National Institute of Justice

NIJ



Evaluating IEEE 802.16 Broadband Wireless as a Communications Infrastructure for Public Safety Activities

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Agenda

- Project description
  - Contributions to law enforcement
- Project status
- Project details
- Comments/Questions
- Appendix:
  - Project website
  - Further information



Project Description

Executive Overview

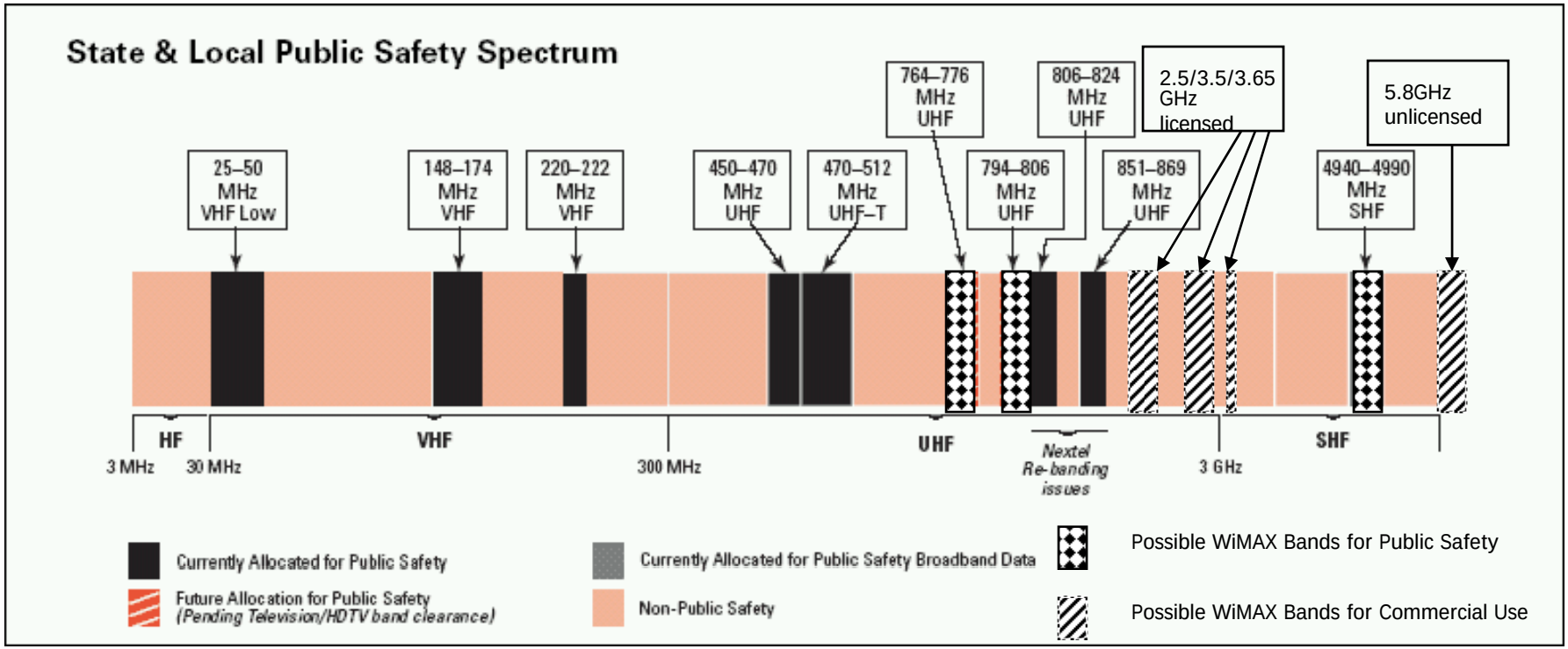
- We have been funded by the Communications Technology Office of the NIJ to help the public safety community understand WiMAX and more importantly how law enforcement can make use of WiMAX.

Executive Overview

- WiMAX is a wireless network technology that can be deployed on a small scale (the scene of an incident), a campus-wide scale, a city-wide scale, a state-wide scale, or a national scale.

Executive Overview

- Location, location, location. 4.9 GHz is licensed spectrum readily available to public safety.



