Introduction to Ultra Wide Band

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Today’s agenda

- Introduction to UltraWideBand
- DS-UWB PHY – Matt Welborn
- 802.15 TG3b MAC – Bill Shvodian
- MB-UWB PHY – Serdar Yurdakul
- MBOA MAC – Patrick Worfolk
- WiMedia Convergence Architecture – Glyn Roberts
- Wireless 1394 – Peter Johansson
- Wireless USB – Jeff Ravencraft
Wireless Data Technology Menagerie
- WAN, MAN, LAN, PAN

802.15.3: First high Rate PAN

Benefits of high rate PANs

Ultra Wide Band history

Current UWB technologies

Industry politics

Resources
Range of Wireless data choices

- Wide Area Networks
  - 2G and 3G cellular data systems
- Metropolitan Area Networks
  - 802.16, wireless broadband
- Local Area Networks
  - 802.11/a/b/g/…, wireless LAN
- Personal Area Networks
  - 802.15.1 (Bluetooth™), 802.15.3 & 802.15.4
Network Scales

- **PAN (Personal Area Network)**
  - Protocol: 802.15.x
  - Range: <10m

- **LAN (Local Area Network)**
  - Protocol: 802.11
  - Range: 100m

- **MAN (Metropolitan Area Network)**
  - Protocol: 802.16
  - Range: 2-4km

- **WAN (Wide Area Network)**
  - Protocols: 2G, 3G
  - Range: 2km/link (national areas)
## Wireless Comparisons

<table>
<thead>
<tr>
<th>Wireless technology</th>
<th>Power mW</th>
<th>Range meters</th>
<th>operating BW</th>
<th>Peak Rate bps</th>
</tr>
</thead>
<tbody>
<tr>
<td>EDGE 2.5G GSM</td>
<td>600</td>
<td>~2000</td>
<td>200kHz channel</td>
<td>384k</td>
</tr>
<tr>
<td>1xEVDO 3G CDMA</td>
<td>600</td>
<td>~2000</td>
<td>1.25MHz/channel</td>
<td>2.4M</td>
</tr>
<tr>
<td>802.16 WiMax</td>
<td>250</td>
<td>~4000</td>
<td>25MHz/channel</td>
<td>120M</td>
</tr>
<tr>
<td>802.11g WiFi</td>
<td>50</td>
<td>100</td>
<td>25MHz/channel</td>
<td>54M</td>
</tr>
<tr>
<td>802.15.1a Bluetooth</td>
<td>1</td>
<td>10</td>
<td>1MHz/channel</td>
<td>&lt;1M</td>
</tr>
</tbody>
</table>
Wireless technologies have impairments:
- Noise sources, including intentional radiators
- Weather & physical barriers
  - Rain impairs some frequencies
  - People, buildings and furniture absorb microwaves
- Multiple signal paths (self interference)
- Vulnerable systems (pacemakers, aircraft navigation)
- Other contending devices:
  - Other cell phones & towers
  - Other piconets of similar short range technologies

All MAC layers have overhead
- e.g. Bluetooth MAC uses 28%
Diverse applications

- Cellular data is for wide ranging mobile access to email and to the Web, leveraging the cellular voice infrastructure.
- WiMax: wireless broadband access
  - E.g. bridge to WiFi hot spots, or rural users
- WiFi: fast email & web access at short range: e.g. homes, offices, hotspots
- Bluetooth™: short range cable replacement
Why go beyond Bluetooth?

- Get much higher data rates
  - Under optimal conditions, Bluetooth is a 1Mbps signaling technology.
  - Bluetooth is increasing signaling data rates, to 4Mbps.

