# Wireless Communications
## Principles and Practice

**Chapter 2: Modern Wireless Communication Systems**

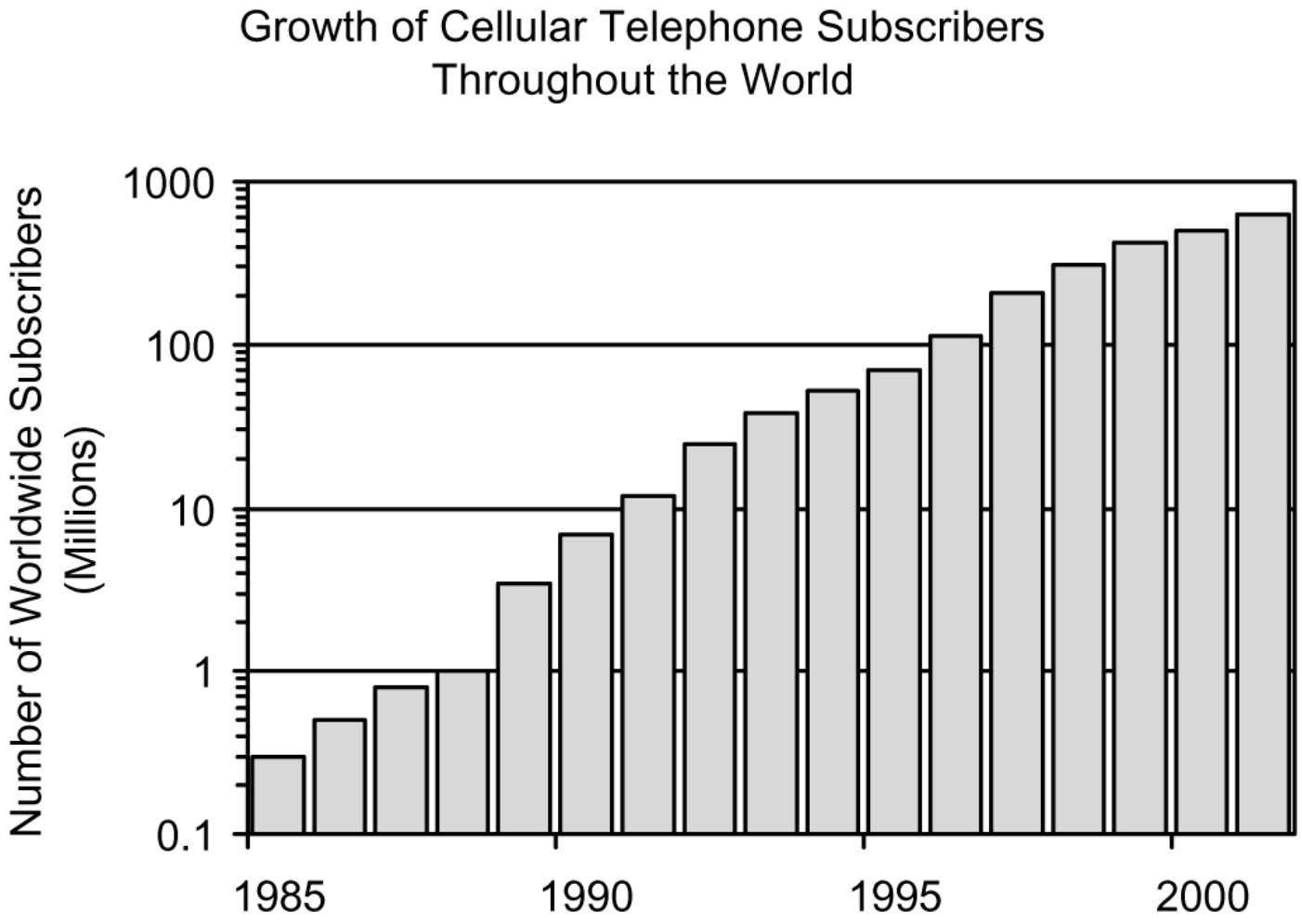



**Figure 2.1** Growth of cellular telephone subscribers throughout the world.

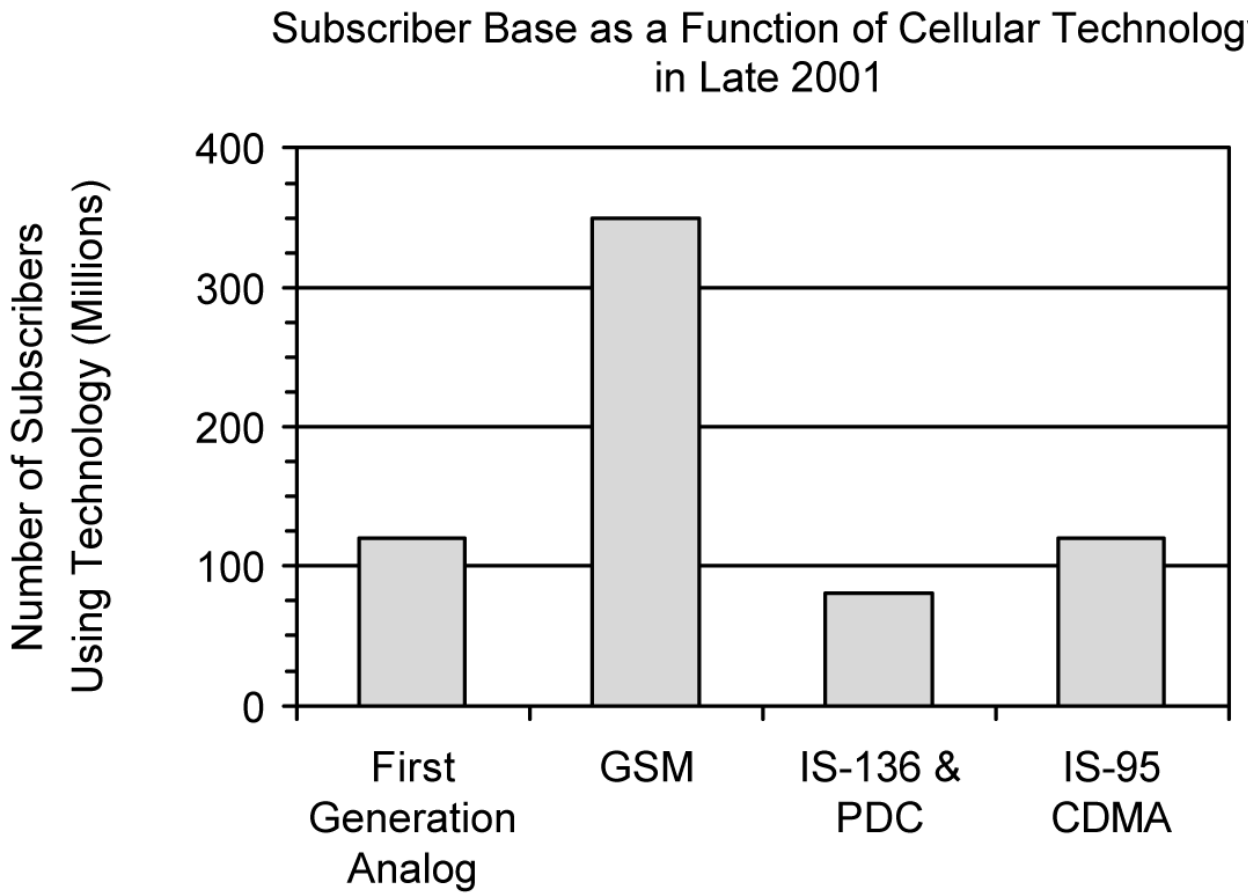



**Figure 2.2** Worldwide subscriber base as a function of cellular technology in late 2001.

**Table 2.1** Key Specifications of Leading 2G Technologies (adapted from [Lib99])

| | cdmaOne, IS-95, ANSI J-STD-008 | GSM, DCS-1900, ANSI J-STD-007 | NADC, IS-54/IS-136, ANSI J-STD-011, PDC |
|---|---|---|---|
| Uplink Frequencies | 824-849 MHz (US Cellular)<br>1850-1910 MHz (US PCS) | 890-915 MHz (Europe)<br>1850-1910 MHz (US PCS) | 800 MHz, 1500 MHz (Japan)<br>1850-1910 MHz (US PCS) |
| Downlink Frequencies | 869-894 MHz (US Cellular)<br>1930-1990 MHz (US PCS) | 935-960 MHz (Europe)<br>1930-1990 MHz (US PCS) | 869-894 MHz (US Cellular)<br>1930-1990 MHz (US PCS)<br>800 MHz, 1500 MHz (Japan) |
| Duplexing | FDD | FDD | FDD |
| Multiple Access Technology | CDMA | TDMA | TDMA |
| Modulation | BPSK with Quadrature Spreading | GMSK with $BT = 0.3$ | $\pi/4$ DQPSK |
| Carrier Separation | 1.25 MHz | 200 kHz | 30 kHz (IS-136)<br>(25 kHz for PDC) |
| Channel Data Rate | 1.2288 Mchips/sec | 270.833 kbps | 48.6 kbps (IS-136)<br>(42 kbps for PDC) |
| Voice channels per carrier | 64 | 8 | 3 |
