A Comparison of Bluetooth and IEEE 802.11

Ken Noblitt
Manager, Technical Marketing
North America
Email: Ken.Noblitt@csr.com

Cambridge Silicon Radio
1651 N Collins Blvd
Richardson, Texas 75080
Tel: +1 (972) 238-2300
www.csr.com
Agenda

• Markets
• 802.11 technical overview
  – OSI models
  – Modes, Features
  – International Band Plans
• Usage scenarios
• Interoperability – UPF, Wi-Fi
• Coexistence
  – Interference
  – Associations – 802.15.1
  – Band plan, FCC
• Comparison Summary of Bluetooth to 802.11b
• Bill of materials
• CSR Wireless Strategy
• Summary
Bluetooth Market

Total Number of Bluetooth End Points Shipped Per Year Estimate: January, 2001

- Cars
- Digital TV/Set Top Box (m)
- Industrial Applications (m)
- Digital Still Cameras (m)
- Modems
- Printers (m)
- Notebook PCs (m)
- Desktop PC Mouse/Keyboard
- Desktop PC Motherboard
- Sub Notebooks
- PDAs
- Headsets
- Smart Handhelds (Nokia Communicator)
- Mobile Phones (Voice+)
- Mobile Phones (Voice Only)

Source: Merrill Lynch
IEEE 802.11 Market

Source: Cahners In-Stat
History of IEEE 802.11

• 802.11 standard first ratified in July 1997
  – 802.3 LAN emulation
  – 3 PHY’s were specified for 1 & 2 Mbps
    • FHSS – Frequency Hopping Spread Spectrum
    • DSSS – Direct Sequence Spread Spectrum
    • Infrared

• Two High Rate PHY’s ratified in September 1999
  – 802.11a 6 to 54Mbps in the 5GHz band
    • OFDM – Orthogonal Frequency Division Multiplex
  – 802.11b 5.5 and 11Mbps in the 2.4GHz band
The Beat Goes On

- 802.11c – support for 802.11 frames
- 802.11d – support for 802.11 frames, new regulations
- 802.11e – QoS enhancements in the MAC
- 802.11f – Inter Access Point Protocol
- 802.11g – High Rate or Turbo Mode – 2.4GHz bandwidth extension to 22Mbps
- 802.11h – Dynamic Channel Selection and Transmit Power Control
- 802.11i – Security Enhancement in the MAC
- 802.11j – 5 GHz Globalization among IEEE, ETSI Hiperlan2, ARIB, HiSWANa
Range of Devices

Radio Range Equation:

\[ P_{RX} = P_{TX} G_{RX} G_{TX} \left( \frac{?}{4? R} \right)^2 \]

Bluetooth achieves 100m with minimum requirements:
Where minimum sensitivity of \( P_{RX} = -70 \text{ dBm} \),
Where maximum power (Class 1) = +20 dBm,
Where \( ? \) is the wavelength of the ISM band (12cm),
Where the gain of both antennas are \( \sim -5 \text{ dB} \).

Then \( R \) (range) is \( 100 \text{ meters} \)
Bluetooth™ Scatternet

2 Piconet - Scatternet

FHS Piconet 1

FHS Piconet 2
Interoperability & Compatibility

**Interoperability** – The ability for devices within the same standard to operate with one another independent of manufacturer.

**Bluetooth** – UnPlugFests
Interoperability testing will occur in 3 Categories:
- Category-1 (RF, BB, LM),
- Category-2 (L2CAP, SDP, RFCOMM, TCS), and
- Category-3 (Application profiles).

**IEEE 802.11** – Wi-Fi, IEEE 802.11j
WECA - Wireless Ethernet Compatibility Alliance
WECA’s mission is to certify interoperability of Wi-Fi™ (IEEE 802.11) products.
Coexistence

Coexistence – The ability for devices from two or more standards to operate within their own parameters with limited degradation to one another.

