Wireless Broadband Networks for ITS and Traffic Applications

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TexITE Fall Meeting - August 30, 2012 - Fort Worth, Texas

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Outline

Wireless Broadband Networks for ITS and Traffic Applications

- Intelligent Transportation Systems (ITS)
- Traffic Applications
- Wireless Broadband Networks
 - Communication Technologies
- Success Story
 - Round Rock, Texas

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Intelligent Transportation Systems (ITS)

- "Advanced applications which aim to provide innovative services relating to different modes of transport and traffic management and enable various users to be better informed, and make safer, more coordinated, and smarter use of transport networks."
- "Systems in which information and communication technologies are applied in the field of road transport, including infrastructure, vehicles, and users, and in traffic management."

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Traffic Applications

- Traffic Signal Interconnect
 - Central system management, peer-to-peer management
 - Coordinated systems, traffic responsive systems, adaptive systems
- CCTV and PTZ cameras
 - City wide surveillance and homeland security
 - Roadway and highway monitoring
- Traveler Information
 - Variable message signs
 - Weather monitoring stations
 - Incident detection and reporting
- School Zone and Advanced Warning Flashers
- Preemption and Transit Priority

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Wireless Broadband Network

Cost Effective

- No cabling or trenching costs (US DOT estimates 90% cost savings)
- No recurring access fees

Scalable

- Networks can be easily expanded
- Deployable virtually anywhere rugged terrain, bodies of water, remote areas (solar friendly)

- Standards Based (Ethernet, WiFi, WiMAX, etc.)
 - Movement from proprietary protocols to IP based communications
- Licensed and Unlicensed Frequencies
- High Data Rates With Low Latency
 - Rapidly increasing use of video on networks
- Secure with Carrier Class Uptimes

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Wireless Broadband Network

Communication Technologies

- Architectures
- Modes
- Modulation
- Frequencies
- Standards
- Engineering
- Noise and Interference
- Security



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The Challenge

Growing city, growing needs

- Round Rock, Texas was recently rated as the seventh-best small American city in which to live.
- It's currently the second-fastest growing city in the United States, and its population has tripled in the past 10 years, topping 104,000 in the latest census.
- And that's exactly why City of Round Rock traffic officials felt they needed something more than a 900 MHz radio system to manage their growing infrastructure.
- "As we were growing, we needed to be able to better program traffic," says David Walther, superintendent of the street and drainage department with the City of Round Rock. "When we have a ball game (involving the Triple-A Round Rock Express), we've got 10,000 to 14,000 people leaving Dell Diamond at one time, and we needed a traffic system that could communicate with us, so we wouldn't have to send a technician to the park and hang out there to know when things thinned out. We went from 20 to 50 intersections in a decade, and we needed to be in a better position to manage the demands. When we do surveys, traffic congestion is always a big issue. If it's not the No. 1 complaint, it's close."

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The Encom Solution

- The City looked at the possibility of T1 or DSL high-speed wired connections for their new traffic network, but soon chose an ENCOM Wireless broadband system — thanks to ENCOM's reliability, capability, low costs and future-minded attitude.
- A six-month audition of all the available candidates, including ENCOM's broadband technology, was all bit took.
- "We had T1 and DSL lines out there that were pretty expensive and weren't able to supply the bandwidth," recalls Walther. "We had other groups out there. Then we used two ENCOM radios, one on our building and one about four miles away on the highway.
 . and we brought back video detection, traffic signal timing, and a PTZ (pan tilt zoom) camera, brought back all that information on two little radios. That really sold us."
- ENCOM's engineering team rolled out a high-bandwidth, high-speed wireless broadband traffic system for Round Rock. And one of the keys to the network's success was the installation of a relatively new ENCOM product, the COMMPAK BB 24/58INT, at every traffic intersection — setting up WiFi hot spots all over the city grid, and putting Round Rock on the cutting edge of an emerging trend in Intelligent Transportation Systems.