| Speech Coding | Code Excited Linear Prediction (CELP) @ 13 kbps, Enhanced Variable Rate Codec (EVRC) @ 8 kbps | Residual Pulse Excited Long Term Prediction (RPE-LTP) @ 13 kbps | Vector Sum Excited Linear Predictive Coder (VSELP) @ 7.95 kbps |

# 2.5G TDMA Standards

**High Speed Circuit Switched Data (HSCSD):**

- **Relaxes error control codes**
- **Uses 4 time slots (Circuit switched)**
- **Data rate achieved is 57.6 Kbps**
- **Requires software update at base stations.**

**General Packet Radio Service (GPRS):**

- **Can use up to 8 time slots (Packet switching)**
- **By relaxing coding schemes it can deliver up to 171.2Kbps (21.4x8)**
- **Requires new handset**
- **Requires new gateways and routers**

# 2.5G TDMA Standards

**Enhanced Data Rates for GSM Evolution (EDGE):**

- **Requires new hardware and software at the base station**
- **Requires new handset**
- **Uses 8-PSK modulation in addition to GMSK**
- **Allows 9 different Modulation and Coding Schemes (MCS) with varying degrees of error control depending on the demand and operating conditions.**
- **With 8-PSK and no coding scheme and using 8 time slots it can achieve a throughput of 547.2Kbps (practically 384 Kbps)**

# 2.5G CDMA Standard

**IS-95B**

- **IS-95A CDMA uses 64 channels (Walsh codes) with 14.4 Kbps each**
- **IS-95B allows a user to command 8 Walsh codes simultaneously and in parallel**
- **Throughput is 115.2 Kbps (8x14.4) practically(64 Kbps)**
- **Requires new handset**
- **Requires new software at base station**
- **Requires new handoff procedure (Hard handoff)**

