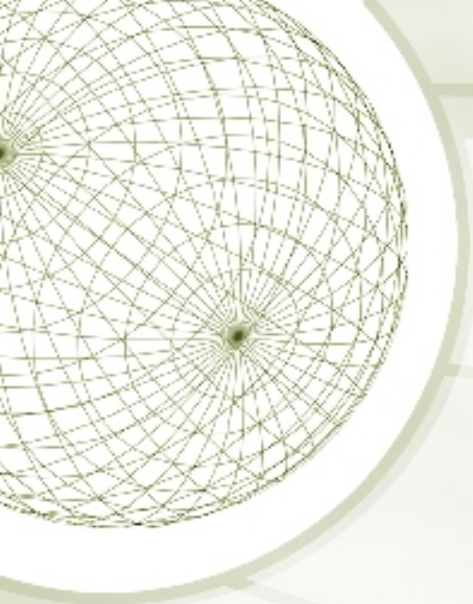

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Wi-Fi: Coming of Age

Ken Biba
WCA/VON
March 21, 2007

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- A time of major wireless initiatives
  - Metropolitan Wi-Fi
  - Transition to 802.11n: enterprise and metro
  - Metropolitan WiMAX
  - Dramatic expansion of cellular data services
- Enormous confusion
  - Hype, misinformation, vendor BS, politics,
- Novarum's purpose is to cut through that confusion
  - We know a lot about this space
  - We have strong opinions
  - We know how to decode the marketing spin
- Essential to have facts rather than truthiness
  - Novarum Wireless Broadband Review

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Novarum Wireless Broadband Review

- 3rd Party Viewpoint
- Testing from a customer perspective
  - Standard client devices doing standard applications
- All Major Broadband Wireless Data Technologies
  - Cellular variants, Wi-Fi, Wi-Max
- Many Geographic Areas
- Repeat Over Time
  - From same locations
  - Industry standard measurement tools
- Answer Fundamental Questions
  - Performance validation
  - Coverage validation
  - Technology assessment
  - Business model insight

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Review so Far

- 16 cities
  - Palo Alto CA, Santa Clara CA, Sunnyvale CA, Saratoga CA, Galt, CA, Anaheim CA, St. Cloud CA, Tempe AZ, Madison WI, Mountain View CA, Philadelphia PA, Toronto ON, Aurora IL, Rochelle IL, Longmont CO, Portland OR
  - Cities with BOTH deployed Wi-Fi and cellular data
- 45 distinct wireless networks
- Major wireless technologies
  - 1xRTT, 1xEVDO, EDGE, HSDPA, Wi-Fi
  - No WiMax yet available to test
  - High and low power clients
- Major vendors
  - Alvarion, BelAir Networks, Cisco, Motorola, Skypilot, Strix, Tropos
- Major operators and integrators
  - Sprint, Verizon, AT&T, EarthLink, HP, MetroFi, Toronto Hydro, WFI, Kite
- A growing database
  - Over 1,000,000 radio coverage measurements
  - A thousand performance measurements
  - Hundreds of measurement locations

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Evaluation Criteria

- Service Availability
  - Within the advertised coverage area
  - Is it possible to associate, log in and do useful work?
    - If yes then Service Availability is true.
    - Much more than simply hearing Wi-Fi beacons or bars of cellular signal strength
- Performance
  - Delay, upload, download and MOS score
  - IxChariot is the industry standard
- Ease of Use
  - Authentication, roaming, billing, network discovery
- Value
  - Price, advertising, contract
  - Less is more!

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Metro Cellular Review

- 3G broadband data is not ubiquitous
  - Average 58% service availability for 3G service
  - Average 86% combined 2/3G availability within tested areas
  - Metro Wi-Fi is *more* available than 3G
- Metro Cellular services fall back to 2G performance
  - But performance materially suffers
  - EDGE and 1xRTT are OK for smart phones but not laptop users
  - Most Metro Wi-Fi outperforms most 3G cellular
- Cellular's high overall availability makes it very competitive
- Metro 3G delivers 300 to 400 kbps download throughput
  - With < 100 kbps uploads and high delay
- HSDPA is best cellular data service, with growing availability
- Cellular data services are easy to use
- Cellular data services are highly priced with contracts

Metro Wi-Fi Review

- Metro Wi-Fi has competitive availability
  - Average 65% service availability within coverage area
  - Metro Wi-Fi is more available than true 3G
  - Mediocre service availability key issue for Metro Wi-Fi
- Metro Wi-Fi delivers more than twice the throughput of 3G
  - 869 kbps average download throughput/256 kbps upload
  - Business model dictates coverage and performance
  - 5 Mb/s bidirectional performance CAN be delivered
    - VoIP quality can be delivered
- Metro Wi-Fi is immature service compared to 3G
  - Service availability, ease of use
- Best Metro Wi-Fi nets can deliver residential broadband
  - Subscribers will need CPE device
  - Residential broadband is the toughest application for Metro Wi-Fi
- Demand for new applications
  - Voice, higher performance