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How It Works

- The BB 24/58INT, which was developed in less than two months as the direct result of the City of Round Rock's input, is a marriage of convenience and accessibility. It combines a powerful 5.8 GHz broadband unit (the COMMPAK BB 58) with integrated antenna, for high-speed backhaul communication, with a 2.4 GHz connectorized radio (COMMPAK BB 24) and external Omni antenna that provides a remote WiFi access point all in a completely integrated package.
- As for the network itself, ENCOM designed for the City of Round Rock a system that would boost data rate, efficiency, and capability — and accommodate further growth and modernization — by using backbone links that could handle multiple data streams and protocols.
 - Atop the city's traffic management center tower are perched four COMMPAK BB 58 radios, each with a data rate of 54 Mbps for a total capacity at the tower of more than 200 Mbps.
 - Each 5.8 GHz radio is linked to a dual 5.8 GHz/2.4 GHz radio (the COMMPAK BB 24/58) installed on a series of water towers that encircle the town, and each of those four dual radios communicates to a series of 10 to 12 COMMPAK BB 24/58INT units at traffic intersections.

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Another Satisfied Customer

What ENCOM provided the City of round rock

- Instant, widespread access to the city's wireless network, thanks to COMMPAK BB 24/58INT units that provide WiFi hot spots at traffic intersections — and offer a quantum leap in capability and efficiency for mobile municipal employees
- Video monitoring, an extremely powerful weapon in the ITS arsenal. Thanks to the technology
 offered by ENCOM's license-free broadband radios, video cameras with PTZ (pan tilt zoom)
 control provide excellent video images with minimal Ethernet bandwidth consumption
- A reliable, field-proven dedicated wireless network with a fraction of the cost of wired alternatives, such as copper or fiber optics
- A boost in the data rate and the efficiency of the system
- Seamless, error-free, industry-leading radio performance in the most harsh, challenging environments
- The flexibility to position and reposition its wireless network at will, since ENCOM's products operate at license-free radio frequencies, and the flexibility to overcome daunting topographical challenges
- Protection of its client's investment with one of the best warranties in the business
- The promise of a lasting partnership and the security of knowing that ENCOM's investment will
 pay for itself many times over

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THANK YOU!

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Wireless Technology Architectures

Point-to-point Wireless Network

- Typically a backhaul from Point A to Point B
 - Low in complexity and easy to engineer
 - High data rates, low latency

Daisy-chain or Common Point Wireless Network

- Typically a backhaul from Point A to Point B to Point C...
 - A repetitive two-point backhaul, each node can store and forward (repeater), or is a two radio node
 - High data rates, low latency
- Ring Wireless Network
 - Join the ends of the daisy-chain together, not common
- Point-to-multipoint or Star Wireless Network
 - More complex, requires management of spectrum and device data requirements
 - Point A node (master or access point) requires more intelligence
 - Point A node can be an aggregator on a backhaul

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Wireless Technology Architectures

Multipoint-to-multipoint or Mesh Wireless Network

- Very complex, engineered for network churn, provides multi-hop capabilities
- High redundancy with low bit rates, self healing
- Substantial bit rate penalty for each node traversed in the path
- Can be fully connected or partial, which is most common
- Option when a central infrastructure is hard to implement or when the environment is dynamic
- Municipal networks, campus networks, neighborhood networks
- Ad hoc, mobile
- All nodes must run the same mesh routing protocol, but can be different operating systems and hardware types
- Cellular Wireless Network
 - Mobile, users traverse the cells while maintaining connectivity
 - More organized than mesh with distinct hand off protocols as users change cell locations
 - Contains access points and backhauls