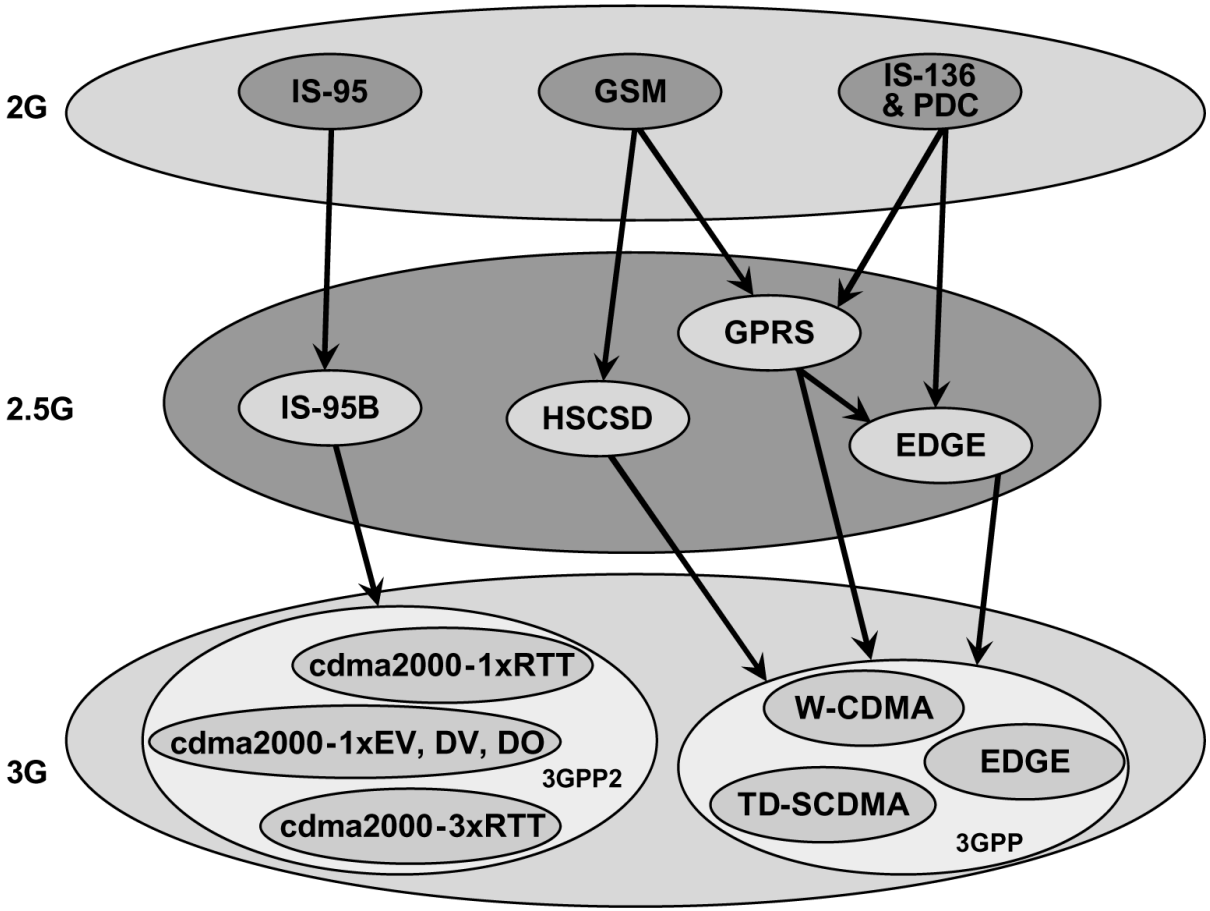



**Figure 2.3** Various upgrade paths for 2G technologies.

# 3G Wireless Technologies

**Wide-Band CDMA (W-CDMA)**

- **Backward compatibility with GSM.**
- **Minimum forward channel BW of 5 MHz.**
- **Uses DS-CDMA with variable spreading factor (4-16 Mchip/sec).**
- **Uses fast closed loop power control (1.5Kbps) to mitigate fast fading**
- **Uses outer loop power control to compensate for changes in environment**
- **Power control achieves desired SIR (up and down links) irrespective of fading**
- **Up to 2 Mbps data rate.**

# 3G Wireless Technologies

**CDMA 2000**

- **Backward compatibility with IS-95A and IS-95B.**
  - **CDMA200 1x provides data rate of 307 Kbps.**
  - **CDMA2000 3xRTT uses 3 adjacent 1.25 MHz channels to achieve 2 Mbps data rate.**
- **Uses Convolutional and turbo coding.**
- **Employs QPSK modulation.**

# 3G Wireless Technologies

**TD-SCDMA (China)**

**Time Division-synchronous CDMA**

**. Relies on existing GSM infrastructure**

**. To yield several times spectral efficiency compared to GSM it uses:**

**1- Smart antennas**

**2- Spatial filtering**

**3-joint detection techniques (to mitigate MAI)**

**. Achieves 384 Kbps data rate**

**. Uses TDD (Time division duplexing) for up and down link using one band to utilize spectrum efficiently under asymetric up-down traffic**

# 4G Wireless Technologies

**4G wireless communications are developed for high speed broadband mobile capabilities.**

**Applications:-**

- **Wireless Broadband Internet Access**
- **Video Chat**
- **Mobile Television**
- **HDTV (High Definition TV)**
- **DVB (Digital Video Broadcasting)**
- **High Speed Data Transfer**

# 4G Wireless Technologies

**Main 4G**

- **WiMAX (Worldwide Interoperability for Microwave Access)**
- **3GPP LTE (3rd Generation Partnership Project Long Term Evolution)**

