Selected wireless link standards

- 54 Mbps: 802.11{a,g}
- 5-11 Mbps: 802.11b
- 1 Mbps: 802.15
- 384 Kbps: UMTS/WCDMA, CDMA2000
- 56 Kbps: IS-95 CDMA, GSM

- Indoor: 10 – 30m
- Outdoor: 50 – 200m
- Mid range outdoor: 200m – 4km
- Long range outdoor: 5km – 20km

3G
2G
Cellular network architecture

**MSC**
- connects cells to wide area net
- manages call setup (more later!)
- handles mobility (more later!)

**Cell**
- covers geographical region
- *base station* (BS) analogous to 802.11 AP
- *mobile users* attach to network through BS
- *air-interface*: physical and link layer protocol between mobile and BS

Public telephone network, and Internet

wired network
Two techniques for sharing mobile-to-BS radio spectrum

- **combined FDMA/TDMA**: divide spectrum in frequency channels, divide each channel into time slots
- **CDMA**: code division multiple access
Cellular standards: brief survey

2G systems: mainly designed for the voice channels only

- IS-136 TDMA: combined FDMA/TDMA (north america)

- GSM (global system for mobile communications): combined FDMA/TDMA
  - most widely deployed

- IS-95 CDMA: code division multiple access
2.5 G systems: voice and data channels

- for those who can’t wait for 3G service
- general packet radio service (GPRS)
  - evolved from GSM
  - data sent on multiple channels (if available)
- enhanced data rates for global evolution (EDGE)
  - also evolved from GSM, using enhanced modulation
  - Date rates up to 384K
- CDMA-2000 (phase 1)
  - data rates up to 144K
  - evolved from IS-95
3G systems: voice/data/video?

- Universal Mobile Telecommunications Service (UMTS)
  - GSM next step, but using CDMA
- CDMA-2000
  - Targets for the TRUE integration of multimedia communication
  - A design challenge to provide the seamless switching between multimedia applications
Code Division Multiple Access

- used in several wireless broadcast channels (cellular, satellite, etc) standards
- unique “code” assigned to each user; i.e., code set partitioning
- all users share same frequency, but each user has own “chipping” sequence (i.e., code) to encode data
- encoded signal = (original data) X (chipping sequence)
- decoding: inner-product of encoded signal and chipping sequence
- allows multiple users to “coexist” and transmit simultaneously with minimal interference (if codes are “orthogonal”)
CDMA Encode/Decode

sender

data bits

\[ d_1 = -1 \]
\[ d_0 = 1 \]

code

\[ \begin{array}{cccc}
1 & 1 & 1 & 1 \\
-1 & -1 & -1 & -1 \\
\end{array} \]
slot 1

\[ \begin{array}{cccc}
1 & 1 & 1 & 1 \\
-1 & -1 & -1 & -1 \\
\end{array} \]
slot 0

channel output \( Z_{i,m} = d_i \cdot c_m \)

receiver

received input

code

\[ \begin{array}{cccc}
1 & 1 & 1 & 1 \\
-1 & -1 & -1 & -1 \\
\end{array} \]
slot 1

\[ \begin{array}{cccc}
1 & 1 & 1 & 1 \\
-1 & -1 & -1 & -1 \\
\end{array} \]
slot 0

channel output

\[ D_i = \sum_{m=1}^{M} Z_{i,m} \cdot c_m \]

\[ \begin{array}{cccc}
1 & 1 & 1 & 1 \\
-1 & -1 & -1 & -1 \\
\end{array} \]
slot 1

\[ \begin{array}{cccc}
1 & 1 & 1 & 1 \\
-1 & -1 & -1 & -1 \\
\end{array} \]
slot 0

\[ \begin{array}{cccc}
1 & 1 & 1 & 1 \\
-1 & -1 & -1 & -1 \\
\end{array} \]

\[ d_0 = 1 \]

\[ d_1 = -1 \]
CDMA: two-sender interference

senders

channel, $Z_{i,m}$

$Z_{i,m}^1 = d_i^1 c_m^1$

$Z_{i,m}^2 = d_i^2 c_m^2$

$M$

$Z_{i,m}^* c_m^1$

$\phi_i^1 = \sum_{m=1}^{M} Z_{i,m}^* c_m^1$

receiver 1

$\phi_i^0 = 1$

$\phi_i^0 = -1$
WCDMA Networks

- Spread the radio signal over a wide frequency range by modulating it with a code word unique to the user.
- Users can transmit any time using the whole spectrum.
- Receiver distinguishes sender’s signal from other signals by examining the wide spectrum band with a time synchronized duplicate of the spreading code.
- The transmitted signal is recovered by a despreading process at the receiver.
Number of users vs. Spreading factors vs. BER

![Graph showing the relationship between number of users and spreading factors vs. BER. The graph includes multiple lines indicating different spreading factors (SF)].
Broadband Wireless

• The 802.16 Protocol Stack
• The 802.16 Physical Layer
• The 802.16 MAC Sublayer Protocol
• The 802.16 Frame Structure
The 802.16 Protocol Stack

- Physical medium dependent sublayer
  - OPSK
  - QAM-16
  - QAM-64

- Transmission convergence sublayer
- Security sublayer
- MAC sublayer common part
- Service specific convergence sublayer

Upper layers
Data link layer
Physical layer
The 802.16 Physical Layer

The 802.16 transmission environment.

