in Ad Hoc Networks

- Routing:
  - Topology Discovery
  - Route Choice
  - Route Maintenance
- Example with Dynamic Source Routing (DSR)



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## Power Aware Routing

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

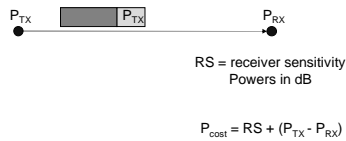
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## Power Metrics

- Measuring Required Link Power



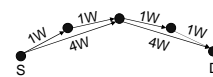
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## Power-Based Routes

- “Shortest” power path
- Not enough



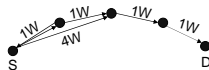
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## Assisted Route Discovery

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



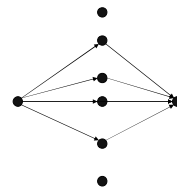
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## Power Based Route Maintenance

- Two aspects
  - Route power changes
  - New opportunities



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## Current Status

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

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## Simulation Experiments

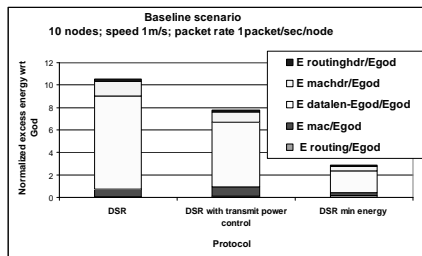
- Nodes wander over a large area
- Generate traffic streams at random intervals
- Carefully measure where energy is spent
- Compare to “God Energy”

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## Experimental Results

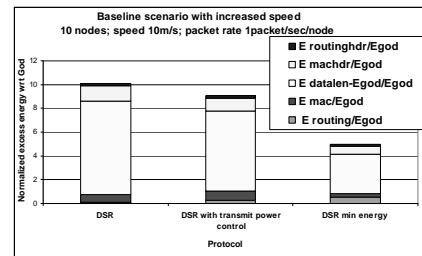


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## Experimental Results



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## 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

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