**Focusing on mobility and broadband**

**UMB (Ultra Mobile Broadband)**

**Flash-OFDM (Fast Hopped OFDM)**

# WIMAX

- **Provides up to 75 Mbps data rate**
- **Uses OFDMA (orthogonal frequency division multiplexing)**
- **High spectral effciency 3-4 bits/sec/Hz**
- **Techniques enabling high data rate**
  - **-Uses adaptive modulation (higher power is assigned for weak channels according to waterfilling principle)**
  - **-Use of smart antennas for beamforming**
  - **-Use of multiple antennas for transmit diversity (MIMO) to reduce fading**
  - **- Use of Error Correcting codes**

# LTE

**Up Link: OFDM**

**Down Link: Single carrie OFDM (SC-OFDM) to reduce the high Peak –to-Average Ratio (PAR) of OFDM that causes problems to amplifiers due to the non-linearity region**

**Bandwidth: choice from 2-20 MHz.**

**Multi –Antennas: Up to 4x4 MIMO (At user and base station)**

**MIMO: 1- Spatial multiplexing (Increse data rare)(sending different data)**

**2- Transmit diversity (sending dependant data)**

**3- MIMO Precoding to maximize SINR**

**Coding: Uses Turbo Codes with interleaving.**

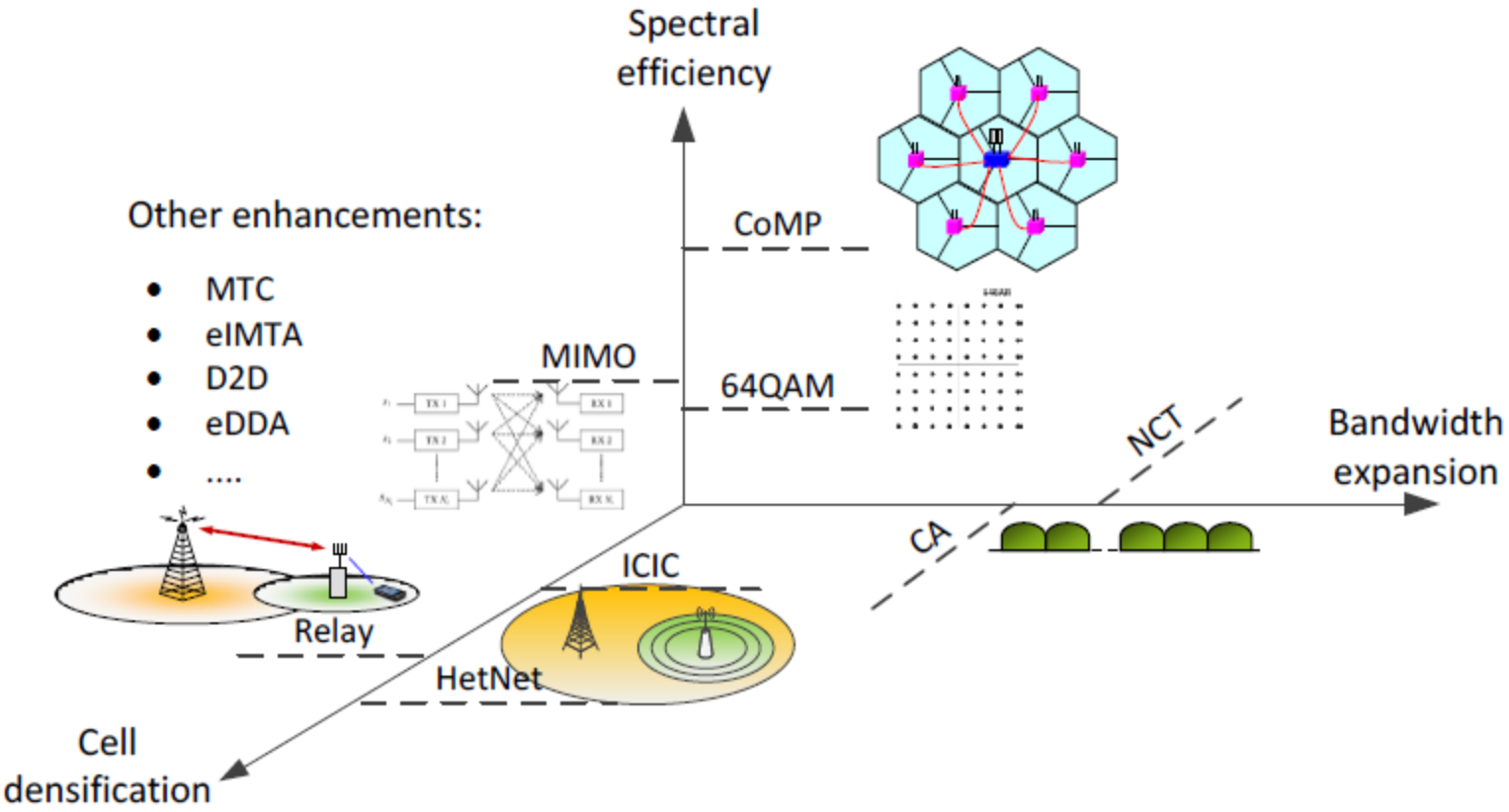
**Downlink peak data rates (64QAM)**

100 Mbps(SISO), 172.8 Mbps (2x2 MIMO) 326.4 Mbps (4x4 MIMO)

**Uplink peak data rates (single antenna)**

50Mbps (QPSK) 57.6Mbps(16QAM) 86.4Mbps(64QAM)

- **The three dimensions for capacity improvement**



# 5G enabling Technologies

**Goals:**

- **100 Mbps for mobile users**
- **1Gbps for fixed users**

using any or combinations of the following three approaches:

- Additional spectrum (bps),• Increase spectral efficiency (bps/Hz)
- Dense deployments - femto cells (bps/Hz/Km).

