Challenges for Broadband Wireless Systems

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OUTLINE
• Evolution of Cellular Systems
• Global Wireless System
• Challenges for Giga-Wireless Technology

Evolution of Cellular Systems

• New systems appeared every decade according to advancements in wireless technology and changes in user demands.

Convergence of Wireless, Computing and Internet is on the Way

“i-mode” type cellular phones @ Sept. 2002
- Cellular users: 72,081,000
- Users connected to Internet: 57,112,700 (79.2%)

3G Services Started in Japan

• Introduction of IMT2000 services took place in Japan in 2001
• The shift to 3G systems is on going
Wireless LAN Trial in Japan

- Terminal
- PDA
- PC
- Wireless LAN access point
- 1Spot services
- HiSWA/N (36Mbps)
- IEEE802.11b (11Mbps)
- Authentication: MAC address (11b), MT-ID (HiSWA/N)
- Wicket area, platform
- Hotel lobby, etc

WLAN standards: HiSWA/N and IEEE802.11b
- Significantly higher data rates of 36~54Mbps than 3G cellular systems
- A shorter-range coverage (100~150m but 500m~1km in LOS condition) than 3G cellular systems

<table>
<thead>
<tr>
<th></th>
<th>HiSWA/N</th>
<th>IEEE802.11b</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency band</td>
<td>5.2GHz</td>
<td>2.4GHz</td>
</tr>
<tr>
<td>Modulation</td>
<td>Coded OFDM</td>
<td>Spectrum spreading</td>
</tr>
<tr>
<td>Data rate</td>
<td>36Mbps</td>
<td>11Mbps</td>
</tr>
<tr>
<td>Multi-access</td>
<td>TDMA-TDD/DSA (centralized control)</td>
<td>CSMA/CA (de-centralized control)</td>
</tr>
<tr>
<td>Coverage</td>
<td>~100m</td>
<td>~100m</td>
</tr>
<tr>
<td>Network interface</td>
<td>Ethernet/IP/ATM/IMT2000</td>
<td>Ethernet</td>
</tr>
<tr>
<td>Authentication</td>
<td>MT-ID</td>
<td>MAC address</td>
</tr>
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</table>

Global Wireless System

- Next generation wireless systems may not be based on a single standard, but a global wireless system that consists of many dedicated wireless systems interconnected by broadband Internet technology
- CRL has initiated the new generation mobile network project (2002~2005) headed by Prof. F. Adachi

Global wireless system to provide nationwide coverage by using different wireless systems
- Hot spot areas with high multimedia traffic can be covered by 4G hot spot access of 100Mbps~1Gbps or wireless LAN
- Relatively wide hot spot areas are covered by 4G cellular of ~100Mbps
- Other places can be covered by present 2G/3G cellular systems

Giga-wireless technology
- Common wireless technology for cellular and wireless LAN applications
- Data rates of ~1Gbps
- Very high spectrum efficiency of 5~10 bps/Hz; multiple-input multiple-output (MIMO) antenna systems will play an important role
Challenges for Giga-Wireless Technology

- Giga-wireless is one of the core technologies for realization of global wireless system

<table>
<thead>
<tr>
<th>Data rate</th>
<th>16G</th>
<th>100M</th>
<th>10M</th>
<th>1M</th>
<th>100K</th>
<th>10K</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wireless LAN</td>
<td>Giga-Wireless</td>
<td>IMT-2000 (3G)</td>
<td>2G cellular (PDC, GSM, IS95)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Wireless Propagation Channel Model

- Understanding of propagation mechanism is important for system development
- Transmitted signal is reflected and diffracted by buildings, resulting in a multipath channel

Frequency-Spatial Distribution of Multipath Fading

Two Approaches for Giga-Wireless

- **DS-CDMA**: Time domain spreading
  - Spreading Code sequence
  - Data symbol
- **MC-CDMA**: Frequency domain spreading
  - Spreading Code sequence
  - Data symbol

Presentation Slides:
- Challenges for Giga-Wireless Technology
- Wireless Propagation Channel Model
- Frequency-Spatial Distribution of Multipath Fading
- Two Approaches for Giga-Wireless
**DS-CDMA vs. C-CDMA**

- **(a) DS-CDMA**
  - 1 chip
  - 1 data symbol

- **(b) MC-CDMA**
  - 1 chip
  - 1 data symbol

**BER Performance**

- DS- and MC-CDMA provide similar performance

![Graph showing BER performance comparison between DS-CDMA and MC-CDMA](image)

**Throughput**

- Hybrid ARQ combined with powerful turbo coding
- Throughput is almost independent of the spreading factor

![Graph showing throughput](image)

**DS- and MC-CDMA Wireless Access systems**

- Either DS- or MC-CDMA can be a common wireless technology for construction of cellular and hot spot systems

![Diagram showing wireless access systems](image)
Virtual Cellular System

- Links for 100Mbps-1Gbps becomes not only interference limited but also severely power limited
- Propagation loss is in proportion to $\frac{\text{transmission rate}}{f^{2.6}}$
- Peak transmission power for 100Mbps@5GHz is about 135,000 times that of 8kbps@2GHz, e.g., 1W → 135kW. This cannot be allowed.
- Cell size should be reduced by about 29 times (pico-cell, e.g., 1,000m → 34m cell)
- Fundamental change in wireless access network architecture is required that allows significant reduction in mobile transmit powers

Virtual cell consisting of many distributed wireless ports for non-real time IP packet transport
- Transmit and receive functions are not necessarily installed at all wireless ports
- Receive-only ports in addition to receive and transmit ports

Total average transmit power per virtual cell can be significantly reduced
Wireless Access Network

- Wireless access network may become closer to present wireless LAN but with nationwide mobility management.

Advanced Antenna Technology

- Adaptive antenna array (AAA) system
- Space-time Transmit Diversity (STTD) system
- Multi-input/multi-output (MIMO) antenna system

AAA System

- AAA system confines the transmitting radio energy in a narrow angle width to increase the link capacity in no. users/Hz and cellular capacity in no. users/Hz/m².
- Interference from other users located at different positions are suppressed by forming narrow beams.

STTD System

- STTD system exploits independent fading seen on different transmit antennas to improve the transmission quality in BER or FER.
- Simple example is Alamouti's STTD, that can achieve MRC diversity improvement with 3dB power penalty.
MIMO System

- MIMO antenna system transmits different data sequences from different antennas to increase achievable data rate within the limited bandwidth, i.e., the channel capacity in bps/Hz.
- If 8 antennas are used with QPSK transmission, then 16bps/Hz can be achieved.

Another Interesting Wireless Technology: UWB

- Ultra wideband (UWB) technology for short range communication (several tens meters) has been attracting strong attention.
- Possible applications: Personal area network, home area network, computer commun., adhoc network.
- CRL has initiated UWB project (2002~2005) headed by Prof. R. Kohno.
- >100Mbps UWB communications system using 3~30GHz and >30GHz.
- Devices, pulse signal processing, interference suppression techniques, propagation modeling, etc.

Conclusion

- Wireless systems are now becoming an important infrastructure of our society.
- A global wireless system was suggested to offer broad ranges of Internet services to cellular and nomadic users.
  - Many dedicated wireless systems are efficiently interconnected, including 2~4G cellular systems, wireless LANs, broadcasting systems, etc., each optimized to each communications environment.
  - Common wireless technology is desirable to be used in 4G cellular and wireless LAN type systems.
  - Either DS- or MC-CDMA can be used.
- Wireless technology of 100M~1Gbps capability is a challenging research for the coming 10 years.