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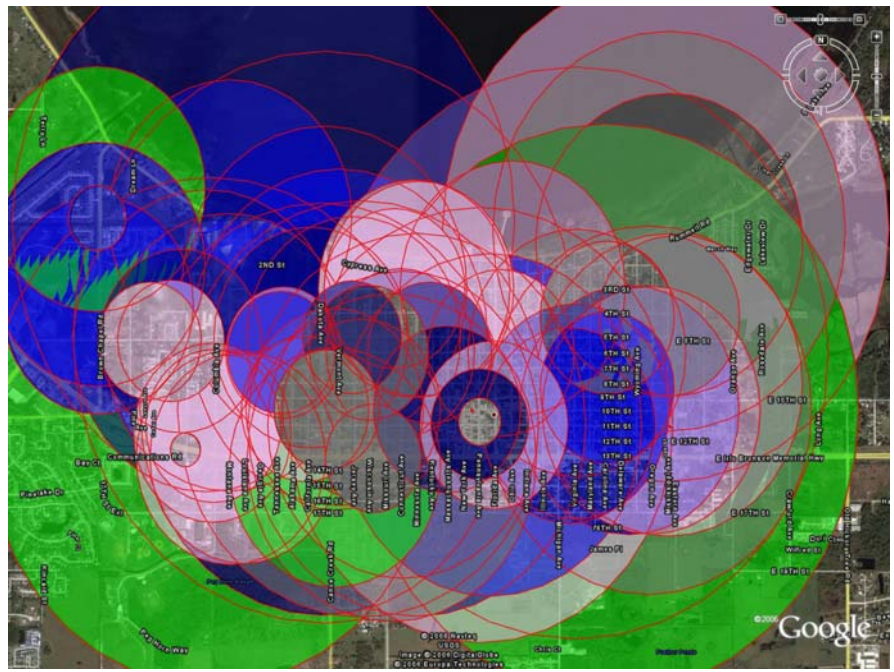
Wi-Fi of the Present: CyberSpot: St. Cloud, Florida

- It's free
- It's ubiquitous
  - 100% outdoor Service Availability
  - 77% of households use
- Good performance
  - DSL lite
  - Mostly residential broadband
  - Mobile, visitor use works well too
  - Not really VoIP capable
- Hassle-free authentication and roaming
- Facts
  - 184 nodes over 4.8 sq mi
  - Tropos edge nodes
  - Motorola Canopy backhaul



Some Trends to Consider

- Two Networks Separated by a Membrane
  - Indoor - Wi-Fi dominated
  - Outdoor - lots of competition (DSL, cable, Wi-Fi, WiMax)
- Lots of underutilized local fiber
  - Inexpensive, high capacity backhaul
- Wi-Fi technology rapidly moving
  - .11n and inexpensive MIMO
    - In two years every laptop will be .11n and MIMO
  - New spectrum that .11n makes useful - 5 GHz
- Effect of the Enterprise
  - Converged solutions on Wi-Fi
  - High capacity voice and media applications
- Physics of Finance

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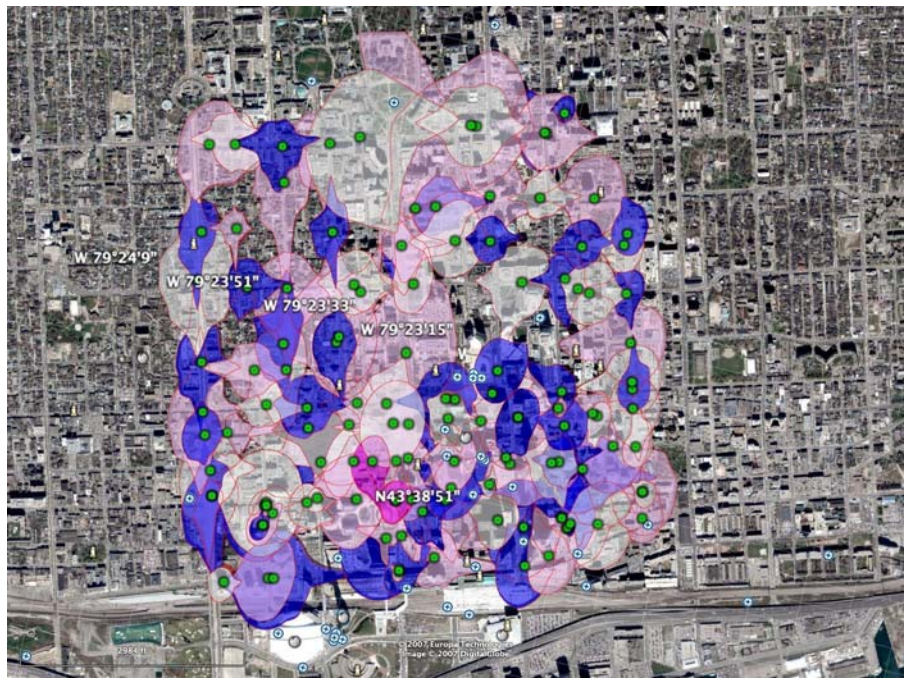
Wi-Fi of the Future: OneZone: Toronto, Ontario

- Toronto Hydro
- BelAir equipment for edge and backhaul
  - Fiber ring backhaul
- Stunning performance
  - Better than my home broadband
  - VoIP capable
- Dense urban canyon
- Likely indoor coverage
- Facts
  - 126 nodes
  - 1 sq mi



Summary

- Wi-Fi can deliver Metro Wireless
  - delivers twice the throughput of cellular data
  - less than half the delay of cellular data systems
  - VoIP at high deployment densities
  - service availability is still a challenge
- 3G cellular is not really ubiquitous in the US
  - Rollout continues
- Performance of deployed wireless broadband networks constrained by economics not technology
  - Mbps/$/square mile
  - Speed of technology innovation will drive cost
- Can WiMAX deliver a compelling service?
  - 1.5/.5 mbps is effectively what cellular and Wi-Fi do today

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Thank you.

Cutting through the wireless noise.