A Primer on Wireless Data Transport Systems: Wireless Trends, Tools and Tips

Intelligent Transportation Systems Department
Southwest Research Institute®
www.swri.org, www.swri.edu
This training is for…

Any ITS or traffic professional that desires to learn more about the basics of wireless solutions, and the components of effective and efficient wireless design
Class Format and Method

- Presentation
- Discussion – Q &A at the end
- Use of product literature
Today’s Agenda

- Session I – The foundation for later engineering and application sessions
  - Wireless Trends
  - Architecture
  - Choosing an Architecture
  - Unlicensed or No Fee Radio Frequencies
  - Standards
Future Topics for Wireless T3 (Proposed)

- Session II
  - Coding Methods
  - Radio Link Engineering
- Session III
  - The Loss Budget
- Session IV
  - Managing Interference
  - Antennas
- Session V
  - Application Engineering, Rules of Thumb
We would like you to walk away with…

Three things:

1) An expanded understanding of the trends at work in the ITS and traffic wireless arena
2) Some new techniques in your toolbox to address wireless implementation and service issues
3) An increased comfort level with wireless technology
Wireless Trends
The Mobility Market – It is big and getting bigger

Focus on three measures...

- The number of online users
- The battle for the small screen – Your mobile phone, PDA or vehicle LCD monitor
- Our growing impatience with low speed channels
Growth in Users

- Millions of Online Users (www.internet2.edu)
The Valuable Two Square Inches

- The battle for the small screen

US Consumers Who Watch TV Programming on Their Mobile Phone*, 2005, 2006 & 2009 (in millions and as a % of mobile phone subscribers)

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of Users</th>
<th>% of Subscribers</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>1.2</td>
<td>0.6%</td>
</tr>
<tr>
<td>2006</td>
<td>3.0</td>
<td>1.4%</td>
</tr>
<tr>
<td>2009</td>
<td>15.0</td>
<td>6.2%</td>
</tr>
</tbody>
</table>

Note: *includes live and pre-recorded programming as well as downloads from a DVR  
Source: eMarketer, December 2005

- Our growing impatience, willingness to buy speed

<table>
<thead>
<tr>
<th>Access Type</th>
<th>2001</th>
<th>2003</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dial-Up</td>
<td>44.2</td>
<td>38.6</td>
<td>-12.7%</td>
</tr>
<tr>
<td>DSL</td>
<td>3.3</td>
<td>9.3</td>
<td>181.8%</td>
</tr>
<tr>
<td>Cable</td>
<td>6.6</td>
<td>12.6</td>
<td>90.9%</td>
</tr>
<tr>
<td>Wireless</td>
<td>0.5</td>
<td>0.9</td>
<td>80.0%</td>
</tr>
<tr>
<td>Number of Homes with Internet</td>
<td>54.6</td>
<td>61.5</td>
<td>12.6%</td>
</tr>
<tr>
<td>Total Number of Households</td>
<td>108.6</td>
<td>112.6</td>
<td>3.7%</td>
</tr>
</tbody>
</table>
Putting it all Together

- Why wireless is important
  
  If…
  
  – Technology exists and is searching for markets;
  – People are data hungry and will become hungrier;
  – As a society we will neither sit still nor slow down;
  – Then…
Then…

- The wave of new products will continue
- Specialized applications like traffic and ITS will reap the benefits as we selectively apply wireless technology
- Especially adept systems integrators of software driven COTS products
Wireless Architectures and Use Cases

- Point-to-Point
- Point-to-Multipoint
- Multipoint-to-Multipoint, Mesh, Adhoc
- Cellular
Point-To-Point (PTP)

- Typically a “Backhaul”, from Point A to B
  - Easiest to engineer, low in relative complexity

Wireless Point to Point
Daisy-Chain or Common Point (CP) Networks

- Typically a Backhaul or Path from Point A to B to C to D.