- Much lower transmit power
  - Bluetooth is 1mW
  - UWB variations are much lower

- New applications
New applications

- Mobile Internet access for handhelds
  - Comparable or higher speeds than WiFi
  - Much lower RF power than WiFi
  - Higher spatial capacity (bps/sq. meter)
- Fast wireless peripheral access
  - Transfer photos, files, music, video
  - Stream audio and/or video
  - Wireless USB
- Living room multimedia: Wireless 1394
All 802 family standards focus on
- PHY layer (e.g. signals, carriers)
- MAC (media access control) layer
- See model on next slide

Original scope was at least 20Mbps, but with similar range and power to Bluetooth, using 2.4 GHz ISM band

Subsequent UWB work, e.g. 802.15 Task Group 3a, builds on this standard
Figure 3—The reference model used in this standard
2.4GHz ISM band (2.4000-2.4835 GHz)
- Shared with Bluetooth, 802.11/b/g, etc

Split into 5 bands
- 3 bands used to avoid collision with 802.11
- 15 MHz per channel

Symbol timing is similar to 802.11b
- 11 Mbaud symbol rate
- Data rates of 11, 22, 33, 44 and 55 Mbps
- Trellis coding used for all but 22Mbps
802.15.3 MAC Goals

- Fast Connect Time
- Ad Hoc Networks
- Dynamic Membership
- Efficient Data Transfer
- Data transport Quality-of-Service (QoS)
- Security, including:
  - Data encryption
  - Data integrity
  - Command integrity
The PicoNet Controller (PNC) manages piconets = ad hoc associations (next slide)

- Controls PicoNet security
- Allocates PicoNet data transfer capacity by allocating piconet time
- Manages traffic in SuperFrames
- Manages service discovery and configuration
- Manages PicoNet range via beacon power
IEEE 802.15.3
Piconet Elements

Figure 1—802.15.3 piconet elements
This measures the amount of data delivered per user in a given space.

Example: early cell phones had a few towers and a lot of power
- In 1976, NYC could only support 545 users
- By reducing power, tower spacing is reduced
- Denser tower spacing covers more users

High capacity = more users, better served

Note: the following table is not corrected for MAC overhead
## Spatial Capacity Comparisons

<table>
<thead>
<tr>
<th>Type</th>
<th>Range m</th>
<th>area m²</th>
<th>data rate</th>
<th>capacity kbps/m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>802.15.1</td>
<td>10</td>
<td>314</td>
<td>1M</td>
<td>3.2</td>
</tr>
<tr>
<td>802.11b</td>
<td>100</td>
<td>31416</td>
<td>11M</td>
<td>0.35</td>
</tr>
<tr>
<td>802.11g</td>
<td>100</td>
<td>31416</td>
<td>54M</td>
<td>1.72</td>
</tr>
<tr>
<td>802.11a</td>
<td>50</td>
<td>7854</td>
<td>54M</td>
<td>6.88</td>
</tr>
<tr>
<td>802.15.3</td>
<td>10</td>
<td>314</td>
<td>55M</td>
<td>175</td>
</tr>
</tbody>
</table>
Benefit: RF Power per bit

- This measures the energy (joules) it takes to deliver a fixed amount of data.
- Approximate calculation is simple:
  - Time to send data (data/time) x
  - Transmit power (energy/time)
- These are lower bounds, due to MAC overhead and MAC&PHY chip power
  - e.g. Bluetooth MAC will eat at least 28%
  - chip power may far exceed RF power
- To get rid of leading zeros, calculate microJoules/MB rather than joules/bit.
## RF Power per MB

<table>
<thead>
<tr>
<th>Type</th>
<th>Bit rate</th>
<th>TX Power</th>
<th>uJ/MB</th>
</tr>
</thead>
<tbody>
<tr>
<td>802.11b</td>
<td>11Mb</td>
<td>50mW</td>
<td>36,400</td>
</tr>
<tr>
<td>802.11a</td>
<td>54Mb</td>
<td>200mW</td>
<td>29,600</td>
</tr>
<tr>
<td>802.11g</td>
<td>54Mb</td>
<td>50mW</td>
<td>7,400</td>
</tr>
<tr>
<td>802.15.1</td>
<td>1Mb</td>
<td>1mW</td>
<td>8,000</td>
</tr>
<tr>
<td>802.15.3</td>
<td>55Mb</td>
<td>1mW</td>
<td>150</td>
</tr>
</tbody>
</table>
Ultra Wide Band

- Very low power: -41dbm/MHz (FCC)
- Very wide bandwidth: 3.1-10.6 GHz
- First UWB designs: strings of pulses
- IEEE 802.15 Task Group 3a: new PHY (& related MAC updates)