Bluetooth SIG Coexistence Working Group:
has established a working group similar to TG2 to address the same concerns of coexistence in the 2.4 GHz band. Tod Sizer of Lucent is the chair of this group.

IEEE 802.15 WPAN™ Task Groups:

802.15 has established three technical task groups:
- TG1 - objective of reformulating the lower levels of the Bluetooth 1.x spec into an IEEE standard for MAC and PHY.
- TG2 - objective of creating Recommended Practices for the Coexistence of wireless devices operating in the 2.4 GHz ISM band.
- TG3 - objective of creating MAC and PHY standards for a High Rate WLAN capable of delivering 20 MB/s and somehow remaining compatible with the output of TG1 (i.e., Bluetooth 1.x).
Physical Layer

**Bluetooth**

2402 – 2480 MHz
In 1MHz steps

FHSS hopping across
All geographical channel
Allocations.

<table>
<thead>
<tr>
<th>CHANNEL NUMBER</th>
<th>CHANNEL FREQUENCY</th>
<th>GEOGRAPHIC USAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2412MHz</td>
<td>US, CA, ETSI</td>
</tr>
<tr>
<td>2</td>
<td>2417MHz</td>
<td>US, CA, ETSI</td>
</tr>
<tr>
<td>3</td>
<td>2422MHz</td>
<td>US, CA, ETSI</td>
</tr>
<tr>
<td>4</td>
<td>2427MHz</td>
<td>US, CA, ETSI</td>
</tr>
<tr>
<td>5</td>
<td>2432MHz</td>
<td>US, CA, ETSI</td>
</tr>
<tr>
<td>6</td>
<td>2437MHz</td>
<td>US, CA, ETSI</td>
</tr>
<tr>
<td>7</td>
<td>2442MHz</td>
<td>US, CA, ETSI</td>
</tr>
<tr>
<td>8</td>
<td>2447MHz</td>
<td>US, CA, ETSI</td>
</tr>
<tr>
<td>9</td>
<td>2452MHz</td>
<td>US, CA, ETSI</td>
</tr>
<tr>
<td>10</td>
<td>2457MHz</td>
<td>US, CA, ETSI, FR, SP</td>
</tr>
<tr>
<td>11</td>
<td>2462MHz</td>
<td>US, CA, ETSI, FR, SP</td>
</tr>
<tr>
<td>12</td>
<td>2467MHz</td>
<td>ETSI, FR</td>
</tr>
<tr>
<td>13</td>
<td>2472MHz</td>
<td>ETSI, FR</td>
</tr>
<tr>
<td>14</td>
<td>2484MHz</td>
<td>Japan†</td>
</tr>
</tbody>
</table>

KEY: US = United States, CA = Canada, ETSI = ETSI countries (except France and Spain), FR = France, SP = Spain.
†In Japan, authorization for Channels 1 through 11 is pending.
2.4GHz ISM Shared Band

- Ovens
- 802.11b
- Bluetooth

Frequency (MHz)
5GHz ISM Band Allocations

Europe
- Hiperlan: 5.15 - 5.35 GHz
- High Speed Wireless Access: 5.15 - 5.25 GHz

Japan
- U-NII: 5.15 - 5.35 GHz

US
- U-NII: 5.725 - 5.825 GHz

Licensed exempt
- 455 MHz

Unlicensed
- 300 MHz
- 100 MHz
5GHz ISM Band Power Restrictions

- **Europe**
  - Indoor: DFS & PC, 200 mW EIRP
  - Outdoor: DFS & PC, 1 W EIRP

- **Japan**
  - Carrier sensing every 4 ms
  - Indoor / Outdoor: 200 mW / 1 W EIRP

- **US**
  - Outdoor: 4 W EIRP

Max mean Tx power

Max peak Tx power
WLAN Usage Scenarios

Data & Voice Access Points
- Using the medium as a gateway
  - GSM gateway scenario
  - 802.3 gateway scenario
- Point to point vs. multi-link

Ad-Hoc Networking
- Roaming in and out of range -> establish connections
  - Peer to peer
  - Multipoint data distribution