- A repetitive two-point backhaul. Each node can “store and forward”, or is a tandem node. There are channel and bit rate issues; interference and latency can be a problem.
A Ring, the joined ends of a PTP
Point-To-Multipoint (PTM)

- Complex, requires knowledge of user or device behavior and spectrum management
- “A” requires more intelligence
PTM is sometimes called Tree and Branch
Multipoint-to-Multipoint, Mesh

- Complex, engineered for network churn, provides multi-hop capabilities
Cellular

- Users traverse the cells while maintaining connectivity
- More organized than Mesh

Associated Backhaul – One of many
Adhoc

- Temporary wireless connections
  - Typically operate over limited distances
  - A piconet or personal area network when associated with Bluetooth™ or similar devices
  - Network clients come and go in an unscheduled manner
Choosing an Architecture
Low Bit-Rate Closed Systems

- PTP and PTM networks (not all devices shown)
  - Data rates less than 19,200 bps
  - 1200 bps common
Medium to High Bit Rate Open Systems

- PTM aggregation networks, with a connecting backhaul point-to-point
Practical Uses of Wireless

- No longer the technology of last resort
  - Applications and costs can be attractive
- Applications include low to high bit rate and open and closed systems
Radio Frequency (RF) and Wireless Standards
Wireless Radio Frequency (RF)

- **Unlicensed Bands in US**
  - Industry, Science, and Medical (ISM)
    - Microwave ovens, the wireless LAN, the cordless phone and the wireless telemetry in the hospital.
  - Uniform – National Information Infrastructure (U-NII)
- **Licensed**
  - No fee, must be Public Safety related
  - 4.9 GHz
<table>
<thead>
<tr>
<th>Frequency Range</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>902-928 MHz</td>
<td>Authorized in 1985 in the initial Industry, Scientific, and Medical (ISM) grant for spread spectrum equipment.</td>
</tr>
<tr>
<td>2.403 to 2.483 GHz</td>
<td>Authorized by the FCC in 1985 in the ISM grant for spread spectrum equipment.</td>
</tr>
<tr>
<td>5.725 to 5.875 GHz</td>
<td>Authorized by the FCC in 1985 in the ISM grant for spread spectrum equipment.</td>
</tr>
<tr>
<td>59 to 64 GHz</td>
<td>Authorized by the FCC in 1999 in the ISM grant to provide the wireless equivalent of optical data rates.</td>
</tr>
<tr>
<td>Frequency Range</td>
<td>Authorization Details</td>
</tr>
<tr>
<td>--------------------</td>
<td>---------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>5.15 to 5.25 GHz</td>
<td>Authorized by the FCC in 1997 in the Unlicensed Network Information Infrastructure (U-NII) for non-spread spectrum equipment.</td>
</tr>
<tr>
<td>5.25 to 5.35 GHz</td>
<td>Authorized by the FCC in 1997 in the U-NII for non-spread spectrum equipment.</td>
</tr>
<tr>
<td>5.725 to 5.825 GHz</td>
<td>Authorized by the FCC in 1997 in the U-NII for non-spread spectrum equipment.</td>
</tr>
</tbody>
</table>
4.9 GHz

| 4.940 to 4.990 GHz | Authorized by the FCC in 2003 for Public Safety use. This includes DOTs. 10 year licenses are available if you do not interfere with the Navy and radio-astronomy. |

- A frequency allocation chart is available at:
  
  http://www.ntia.doc.gov/osmhome/allochrt.html
Wireless Standards
Wireless Standards

- The Standards Bodies ISO and IEEE
  - ISO: Worldwide Rules i.e.. MPEG
    - www.iso.org
  - IEEE: The 802.11, 15 and 16 series of standards
    - www.ieee.org
- Expect devices to work together for mature systems, and expect a maturity/interoperability curve
Maturity/Interoperability Curve

- Standards make the curve slope steeper and adoption less painful
- Standards might protect from stranded technology
Standards Bodies

- IEEE – Creates standards
  - IEEE does not put a sticker on devices
- Wireless Fidelity Alliance (WiFi)
  - 802.11 testing
  - www.wi-fi.org
- Worldwide Interoperability for Microwave Access (WiMAX) Forum
  - 802.16 testing
  - www.wimaxforum.org
- You get a sticker on the device or package
Overview of Standards
Standards and Systems Overview