Project Motivations

- Law enforcement faces the following realities:
  - There will be a never-ending stream of advanced communications technologies
  - Most of this technology will be developed for other markets and 'retrofitted' for public safety
  - Public safety organizations are at the mercy of the vendors for technology claims
- Project focus:
  - Focus on emerging broadband wireless access technologies at 4.9 GHz (although results/technology applicable to other frequencies such as 700 MHz)
  - Develop test methods and validation tools
  - Publish performance results of Clemson's WiMAX network
- Synergies at Clemson
  - Active research program in broadband access technologies
  - Ongoing collaboration with University Police, Campus networking, and College of Engineering and Science

Contributions to Law Enforcement

- Public safety technology assessment of 802.16 (d and e) at 4.9 GHz in a campus environment
- Education and guidance:
  - How WiMAX can be used by PDs
  - Positioning to other technologies (WiFi, 802.11 mesh)
  - Feedback to WiMAX vendor and provider community
- Develop open source tools for assessing and validating wireless deployments
- Related activities:
  - Participating with NPSTC Broadband Committee study
  - Co-author of WiMAX Forum white paper “Government Emergency Services in WiMax Networks”
  - Research broadband wireless protocols in ‘disruptive’ environments (‘802.16gov’)



Project Status

Clemson's WiMAX Project

	11/2006 Year 1	11/2007 Year 2	11/2008 Year 3 (proposed)
Summary	•Deployed v1.0 WiMAX equipment from M/A-COM •Published preliminary results and first release of tools	•Clemson University PD using surveillance camera •CU PD client radio in car •Equipment upgrade: 10 Mhz, mobile equipment	•Final equipment upgrade with latest mobile devices •Government service requirements at WiMAX Forum
Deliverables	•Outreach web site released with preliminary data	•Coverage data repository and visualization web site online •Initial results online •Tools made available	•Publish 'best practices' document (white paper) •Conference publication on WiMAX performance at 4.9GHz
Impact	•Establish relationships with public safety and vendor communities	•Published data of WiMAX at 4.9 GHz •Results from other deployments available (City of Marietta & VA) •WiMAX Forum 4.9 GHz profile •Coordinated effort with other agencies	•Tools commercialized •CommTech hosts web site •Center for advanced broadband wireless established at Clemson

Red indicates milestone is complete

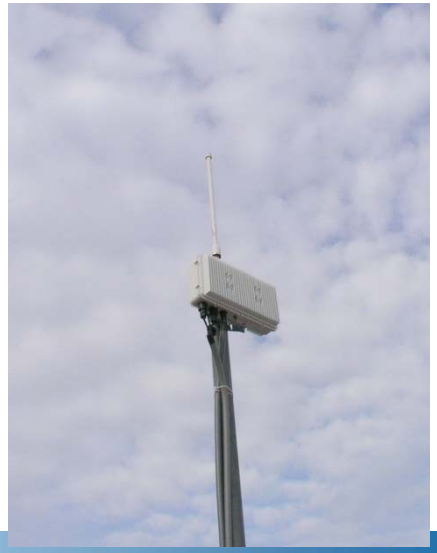


Project Details

Equipment: 1 BS, 6 Subs

M/A-COM Wireless Systems
P. O. Box 2000
Lynchburg, Virginia 24501
Phone: 1-800-368-3277
www.macom-wireless.com

Base station : (1) 4.9 GHz Hardened BS (MAVM-VMXDB)
Client station: (4) 4.9 GHz Low Power Hardened Client (MAVM-VMCLH)
(2) Low Power EasyST CPE from AirSpan



VIDA Broadband Base Station
4.9 GHz Broadband Distribution System





VIDA Broadband Client
4.9 GHz Broadband Distribution System

M/A-COM Equipment

- Airlink:
  - IEEE 802.16e function – only supports “hard hand off”
  - 5MHz channels at 4.9 GHz (10 Mhz by end of year)
  - OFDM 256 FFT
  - BS: 27dBm output power, client SS: 20 (27) dBm output power
  - TDD operation, 10 ms frame time, variable US/DS split
  - Supported modulation methods: BPSK (1/2) QPSK (1/2, 3/4), 16 QAM(1/2,3/4), 64QAM (2/3,3/4)
- Interfaces:
  - RJ-45 Ethernet
  - 24 V DC Power
  - 4.9 GHz RF and GPS Antenna