Cable Replacement
- 802.3 connections -> Ethernet
- Serial port connections -> Synchronizing
- USB connections -> Printing, mice, keyboards
- Proprietary connections -> Gaming (Joysticks)
Bluetooth and 802.11 Usage Scenarios

Data/Voice Access Points

Ad Hoc Networking

Cable Replacement

Access Point

BT or 802.11

BT

GSM

BT

BT

BT

BT

BT

BT

BT

BT

BT

BT or 802.11

BT or 802.11

BT

GSM
Interference power from a 1mW Bluetooth transmitter into an WLAN receiver, as a function of separation distance.
Comparison of BT to 802.11b

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Bluetooth</th>
<th>802.11</th>
</tr>
</thead>
<tbody>
<tr>
<td>Access</td>
<td>Point to Multipoint</td>
<td>Point to point only</td>
</tr>
<tr>
<td>Symbol Rate</td>
<td>1 Msp</td>
<td>11Msp</td>
</tr>
<tr>
<td>Spread Spectrum</td>
<td>FHSS</td>
<td>DSSS</td>
</tr>
<tr>
<td>Profiles</td>
<td>Almost unlimited</td>
<td>LAN station or access point</td>
</tr>
<tr>
<td>Data Distribution</td>
<td>No restriction</td>
<td>Access point only</td>
</tr>
<tr>
<td>Current Consumption</td>
<td>60mA</td>
<td>300mA</td>
</tr>
<tr>
<td>Audio</td>
<td>PCM channels</td>
<td>Voice over 802.3</td>
</tr>
<tr>
<td>Cable Replacement</td>
<td>Serial, USB, UART, Audio</td>
<td>802.3</td>
</tr>
<tr>
<td>Mobility Management</td>
<td>Master</td>
<td>Mobile Station</td>
</tr>
<tr>
<td>Circuit Cost (est. Sept 2001)</td>
<td>$11.00</td>
<td>$46.00</td>
</tr>
</tbody>
</table>
HIPERLAN/1 devices may be operated in Europe in the 5.15-5.30 GHz frequency band and a signaling rate for high rate transmission is 23.5 Mbit/s (this results in net data rates approximately up to 20 Mbit/s).

HIPERLAN/2 is a flexible Radio LAN standard designed to provide high speed access (up to 54 Mbit/s at PHY layer) to a variety of networks including 3G mobile core networks, ATM networks and IP based networks, and also for private use as a wireless LAN system. Basic applications include data, voice and video, with specific QoS parameters taken into account.
## HiperLAN/2 Channel vs. Output Power Scheme

<table>
<thead>
<tr>
<th>Channel Number</th>
<th>Band</th>
<th>Frequency (MHz)</th>
<th>EIRP (dBm) mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>36</td>
<td>Lower</td>
<td>5180</td>
<td>23</td>
</tr>
<tr>
<td>40</td>
<td>Lower</td>
<td>5200</td>
<td>23</td>
</tr>
<tr>
<td>44</td>
<td>Lower</td>
<td>5220</td>
<td>23</td>
</tr>
<tr>
<td>48</td>
<td>Lower</td>
<td>5240</td>
<td>23</td>
</tr>
<tr>
<td>52</td>
<td>Lower</td>
<td>5260</td>
<td>23</td>
</tr>
<tr>
<td>56</td>
<td>Lower</td>
<td>5280</td>
<td>23</td>
</tr>
<tr>
<td>60</td>
<td>Lower</td>
<td>5300</td>
<td>23</td>
</tr>
<tr>
<td>66</td>
<td>Lower</td>
<td>5320</td>
<td>23</td>
</tr>
<tr>
<td>100</td>
<td>Upper</td>
<td>5500</td>
<td>30</td>
</tr>
<tr>
<td>104</td>
<td>Upper</td>
<td>5520</td>
<td>30</td>
</tr>
<tr>
<td>108</td>
<td>Upper</td>
<td>5540</td>
<td>30</td>
</tr>
<tr>
<td>112</td>
<td>Upper</td>
<td>5560</td>
<td>30</td>
</tr>
<tr>
<td>116</td>
<td>Upper</td>
<td>5580</td>
<td>30</td>
</tr>
<tr>
<td>120</td>
<td>Upper</td>
<td>5600</td>
<td>30</td>
</tr>
<tr>
<td>124</td>
<td>Upper</td>
<td>5620</td>
<td>30</td>
</tr>
<tr>
<td>128</td>
<td>Upper</td>
<td>5640</td>
<td>30</td>
</tr>
<tr>
<td>132</td>
<td>Upper</td>
<td>5660</td>
<td>30</td>
</tr>
<tr>
<td>136</td>
<td>Upper</td>
<td>5680</td>
<td>30</td>
</tr>
<tr>
<td>140</td>
<td>Upper</td>
<td>5700</td>
<td>23</td>
</tr>
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</table>
# Comparison of WLAN Standards