- IEEE 802.3
- IEEE 802.11 WiFi
- 802.16 WiMAX, proprietary uWave
- 802.15.1 Bluetooth™
- 802.15.3 Ultra Wide Band (UWB)
- 802.15.4 Zigbee
- Radio Frequency Identifiers (RFIDs)
- Cellular: 3G and 4G
- Paging Systems, Free-Space Optics
802.3 Ethernet

- The original **wired** Local Area Network (LAN) standard – Full and Half-Duplex
  - Adopted in 1983
  - Bit-rate now a maximum of 10 Gbps
  - 802.3 10/100 Mbps wire limited to ~ 100 meters
- Many wireless systems have adopted the wired LAN protocol (With extensions)
- See the Motorola datasheet
Adopted in 1997, 802.11 is the first of the wireless standards - Half-Duplex (Take turns talking)
- Bit-rate was limited to a maximum aggregate of 2 Mbps in the 2.4 GHz band
- Original deployments were indoor LANs
802.11b

- 802.11b: Adopted in 1999, 802.11b is an addition to 802.11
  - Bit-rate a maximum aggregate of 11 Mbps
  - In the 2.4 GHz band
802.11a

- Adopted in 1999
  - Bit-rate a maximum aggregate of 54 Mbps
  - In the 5 GHz band
802.11g

- 802.11g: Adopted in 2003, 802.11g combines attributes of 802.11a and b
  - Bit-rate a maximum aggregate of 54 Mbps
  - In the 2.4 GHz band
  - 802.11g most common on laptops
  - See the ENCOM datasheet
802.11n

- For data rates in excess of 100 Mbps
  - Targeted for 500 Mbps
  - Pre-“N” devices in stores now with Pre-N stickers
  - 100-200 Mbps claims seem to be common
  - Expect IEEE to ratify in 2008
Wireless Access for the Vehicular Environment (WAVE)
- Basis for Dedicated Short Range Communication (DSRC) for the Vehicle Infrastructure Integration (VII)
- Planned bit-rate an aggregate of 6 Mbps
- 5.9 GHz band
- Distance of up to 1,000 feet for mobile xmit/rcv
FHWA Initiative - VII Use Cases

- Intersection Cooperation
  - Vehicle to Vehicle (V2V) and Vehicle to Roadside (V2R)
- Road or Lane Departure
- Vehicle Cooperation
  - V2V

Information can be found at www.dot.gov
Standards Work

- IEEE P1609 Working Group chartered
- Developing probe mgmt. messages for ISO/SAE
- Developing IEEE P1609 DSRC test methods
Putting it all Together

• Comparing service footprints
  – Data rates vary widely
The iPhone

- Wireless Convergence (www.att.com)

Technical Specs for iPhone

- Screen size: 3.5 inches
- Screen resolution: 320 by 480 at 160 ppi
- Input method: Multi-touch with on-screen predictive QWERTY keyboard
- Operating system: OS X
- Storage: 4GB or 8GB
- GSM: Quad-band (MHz: 850, 900, 1800, 1900)
- Wireless data: Wi-Fi (802.11b/g) + EDGE + Bluetooth 2.0@
- Camera: 2.0 megapixels
- Battery: Up to 8 hours of talk time, 250 hours of standby, 6 hours of Internet use, 7 hours of video playback or 24 hours of audio playback*
- Dimensions: 4.5 x 2.4 x 0.46 inches / 115 x 61 x 11.6mm
- Weight: 4.8 ounces / 135 grams

*All battery claims are dependent upon network configuration and many other factors; actual results may vary. See www.apple.com/batteries for more information.
802.11i - Security: Enterprise Encryption and Authentication (E&A)

- Encoding to make data unreadable without permission
  - Password
  - Data-stream
  - WiFi Protected Access 2 (WPA2)
  - www.wi-fi.org

Source: www.wi-fi.org
802.11i - Small Office/ Home Office

- Security usually administered on local device or via Internet

Source: www.wi-fi.org
802.11 Security Certification

- Look for the Sticker!