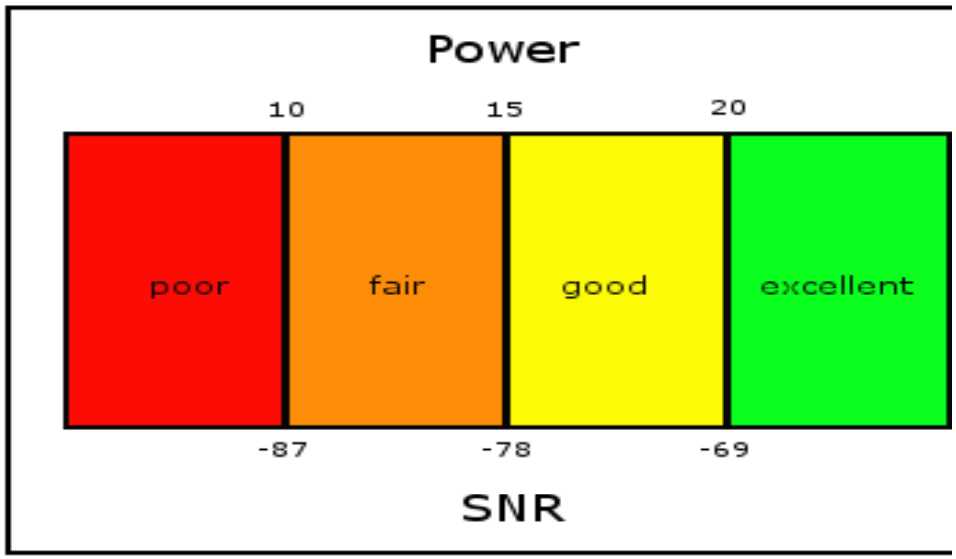
M/A-COM Equipment

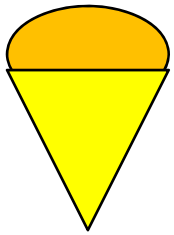
- Client receiver sensitivity (at BER 10E-6)
  - BPSK-1/2: -96dBm
  - QPSK-3/4: -91dBm
  - 16-QAM ¾ -85dBm
- Base station receiver sensitivity (at BER 10E-6)
  - BPSK-1/2: -96dBm
  - QPSK-3/4: -91dBm
  - 16-QAM ¾ -85dBm

What is a 'Coverage' Map?

- A coverage map visualizes the observed performance of a WiMAX deployment
- Methodology
  - Measurement method
    - With a SS installed in a car, drive around campus (attempt to maintain a constant speed of 10 mph)
    - Periodically, while moving and when stopped, capture a set of performance information along with a GPS waypoint (including velocity) and current time and day.
    - Do this on a regular basis and build a database of performance results (include in the data weather information associated with a data set).
  - Performance Information
    - RF Information: rx power, SNR
    - Link Information: modulation method, link status
    - IP Information: UDP/ICMP ping connectivity
    - Application Information: UDP/TCP throughput, response time, VoIP MOS, Video stream MOS, other application specific metrics
- Provide a web interface for data analysis
  - Scatter plot of downstream modulation method versus rx power
  - Path loss versus received power

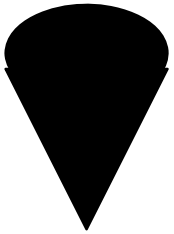
Coverage Map Visual Key





ICE CREAM: Power (received signal strength, RSS)