Current Proposals in 802.15 TG3a:
- Merged Proposal #1: MultiBand OFDM
- Merged Proposal #2: Direct Sequence-UWB
**Spectra Comparison**

- **GPS**
  - Frequency: 1.6 GHz
  - Emitted Signal Power: 10.6 dBm/MHz

- **PCS**
  - Frequency: 1.9 GHz
  - Emitted Signal Power: 10.6 dBm/MHz

- **Bluetooth, 802.11b, 802.11g, 802.15.3 Cordless Phones, Microwave Ovens**
  - Frequency: 2.4 GHz
  - Emitted Signal Power: 3.1 dBm/MHz

- **802.11a**
  - Frequency: 5 GHz
  - Emitted Signal Power: 8.0 dBm/MHz

- **UWB Spectrum**
  - Frequency: 3.1 to 10.6 GHz
  - Emitted Signal Power: -41 dBm/MHz

**Part 15 Limit**
First UWB Designs

- Used similar wide bandwidth and low power
- Used wavelet pulses (see below)
- Data modulated by amplitude and pulse-to-pulse period
- Many technical and regulatory issues
Proposed PHY Changes: DS-UWB & MB-UWB

- **DS-UWB:** “Merged Proposal #2”
  - Uses wideband pulses in one of two bands
  - promoted by UWB Forum
  - See presentation by Matt Welborn

- **MB-UWB:** “Merged Proposal #1”
  - Replace wideband pulses with OFDM
  - Multiple bands used in sequence
  - Promoted by MBOA
  - See presentation by Serdar Yurdakul
Proposed MAC changes: TG3b & MBOA

- IEEE 802.15 TG3b is working on an improved MAC, in parallel with TG3a:
  - Merge Device Mgmt (DME) into the MAC
  - Add bi-directional transmission within CTA
  - New frame type for protocol multiplexing
  - See presentation by Bill Shvodian

- MBOA is finishing a new MAC, including:
  - Fully distributed peer-to-peer
  - Improved spatial re-use
  - Tuned to the needs of WUSB and W1394
  - See presentation by Patrick Worfolk
FCC Regulatory Issues

- Freescale was granted FCC (USA only) approval for DS-UWB chips.
- The MBOA has applied for FCC ‘waiver’ for their design.
  - The FCC tends to respond to waiver requests, rather than anticipating new technologies.
  - Prediction: eventual approval is likely
Any design has to work worldwide.
- There are several masks for WiFi & Bluetooth

ITU-R TG1-8 will consider international UWB regulations soon: May in San Diego CA
- The FCC will propose its own emissions limits.
- OFCOM (UK) will probably be similar to FCC.

CEPT (EC) is likely to be stricter, given strong opposition from cellular carriers.

Many countries will protect radio astronomy, WiMAX (licensed) & 4G cellular
Other Contrasts

- DS-UWB has simpler digital hardware
  - rake filters and notch filters add analog complexity
- Both designs scale up data rate at close range.
- Simultaneously Operating Piconet (SOP) mechanisms:
  - DS-UWB uses offset chipping rates & DS codes.
  - MB-UWB uses different hopping sequences.
  - Both can operate in different bands
- Both radios have options to measure the range between devices, for basic location awareness.
- MB-UWB facilitates cognitive radio:
  - Listen to other radio usage & adaptively adjust transmit spectra
  - Not yet an FCC or market requirement
Industry Politics

- IEEE Standards Association process
- Contrast to other standards bodies
- Industry trade groups
- Predicted outcomes
In IEEE standards groups, membership and voting is by individual engineer.

Membership in IEEE or IEEE-SA not needed.

Voting rights are earned by attendance, and maintained by attendance and voting.

Affirmative votes on propositions requires 75% in favor.

NO votes should be technical, and include what would be required for a YES vote.