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Wireless Technology Modes

- All Wireless Communication is Two Way
 - Except for passive sniffing
- Wireless is Layer 1 in the Overall Network Topology
- Infrastructure Mode
 - Normally a permanent connection, with master (access point) and remotes (or client)
 - Can operate over long distances and is easily scalable
 - Generally connects to a backhaul (WAN)
 - Clients are usually permanently in the network
 - Channel is set in access point and discovered by clients
- Ad hoc Mode
 - Temporary wireless connection, can be device to device without central access point
 - Typically operated over limited distance and is not scalable
 - Personal area network when associated with Bluetooth
 - Network clients come and go in an unscheduled manner
 - All nodes need to use the same SSID and channel

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Wireless Technology Modulation

Spread Spectrum Technology

- Data is sent by modulating the carrier frequency
- The signal is spread over wider area than is required for the data to be sent
- Yields higher throughput rates and lower data bit error
- Direct Sequence Spread Spectrum (DSSS)
 - Spreads the signal energy over the available spectrum band
 - Provides high bandwidth, but susceptible to noise
- Frequency Hopping Spread Spectrum (FHSS)
 - Spreads the signal by hopping the narrowband signal using matching hopping patterns
 - Developed by Nikola Tesla
 - Allows for some noise immunity
 - Reliable and secure (hopping is pseudo-random)
 - Not for broadband applications (limited to ~1Mbps)

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Wireless Technology Modulation

Orthogonal Frequency Division Multiplexing (OFDM)

- Create tight sub-carriers at the assigned bandwidth, signals are transmitted at the same time, orthogonality prevents crosstalk between the sub-carriers
- Provides some noise immunity
- Reliable and secure
- Ideal for high bandwidth applications
- Good for high bit rate backhauls
- Used for wideband communications wireless and copper in applications such as digital TV and audio broadcasting, DSL broadband internet access, wireless networks, and 4G mobile communications

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Wireless Technology Frequencies

Industry, Science, and Medical (ISM)

- FCC 1985: 902-928MHz, 2.403-2.483GHz, 5.725-5.875GHz
 - Unlicensed Spread Spectrum for Wireless LANs, Cordless Phones, Wireless Telemetry
- Unlicensed National Informational Infrastructure (UNII)
 - FCC 1997: 5.15-5.25GHz, 5.25-5.35GHz, 5.725-5.825GHz
 - Non Spread Spectrum (OFDM)
- Public Safety (including DOT)
 - FCC 2003: 4.94-4.99GHz, Licensed
- 900MHz Band
 - Advantages: Foliage penetration, near line-of-site, long range, no interference with WiFi
 - Disadvantages: Lower bandwidth, narrow bands
- 2.4GHz Band
 - Advantages: Higher bandwidth, WiFi standard frequencies, standard for consumer electronics
 - Disadvantages: Can be saturated with WiFi
- 4.9/5.8GHz Band
 - Advantages: Higher bandwidth, less interference
 - Disadvantages: 4.9Ghz is licensed by Public Safety, 20MHz bands

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Wireless Technology Standards

Wireless devices utilize ISO and IEEE standards

- ISO/ITU are worldwide standards i.e. MPEG and H.264 video encoding standards
- IEEE, Institute of Electrical and Electronics Engineers, 802.11/15/16 standards (www.ieee.org)
- Wireless Fidelity Alliance (WiFi)
 - 802.11 testing and certifications body (www.wi-fi.org)
- Worldwide Interoperability for Microwave Access (WiMAX)
 - 802.16 testing and certification body (www.wimaxforum.org)

 Important to use standards because system integration is well understood for standards driven devices

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Wireless Technology Standards