CONE: SNR

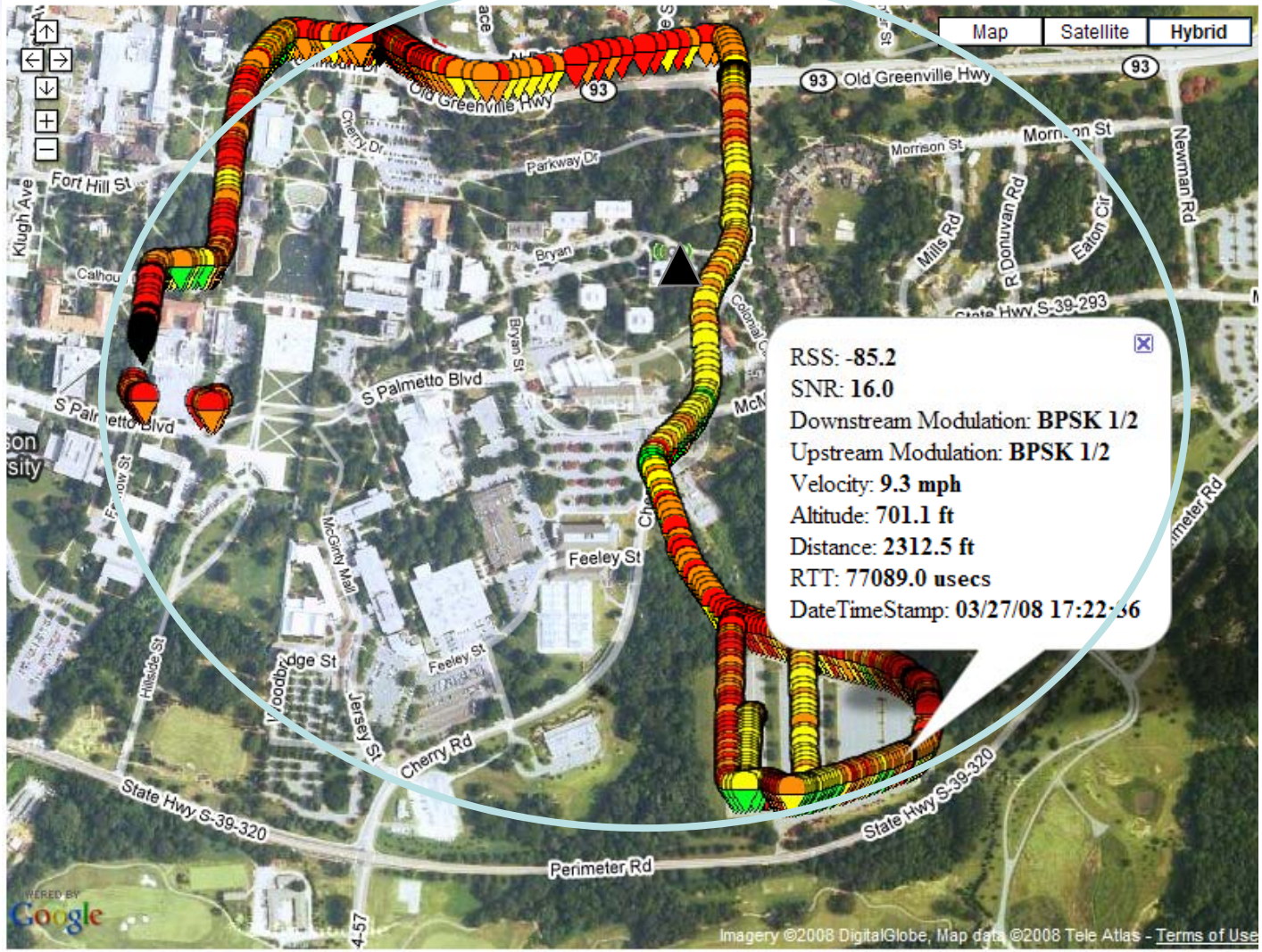


Link connectivity mode
black: no link,
green: link exists

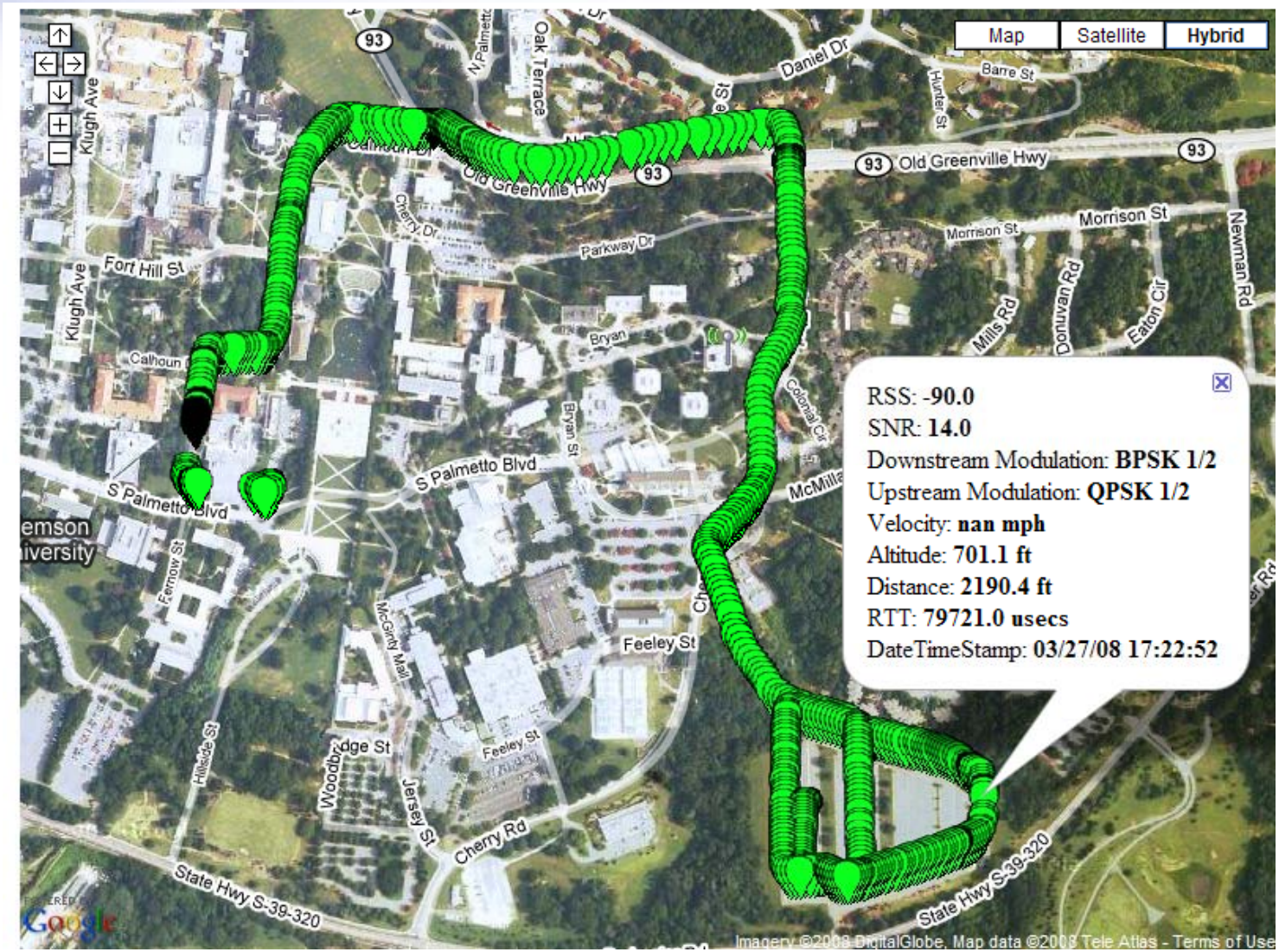
Currently the tool provides two assessments:

- RF (see color code above)
- Connectivity (green) based on either:
  - SNR > 5
  - IP Ping Succeeds