**Enabling technologies**

- 20-60 MHz channel BW
- Opportunistic OFDMA (Multiuser diversity)
- cognitive radio,
- cooperative methods,
- distributed MIMO and
- Massive MIMO

# 5G enabling Technologies

**Opportunistic OFDM (multiuser diversity)**

- **Multiuser diversity schedule users when their fading channels experience high SNR's.**
- **A certain level of fairness among users must be preserved while keeping the benefits of MU diversity.**
- **This, however requires knowledge of all users channels.**

**Cognitive radio**

- **Temporal and Geographical utilization of the assigned spectrum is from 15% to 85%.**
- **Exploit instantaneous spectrum availability (spectrum holes)by opening licensed spectrum to secondary users when idle.**
- **Secondary users must have very limited Interference to primary users.**

# 5G enabling Technologies

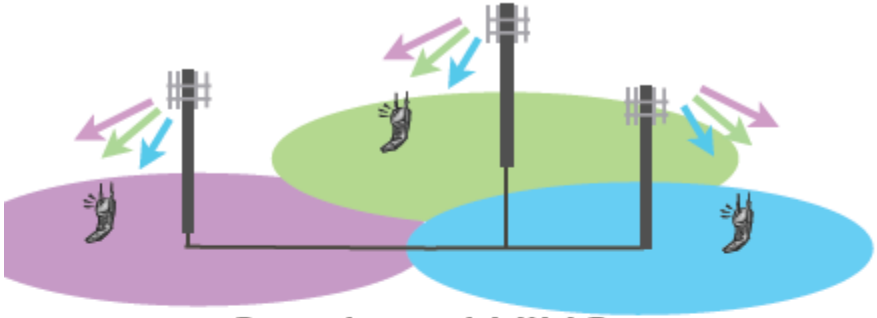
**Coperative Diversity**

- **MIMO size is limited for portable devices.**
- **An alternative for the MIMO spatial diversity, cooperation of in-cell users.**
  - **1- One user may use anothers user's resources to improve his transmission rate.**
  - **2- A Relay node may be added to assist all users.**
- **Requires channels knowledge.**

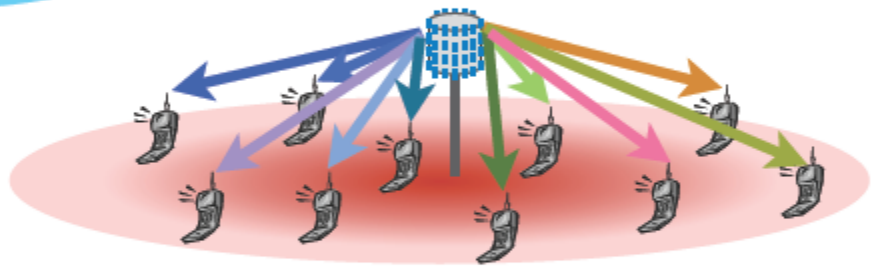
**Distributed antenna systems**

- **Antenna elements are spatially distributed in the cell**
- **Each distributed antenna element is connected to BS by fiber optics or LOS.**
- **This acts as a large MIMO system.**
- **Disadvantage requires channel knowledge**

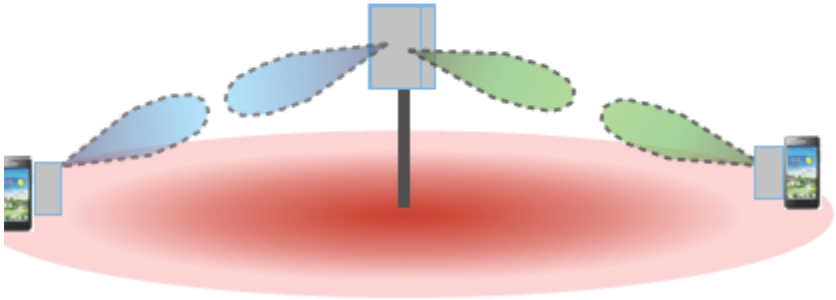
# Where is MIMO Headed?



Coordinated MIMO



Massive MIMO



mmWave MIMO

Candidate architectures for 5G cellular

# Wireless Local Area Networks WLAN

- **Are low-power short range devices for providing private computer communications over a workplace**