- QAM-64 (6 bits/baud)
- QAM-16 (4 bits/baud)
- QPSK (2 bits/baud)
The 802.16 Physical Layer (2)

Frames and time slots for time division multiplexing.
Service Classes

- Constant bit rate service
- Real-time variable bit rate service
- Non-real-time variable bit rate service
- Best efforts service
(a) A generic frame.  (b) A bandwidth request frame.
Bluetooth

- Bluetooth Architecture
- Bluetooth Applications
- The Bluetooth Protocol Stack
- The Bluetooth Radio Layer
- The Bluetooth Baseband Layer
- The Bluetooth L2CAP Layer
- The Bluetooth Frame
802.15: personal area network

- less than 10 m diameter
- replacement for cables (mouse, keyboard, headphones)
- ad hoc: no infrastructure
- master/slaves:
  - slaves request permission to send (to master)
  - master grants requests
- 802.15: evolved from Bluetooth specification
  - 2.4-2.5 GHz radio band
  - up to 721 kbps
# Bluetooth Applications

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generic access</td>
<td>Procedures for link management</td>
</tr>
<tr>
<td>Service discovery</td>
<td>Protocol for discovering offered services</td>
</tr>
<tr>
<td>Serial port</td>
<td>Replacement for a serial port cable</td>
</tr>
<tr>
<td>Generic object exchange</td>
<td>Defines client-server relationship for object movement</td>
</tr>
<tr>
<td>LAN access</td>
<td>Protocol between a mobile computer and a fixed LAN</td>
</tr>
<tr>
<td>Dial-up networking</td>
<td>Allows a notebook computer to call via a mobile phone</td>
</tr>
<tr>
<td>Fax</td>
<td>Allows a mobile fax machine to talk to a mobile phone</td>
</tr>
<tr>
<td>Cordless telephony</td>
<td>Connects a handset and its local base station</td>
</tr>
<tr>
<td>Intercom</td>
<td>Digital walkie-talkie</td>
</tr>
<tr>
<td>Headset</td>
<td>Intended for hands-free voice communication</td>
</tr>
<tr>
<td>Object push</td>
<td>Provides a way to exchange simple objects</td>
</tr>
<tr>
<td>File transfer</td>
<td>Provides a more general file transfer facility</td>
</tr>
<tr>
<td>Synchronization</td>
<td>Permits a PDA to synchronize with another computer</td>
</tr>
</tbody>
</table>
The Bluetooth Protocol Stack

The 802.15 version of the Bluetooth protocol architecture.

![Diagram of the Bluetooth Protocol Stack]

- **Applications/Profiles**
  - Other LLC
  - RFcomm
  - Telephony
  - Service discovery

- **Control**
  - Logical link control adaptation protocol
  - Link manager

- **Baseband**

- **Physical radio**

Layered structure:
- Application layer
- Middleware layer
- Data link layer
- Physical layer
The Bluetooth Frame Structure

A typical Bluetooth data frame.

<table>
<thead>
<tr>
<th>Bits</th>
<th>72</th>
<th>54</th>
<th>0-2744</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Access code</td>
<td>Header</td>
<td>Data</td>
</tr>
</tbody>
</table>

- The 18-bit header is repeated three times for a total of 54 bits.
IEEE 802.15.3 - Overview

- High data rate WPAN
- Potential future standard
- Motivation: The need for higher bandwidths currently supported with 802.15.1
  - 100 Mpbs within 10 meter
  - 400 Mpbs within 5 meter
- Data, High quality TV, Home cinema
IEEE 802.15.3 - Overview

• Dynamic topology
  – Mobile devices often join and leave the piconet
  – Short connection times
• High spatial capacity
• Multiple Power Management modes
• Secure Network
IEEE 802.15.3 - Overview

• Based on piconets
• Data Devices (DEV) establish peer-to-peer communication
• Includes also a Piconet Coordinator (PNC)
IEEE 802.15.3 - Topology

- Parent Piconet Controller
- Piconet Device
- Child/Neighbor Piconet Controller
- Piconet Relationship
- Peer to Peer Data Transmission
- Independent Piconet Controller

- Parent and Child/Neighbor piconets share common frequency channel.
- Independent piconet is either far enough apart or on different frequency channel. It operates independently of other piconets.
- Child piconet controller can exchange data with parent piconet controller.
- Neighbor piconet controller only shares frequency channel.
IEEE 802.15.3 - Superframe
IEEE 802.15.3 - Beacon

- Beacon
  - Control information
  - Allocates GTS
  - Synchronization
IEEE 802.15.3 - CAP

• CAP
  - Allows contention via CSMA/CA
  - Command exchange between DEV and PNC
  - File transfers from DEV without request
IEEE 802.15.3 - CFP

- CFP
  - Time slot allocation specified in the beacon
  - Reserved bandwidth for DEV
  - MTS: Command, GTS: Data
IEEE 802.15.3 - GTS

• GTS reservation
  - DEV sends a Channel Time Request (CTR) to PNC
    • Isochronous data: number and duration of slot(s)
    • Asynchronous data: Total amount of data
  - PNC allocates GTSs to DEV via CTA
  - DEV is responsible of utilizing allocated GTSs
IEEE 802.15.3 - GTS

- Two types of GTSs
  - Dynamic GTS
    • Location within a superframe may change
    • PNC can optimize channel utilization
  - Pseudostatic GTS
    • Only for isochronous data
    • Fixed location within a superframe
    • May be changed, but only after a series of notifications to the DEV
IEEE 802.15.3

Starting a piconet

- DEV scans the for the best channel and sends out beacons -> the DEV becomes PNC
- If no channels available: Establishes a child or neighbor piconet instead
  - Requests a private GTS from parent PNC
  - All communication takes place within assigned GTS