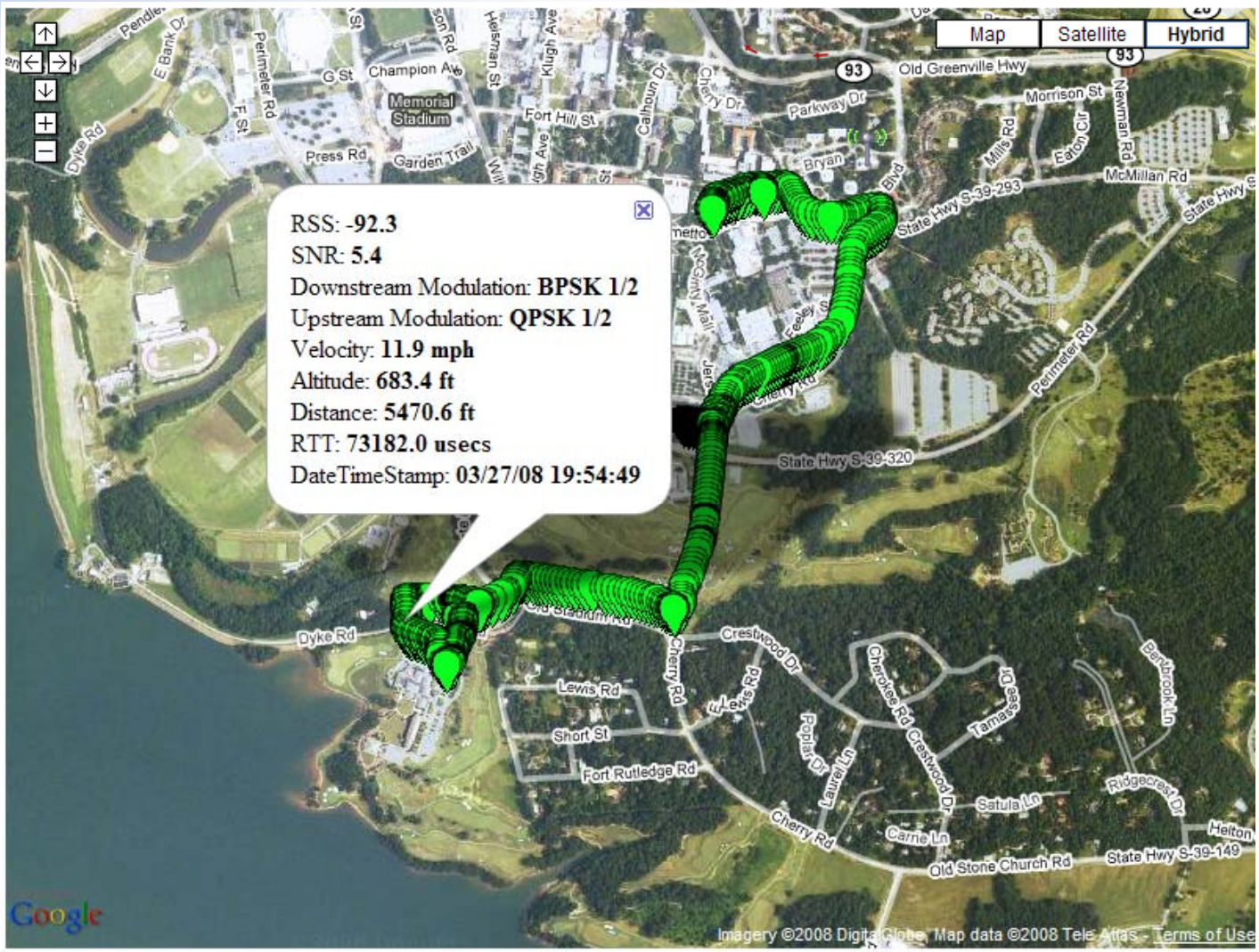
RF Coverage


Map
Satellite
Hybrid
RSS: -85.2
SNR: 16.0
Downstream Modulation: BPSK 1/2
Upstream Modulation: BPSK 1/2
Velocity: 9.3 mph
Altitude: 701.1 ft
Distance: 2312.5 ft
RTT: 77089.0 usecs
DateTimeStamp: 03/27/08 17:22:36
93 Old Greenville Hwy
Old Greenville Hwy
Fort Hill St
Parkway Dr
Cherry Dr
Morrison St
Mills Rd
R Donovan Rd
Eaton Cir
Newman Rd
State Hwy S-39-293
Bryan
Bryan St
S Palmetto Blvd
Feeley St
McGinty Mall
Jersey St
Cherry Rd
State Hwy S-39-320
Perimeter Rd
Google
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Link Connectivity Coverage



Link Connectivity Coverage



Observed Upstream Throughput

64QAM 2/3	
16QAM ¾	4.87 Mbps
16QAM 1/2	3.25 Mbps
QPSK ¾	2.47 Mbps
QPSK ½	1.3 Mbps
BPSK ½	.6 Mbps