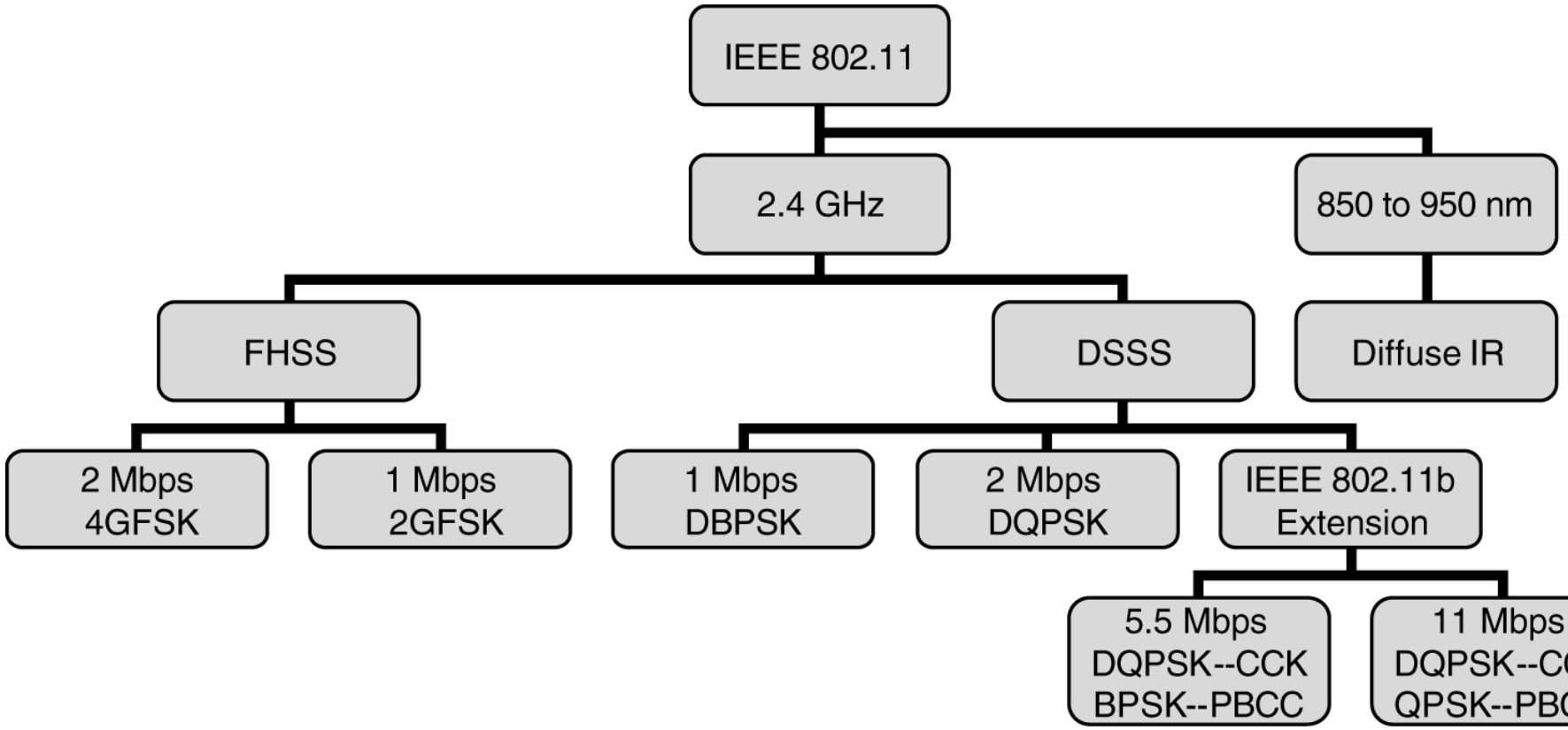





**Figure 2.10** Overview of the IEEE 802.11 Wireless LAN standard.


**Figure 2.11** Photographs of popular 802.11b WLAN equipment. Access points and a client card are shown on left, and PCMCIA Client card is shown on right. (Courtesy of Cisco Systems, Inc.)