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Bluetooth</th>
<th>802.11</th>
<th>802.11b</th>
<th>802.11a</th>
<th>HiperLAN/1</th>
<th>HiperLAN/2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spectrum</td>
<td>2.4 GHz</td>
<td>2.4 GHz</td>
<td>2.4 GHz</td>
<td>5 GHz</td>
<td>5 GHz</td>
<td>5 GHz</td>
</tr>
<tr>
<td>Max Data Rate</td>
<td>723 kbps</td>
<td>1.2 Mbps</td>
<td>5 Mbps</td>
<td>32 Mbps</td>
<td>20 Mbps</td>
<td>32 Mbps</td>
</tr>
<tr>
<td>Connections</td>
<td>PTMP</td>
<td>PTP*</td>
<td>PTP*</td>
<td>PTP*</td>
<td>PTMP</td>
<td>PTMP</td>
</tr>
<tr>
<td>Frequency Selection</td>
<td>FHSS</td>
<td>FHSS</td>
<td>DSSS</td>
<td>OFDM</td>
<td>OFDM</td>
<td>48 subcarrier OFDM</td>
</tr>
<tr>
<td>Authentication</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Address</td>
<td>Address</td>
</tr>
<tr>
<td>Fixed Networks</td>
<td>Any**</td>
<td>Ethernet</td>
<td>Ethernet</td>
<td>Ethernet</td>
<td>Ethernet, ATM, FireWire, UMTS</td>
<td></td>
</tr>
<tr>
<td>CQDDR</td>
<td>Option***</td>
<td>No</td>
<td>No</td>
<td>No***</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Encryption</td>
<td>40-bit RC4</td>
<td>40-bit RC4</td>
<td>40-bit RC4</td>
<td>40-bit RC4</td>
<td>DES</td>
<td>DES, 3DES</td>
</tr>
</tbody>
</table>
How CSR Addresses this Market – Value Proposition

**BlueCore**
Wide Application Adoption
- Battery powered consumer devices
Low to Medium Data Rates
High Integration
Low Cost
Low Power Consumption

**HiperCore**
Dual Mode 802.11a and HiperLAN2
High Data Rates for very high bandwidth applications
- video streaming
Comparison

As an 802.3 gateway, Bluetooth can provide a reasonable bandwidth connection at a reasonable price and power savings.

Bluetooth great for battery operated voice* and data.
802.11b great for point-to-point WLAN on mains.
802.11a great for streaming video.
* - up to 3 channels of audio supported!

<table>
<thead>
<tr>
<th>WLAN</th>
<th>&lt; 723 kbps</th>
<th>&lt; 8Mbps</th>
<th>&lt; 20 Mbps</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bluetooth</td>
<td>?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>802.11b</td>
<td>?</td>
<td>?</td>
<td></td>
</tr>
<tr>
<td>802.11a</td>
<td>?</td>
<td>?</td>
<td>?</td>
</tr>
</tbody>
</table>