Observed Downstream Throughput

64QAM 2/3	5.2 Mbps
16QAM ¾	3.9 Mbps
16QAM 1/2	2.5 Mbps
QPSK ¾	1.9 Mbps
QPSK ½	1.4 Mbps
BPSK ½	.59 Mbps

Project Conclusions

- Coverage at 4.9 GHz is spotty in a campus environment
  - Coverage extends to 1.5 miles if there is clear line of site
  - Hot zone model
- Police applications
  - IP Video surveillance
  - Connect police cars to campus network in hot zones
  - Backhaul
  - New devices will enable new applications
- Technology tradeoffs
  - 4.9 GHz versus service provider model (e.g., Verizon's prioritized cell phone and data service)
    - Likely two different sets of services and applications,
      - differentiator: cost per bps, cost per percentage of coverage
  - 802.16d versus 802.16e
    - Lower cost, but handoffs take seconds
    - Mobile 802.16e requires denser deployment and increases cost
  - 802.16 versus 802.11
    - Standard WiFi (802.11g) is not designed for outdoor, mobile use
    - WiFi mesh: proprietary (at least for now), inherently expensive

Project Conclusions

- Bottom line:
  - 802.16 and 802.11 represent two different approaches to using bandwidth: centralized and distributed. Economics should favor centralized, however poor propagation at 4.9 GHz favors mesh technology. Therefore, it's a price versus acceptable performance tradeoff.
- Recommendation:
  - Assume that the infrastructure required by public safety includes wired and wired IP networks
  - Inspire innovation!!



Evaluating IEEE 802.16 Broadband Wireless as a Communications Infrastructure for Public Safety Activities

Comments or Questions ?



Appendix: Further Information

Project Web Site:
http://people.clemson.edu/~jmarty/publicsafety/PublicSafety.html

WiMAX Standards

- Current standard is IEEE 802.16e, key operating choices:
  - OFDM or OFDMA
  - Support for hand-offs
    - **Nomadic** does not require a handoff. Instead a subscriber simply acquires a new channel as it moves from one BS to another. As long as the entire WiMAX cloud uses one IP subnet for addressing, applications are not impacted aside from the seconds of 'downtime'. The 'downtime' can be limited by reducing the set of allowed channels in the subscriber station. This type of handoff is referred to as a 'hard handover' in WiMAX.
    - **Portable** implies 802.16 Messages that 'hands off' one subscriber from one BS to another. The advantage is that is decreases the 'downtime' from multiple seconds to <1 seconds. There appear to be different methods possible for achieving this – but the standard defines the basic message formats that can be used.
    - **Mobile** simply allows a 'hand off' to occur at speeds higher than 'pedestrian walking'. This assumes 802.16e with OFDMA PHY settings. There are several usage scenarios, one supporting 60kmph (less than 1 second interruption) and one supporting 120 kmph (less than 50ms interruption)
- Next iteration is 802.16m (late 2009 ??)
  - Performance/functional improvements required to support "future advanced services and applications" of 4G as defined by the ITU

Roles of the IEEE 802.16 Working Group and the WiMAX Forum

- The IEEE 802.16 Working Group maintains the current WiMAX specifications
- The WiMAX Forum is all about ensuring interoperability between equipment from different vendors
  - Defines the set of 'configuration profiles' that leads to interoperability
    - Profiles include OFDM/OFDMA, center frequency, and channel bandwidths
  - Defines required testing procedures to enforce interoperability
  - Provides meeting forum to ensure the success of the technology

WiMAX Spectrum: Licensed versus Unlicensed

- Portable WiMAX can operate in the unlicensed 5.8 GHz band
- Initial Mobile WiMAX products will operate at 2.3-2.4 GHz, 2.496-2.69 GHz, 3.3-3.4 GHz and 3.4-3.65 GHz
- Two vendors (that we know of) sell 4.9 GHz WiMAX solutions: M/A-COM and Airspan
  - Airspan will ship 802.16e mobile support Summer 2008.
- 700 MHz spectrum for a national broadband wireless network is unfolding

At least for the next several years, 4.9 GHz is the most realistic option for public safety WiMAX deployments!