- some voters cite market reasons as well
Contrasting Policies

- ITU (International Telecommunications Union) is a UN Treaty organization
  - Voting by country
- TIA (Telecommunications Industry Association) votes by company.
- ETSI (European Telecommunications Standards Institute) votes by administration (e.g. France Telecom) and by company.
- Success requires “consensus”
  - ‘absence of principled dissent’
Some industry trade groups exist to provoke the development of standards by other bodies, and then promote results:

- WiFi Alliance (formerly WECA: Wireless Ethernet Compatibility Alliance) promotes IEEE 802.11
- Zigbee Alliance promotes 802.15.4
- WiMax Alliance promotes 802.16
- 1394 TA (Trade Association) promotes IEEE 1394

Other industry groups also develop specs:
- USB Implementers’ Forum & Device Working Group
- Bluetooth SIG (Special Interest Group)
UWB Trade Groups

- UWB Forum
  - Matt Welborn & Bill Shvodian
- The MultiBand OFDM Alliance
  - Serdar Yurdakul & Patrick Worfolk
- The WiMedia Alliance: Glyn Roberts
- Wireless 1394: Peter Johansson
- The Wireless USB Promoters: Jeff Ravencraft
Other PAN Trade Groups

- Bluetooth Special Interest Group (SIG)
  - Formulated the whole stack, from PHY and MAC up to application profiles
  - PHY and MAC became IEEE 802.15.1.

- ZigBee Alliance
  - Focused on faster and lower power PAN
  - Industrial applications
  - Contributed to IEEE 802.15.4 development
  - Pushes applications and compatibility testing
The deadlock has lasted since July 2003
- Some deadlocks break (e.g. 802.11g)

The majority margin is small and changes:
- DS-UWB had a one vote margin in July 2004.
- MB-UWB had 54% in September 2004
- DS-UWB had 51% in Nov 2004, 54% in Jan 2005.

Neither group has the 75% necessary to win.

TG3a members have proposed:
- Termination if down-selection fails in July 2005
- Splitting the PAR. e.g. two standards.
- Two-headed PHY standard (‘Merged Proposal #3’)

All are controversial; stay tuned
IEEE 802.15 TG3a looks fatally deadlocked.

Both MB-UWB and DS-UWB could become distinct 802.15 standards.
- Like 802.3 (Ethernet) & 802.5 (Token Ring)
- The competitors would need mutual tolerance

DS-UWB may succeed in two markets:
- Handheld devices, given Freescale’s presence there.
- W-1394, given the 1394 support in the TG3b MAC.

MB-UWB should succeed in two markets:
- Wireless peripheral connectivity (e.g. W-USB)
- Wireless multi-media/entertainment (e.g. W-1394)
References

- **Articles:**
  - “A Long-Term View of Short Range Wireless”, IEEE Computer, June 2001
  - “Wireless Data Blaster”, Scientific American, May 2002

- **Primary Standards:**
  - IEEE 802.11 series, WLAN (Wi-Fi)
  - IEEE 802.15.1-2002, Bluetooth
  - IEEE 802.15.2-2003, Co-existence
  - IEEE 802.15.3-2003, High Rate PAN
  - IEEE 802.15.4-2003, Low Rate PAN
  - IEEE 802.16-2001, Fixed Wireless Broadband
IEEE 802.15 TG3a reference contributions

- **DS-UWB**: 15-04-0137-03-003a (doc)
  - Summary: 15-04-0140-11-003a (ppt)
- **MB-UWB**: 15-04-0493-00-003a (doc)
  - summary: 15-05-0081-00-003a (ppt)
IEEE URL Resources

- standards.ieee.org/
- standards.ieee.org/wireless/
- grouper.ieee.org/groups/802/11
- grouper.ieee.org/groups/802/15
- grouper.ieee.org/groups/802/16
- 802wirelessworld.com
- www.1394ta.org
Wireless Trade Group
URL Resources

- www.nict.go.jp
- www.uwbforum.org
- www.multibandofdm.org
- www.wimedia.org
- www.wimaxforum.org
- www.weca.net
- www.bluetooth.com
- www.zigbee.org
- www.ultrawidebandplanet.com
Other URL resources

- Cellular data:
  www.rysavy.com/Articles/3G/3g.htm
- Cellular Telephone Industry Ass’n:
  www.wow-com.com
- Telecommunications Industry Ass’n”
  www.tiaonline.org
- International Telecommunications Union
  www.itu.ch
- USB Implementers Forum
  www.usb.org