Source: www.wi-fi.org
802.16, WiMAX

- WiMAX = Worldwide Interoperability for Microwave Access (Trango AP and SU datasheets)
  - IEEE 802.16, in 10 to 66 GHz range
  - 802.16a, support for 2 to 11 GHz
  - 802.16e, add mobility, less than 6 GHz
WiMAX Speed and Cost

- NASCAR Rules, “Tell me how fast you want to go”
  - Rates start ~ 256 Kbps up to 15 Mbps, typically within 3 km
  - Radio frequency management is key
  - Downstream vs. Upstream
Microwave, uWave

- A generic term, was typically applied to Point-to-Point systems in the spectrum from 300 MHz to 10 GHz.
- Now seems to be generically applied to most wireless systems
802.15.1 - Bluetooth™

- For short-range communications
  - Intended to replace USB and other cables
- Spectrum
  - Operates in the ISM band at 2.4 GHz
- Range - Depends on the device class:
  - Class 3 – up to 1 meter or ~3 feet
  - Class 2 – up to 10 meters or ~30 feet
  - Class 1 – up to 100 meters or ~300 feet
- Raw Data Rate
  - 1 Mbps for Version 1.2; up to 3 Mbps supported for Version 2.0
802.15.3 – Ultra Wide Band (UWB)

- High bit rate suitable for short-range video applications
- Spectrum
  - UWB operates in the ISM band at 2.4 GHz
- Range
  - 10 meters
- Raw Data Rates
  - 110 Mbps at 10 meters, 480 Mbps at 2 meters
802.15.4 – Zigbee

- Low power consumption is differentiator
- Spectrum
  - Operates in the ISM bands at 2.4 GHz and 915 MHz
- Range
  - 50 meters typical
- Raw Data Rate
  - Data rates of 250 kbps @2.4 GHz, 40 kbps @ 915 MHz
Radio Frequency Identifiers (RFID)

- Store limited data, respond when interrogated or transmit autonomously
- Construction
  - RFID tags contain a chipset and antenna to receive and respond to queries from an RFID reader
- Three Types
  - Passive: no battery, receive power when interrogated
  - Semi-Passive: with a battery, but not chatty - toll roads
  - Active: with battery, broadcast information autonomously and when interrogated.
RFID

- **Spectrum**
  - Operate in numerous RF bands from 125 KHz up to 5.8 GHz

- **Range**
  - Passive tags, a few feet, up to 1500 meters for active tags

- **Raw Data Rate**
  - Not applicable, not a transport device
3G and 4G Mobile

- A Disclaimer
  - Technological innovation in cellular telephone and data networks is fast
  - The market is hyper-responsive to technological advances
  - What is true this morning, may be different tomorrow
3G Mobile Features

- 3G provides an expanded set of features and capabilities, some are here:
  - Enhanced multimedia: voice, email, and video
  - High speed data, up to 700 Kbps outdoor and 2 Mbps indoor
- Some not
  - Satellite or terrestrial network route selection
  - Roaming capability throughout Europe, Japan, and North America
3G Mobile

- Two main flavors, CDMA2000 Evolution Data Optimized (EVDO) and GSM Broadband 3G
  - CDMA2000 EVDO
    - CDMA - Sprint, Verizon
    - GSM – T Mobile, AT&T
  - Range
    - Back to the cell site, typically less than 3 miles
  - Raw Data Rate
    - Marketed 400-700 Kbps, up to 2 Mbps (EVDO), user experience will vary
4G Mobile

- The promise of a seamless, high data rate world
  - High quality audio and video
  - Data rate of ~100 Mbps
  - Use of software defined radios - base stations and phones.
  - Packet switching for both voice and data
- Look for 4G capabilities in 2010, sooner if based upon WiMAX
Paging

- Not as widely used due to cell phones
- Metropolitan, or Satellite
- Low bit rate to deliver a machine command or message
  - Some use for remote signs
Free-Space Optics or Photonics

- Coherent light through the atmosphere
  - Spectrum
    • Operate in unlicensed spectrum
  - Range
    • Short distances
    • Mirrors can be used to redirect the light
    • Devices can be placed behind windows.
- Raw Data Rate
  • Rates up to 1.25 Gbps using a single wavelength of light
Putting it all Together

- Comparing service footprints
  - Data rates vary widely

- Personal Networks
- Wireless LANs: WiFi, DSRC
- uWAVE, WiMAX
- CDMA – EVDO
  - GSM – GPRS/EDGE/Broadband
Questions and Answers

- Questions or comments about the class?
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  pclair@swri.org