Wireless Standards

- IEEE 802.11i WiFi Security Encryption and Authentication (E&A)
 - Encoding to make data unreadable without permission
 - Wired Equivalent Privacy (WEP), WiFi Protected Access (WPA2)
- IEEE 802.11p Wireless Access for Vehicular Environment (WAVE)
 - Dedicated Short Range Communications (DSRC) for Vehicle Infrastructure Integration (VII)
 - 5.9GHz band, rates up to 6Mbps, distances up to 1000ft
 - May be used for vehicle-to-vehicle and vehicle-to-roadside
 - Lane departure warning, collision avoidance, intersection cooperation
- IEEE 802.16d/e WIMAX (d is 11GHz, e is 2.4GHz)
 - 75Mbps broadband speeds, 5mile distances
 - Fixed and mobile connectivity
 - "Last mile" wireless broadband solution to compete with DSL and Cable modems
- IEEE 802.15 Bluetooth
 - Short range wireless USB, operates in the ISM band at 2.4GHz
 - 1Mbps rates for version 1.2, 3Mbps rates for version 2.0
 - Range: Class 3 = 1m, Class 2 = 10m, Class 3 = 100m

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Wireless Technology Standards

LAN Standards

- IEEE 802.3 Wired LAN protocol
 - Adopted in 1983 for wired 10Mbps, now up to 10Gbps
- IEEE 802.11 WiFi wireless LAN protocol (300ft range)
 - Adopted in 1997 for first 2.4GHz wireless with rates to 2Mbps
 - 802.11b adopted in 1999 to increase rates to 11Mbps
 - 802.11a adopted in 1999 to add 5.8GHz at 54Mbps
 - 802.11g adopted in 2003 to combine above
 - 802.11n adopted in 2010 for rates above 100Mbps

Other Wireless Standards

- RFID
 - Store limited data and respond when interrogated
 - Toll tags, security devices, inventory management
 - Can be passive, semi-passive, or active
 - Operates in numerous RF bands 125KHz-5.8GHz
 - Range of a few feet to 1500m
- Cellular/Paging CDMA, GSM, 3G/4G, etc.

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Wavelength/Frequency/Power

- The length and power of a wave help determine the ability of the wave to pass through obstacles, the distance the wave can travel, and the wave's immunity to other phenomena
- Waves travel at the speed of light
 - Rate of travel is 186,000 miles/second or 3,000,000 meter/second
 - Dividing the rate of travel by the wave frequency gives the wavelength

100	1MHz (1000KHz AM Radio)	~980'
-	900MHz (ISM Spread Spectrum)	~15″
-	2.4GHz (Wireless LANs)	~5″
-	4.9GHz (Public Safety)	~2.5″
	5GHz (WLANs, WIMAX)	~2"

- 10GHz (Satellite TV) ~1"
- Different wavelengths have different properties
 - With power held constant, longer waves are less susceptible to attenuation
 - A wet leave may attenuate 5.8GHz while have little affect on AM radio
 - A conductor (the wet leaf) of ½ the wavelength can be a problem
 - Hard rain attenuates 10GHz (~1" wavelength) satellite TV, for example

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Wavelength/Frequency/Power

- Power is related to the amplitude of the wave
- For radio wave, power in Watts is converted to decibel milliwatts (dBm)
 - 0.001mW = -30dBm
 - 0.01mW = -20dBm
 - 0.1mW = -10dBm
 - 1mW = 0dBm
 - 2mW = 3dBm
 - 4mW = 6dBm
 - 10mW = 10dBm
 - 100mW = 20dBm
 - 1000mW = 30dBm
- Power in dBm is a log scale
 - 3dBm is twice the power of 0dBm
 - 33dBm is twice the power of 30dBm
 - 27dBm is half the power of 30dBm

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Gains and losses in the wireless link

Gains

- Launch power in dBm
- Power increases from antennas at transmitter and receiver
- Losses
 - Free-space losses due to using air as a transport medium
 - Antenna misalignment
 - Obstruction, line of sight, Fresnel Zone
 - Diffusion, Diffraction
 - Cable and connector losses
- The System Loss is equal to the total gains minus the total losses, should meet the Link Budget for the design
 - Successful link will have enough extra gain (*Fade Margin*) so that the receiver always has enough signal to meet its requirements (*Receiver Sensitivity*) and the link maintains the expected *Quality of Service*
 - The extra gain allowance is needed to overcome the non ideal effect of interference, noise, and other factors