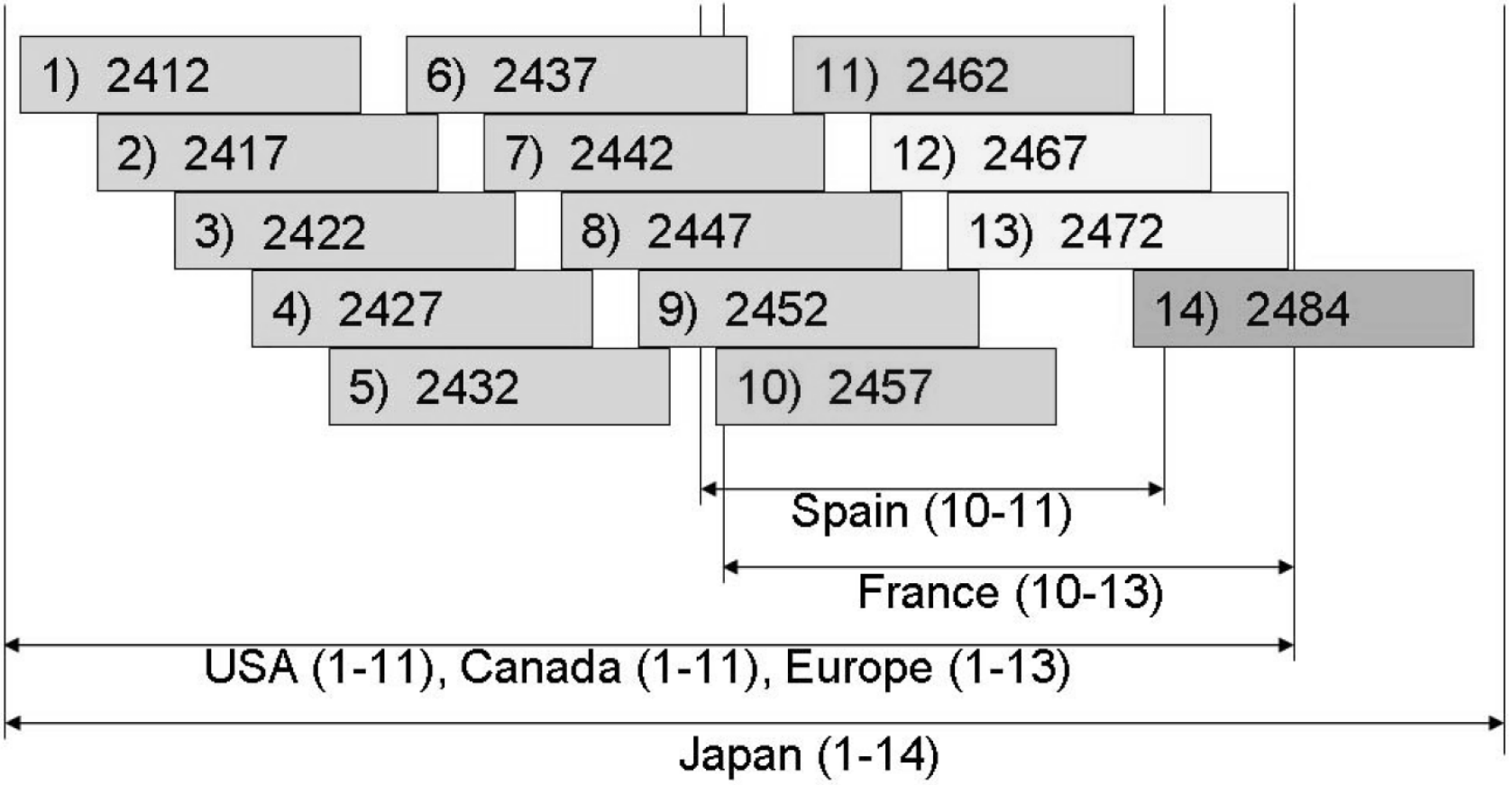



**Figure 2.12** Channelization scheme for IEEE 802.11b throughout the world.

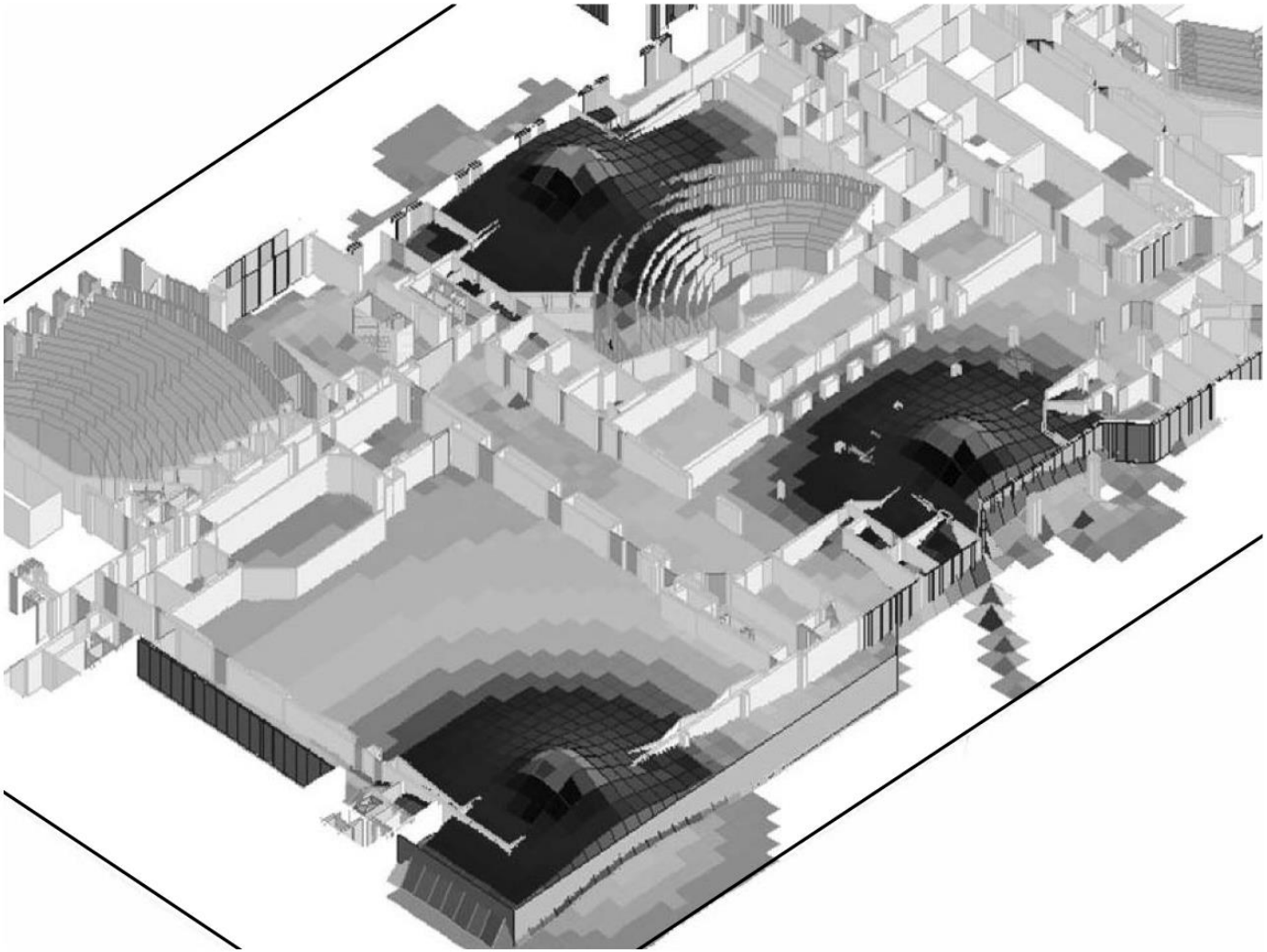


**Figure 2.13** A predicted coverage plot for three access points in a modern large lecture hall. (Courtesy of Wireless Valley Communications, Inc., ©2000, all rights reserved.)

**Table 2.4** IEEE 802.11b Channels for Both DS-SS and FH-SS WLAN Standards

| Country | Frequency Range Available | DSSS Channels Available | FHSS Channels Available |
|---|---|---|---|
| United States | 2.4 to 2.4835 GHz | 1 through 11 | 2 through 80 |
| Canada | 2.4 to 2.4835 GHz | 1 through 11 | 2 through 80 |
| Japan | 2.4 to 2.497 GHz | 1 through 14 | 2 through 95 |
| France | 2.4465 to 2.4835 GHz | 10 through 13 | 48 through 82 |
| Spain | 2.445 to 2.4835 GHz | 10 through 11 | 47 through 73 |
| Remainder of Europe | 2.4 to 2.4835 | 1 through 13 | 2 through 80 |

# Bluetooth and Personal Area Networks (PAN)

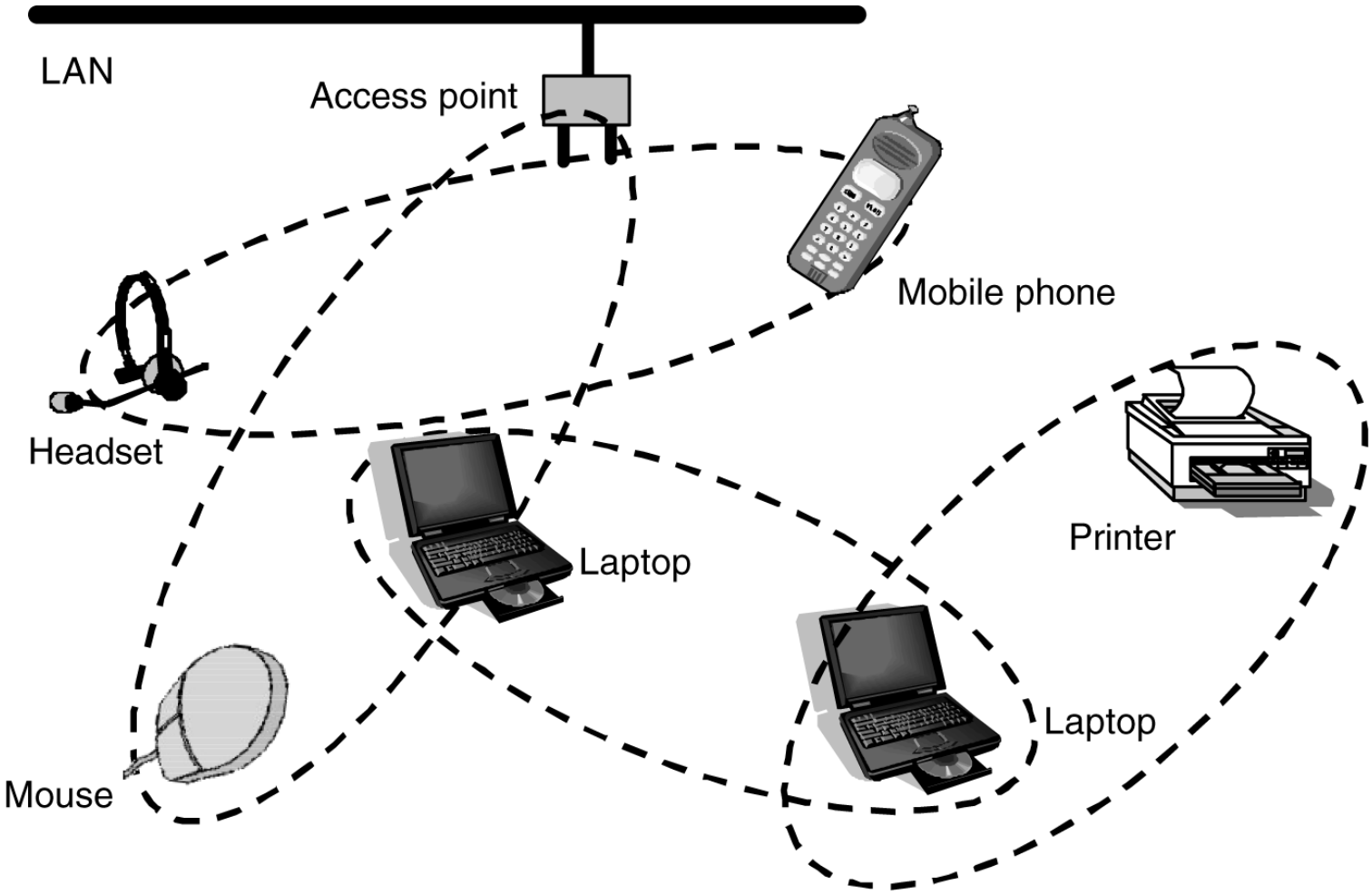



**Figure 2.17** Example of a Personal Area Network (PAN) as provided by the Bluetooth standard.

# Bluetooth and Personal Area Networks (PAN)

**There is a great user appreciation of removing wires from various devices (printers, mouse, headphones,..etc).**

- **. Bluetooth operates in the (2400-2483.5 MHz) band.**
- **. Employs frequency Hopping 1600 Hop/sec (625usec slots).**
- **. One or more data packets over each slot.**
- **. Each channel has a 1MHz BW and 1 Mbps data rate**
- **. Uses GFSK modulation**
- **. Due to FH, it can stand very high interference levels.**
- **. Relies on a number of EC codes and Automatic Repeat Request (ARQ) schemes to support raw channel BER of 0.001.**