 Selection of correct frequency, equipment, distance, path, locations, antennas are all key August 30, 2012
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• Line of Sight

- Human eye line of sight is what you can see
- Radio line of sight is what the radio can see
- They are not the same
- Line of sight: clear path for human and radio
- Near line of sight: a human can see the receiver, but there may be some obstruction in the Fresnel Zone

- Non line of sight: a human cannot see the receiver
- Fresnel Zone
 - Radio line of site can be obstructed by obstacles
 - 60% of Fresnel Zone needed, more is better
- Obstacles can lead to
 - Scattering (trees, rough water)
 - Reflection (buildings, calm water)
 - Diffraction

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By the ground





Wireless Technology Noise and Interference

- Interference and noise affect the bit rate and errors
- Bandwidth and maximum power are controlled (by FCC and the link design), you
 must also control noise and interference
- Noise sources: environment, RADAR, WLANS, microwave ovens, wireless phones, other radio systems
- Also can add to the problem: poor fitting cable/connectors, poor grounding, poor frequency planning
- Normal noise will be 70-100dBm
- Measurements
 - RSSI Received Signal Strength Indicator, typically 60-100dBm
 - SNR Signal to Noise Ratio
 - BER Bit Error Rate

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Wireless Technology Noise and Interference

- Can use hopping patterns to avoid noise issues
- Can use frequency planning to avoid noise issues
- Can use channel planning to avoid noise issues
 - Large channel sizes deliver more data, but also accept more noise
- Antenna selection can be use to avoid noise issues
 - Omni directional (stick) antenna, lowest gain
 - Uni direction (Yaggi) antenna (horizontal versus vertical polarization), higher gain, but can have side lobes and dead spots
 - Sector antenna, higher gain, highly focused radiation pattern
 - Reflectors (Dish), highest gain
- Gain is a misnomer, it is really about focusing the radiation

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Wireless Technology Bandwidth Requirements

Data – 150-300Kbps Video – depends on format (picture quality) and number of cameras

MPEG Format	Resolution in Pels and Lines	Frames per second	Transport
Sub-QCIF	128 × 96	Approximately 10-15	Dial-up Modem
QCIF	176 × 144	Approximately 15-20	ISDN or better
CIF	352 × 288	30	Fast DSL speeds or better
4CIF	704 × 576	30	LAN speeds or better
16CIF	1408 × 1152	30 or better	Fast LANs, Gig-E, Fiber

Full motion MPEG4 (H.262 will typically be less)

Videos	@ 30 FPS	Est. Bits per Video	Total Usage
1	MPEG 4 QCIF	1.5 Mbps	1.5 Mbps
1	MPEG 4 CIF	2 Mbps	2 Mbps
2	MPEG 4 CIF	2 Mbps	4 Mbps
4	MPEG 4 CIF	2 Mbps	8 Mbps
6	MPEG 4 CIF	2 Mbps	12 Mbps
8	MPEG 4 CIF	2 Mbps	16 Mbps
10	MPEG 4 CIF	2 Mbps	20 Mbps

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Wireless Technology Security

Network Access Control

- WiFi Protected Access 2 (WPA2) Authentication, SSID Suppression
- MAC Address Access Control Lists (ACLs) MAC Addresses can be spoofed
- Per-User Group Authentication Policies Using Multiple VLANs and SSIDs
- IP Address, Protocol, and TCP/UDP Port Filtering for Access Control (Firewall)
- Virtual Private Networks (VPNs)
- Network Resource Protection
 - Physical Deterrents, Firewalls, VPNs An unreachable network cannot be hacked
- End Point Protections (human and non-human clients)
 - Multiple VLANs plus WPA2
 - Evil Twin Detection
 - Address Filtering to Block Peer-to-peer Traffic Flows, also with VPNs
 - Use of SSL with Embedded Web Servers
- Secure End-to-End Transmission
 - Encryption (WPA2, SSL, VPNs, AES for Mesh Networks)

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