GSM System for Mobile

GSM History

- In the mid 1980's, most of Europe didn't have a cellular network.
  - They weren't committed to analog.
- After many years of research, GSM was proposed around 1990.
  - Covered Germany, France, England, and Scandinavia.
- Goals:
  - Roaming throughout all of Europe.
  - All digital to have ISDN type throughput (64 Kbps)
    - Never achieved.
  - Low power and inexpensive devices

GSM History

- Main Goal:
  - Compression of voice to allow much better bandwidth usage.
    - GSM would use vocoders that used LPC – linear predictive coding.
- GSM had an advantage in that it didn't have to support any legacy products.
- Security really wasn't the reason digital was chosen at the time.

GSM History

- All of Europe began using the GSM system.
  - Japan also switched to GSM and helped develop very inexpensive SIM cards.
- GSM was an open source standard.
  - Products could be made by many vendors.
- 8000 page standard was published in 1993.

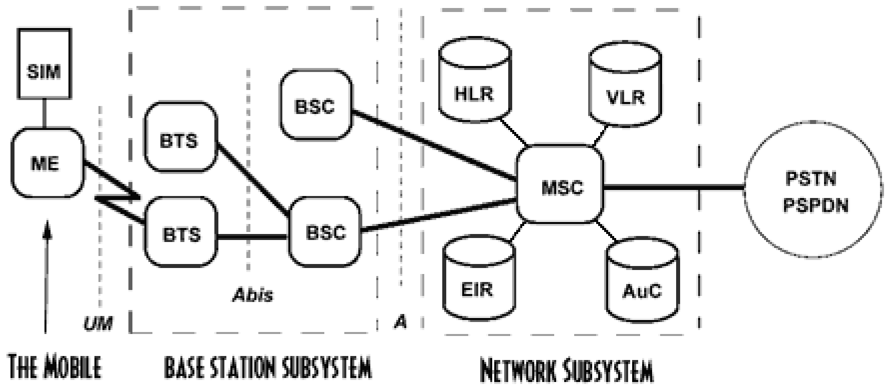
GSM Services

- GSM was designed to do 3 things:
  - 1. Bearer data services: Faxes, text messages, web pages.
    - Basic GSM had a basic data rate that is limited to 9.6 kbps
      - Extended by GMRS and EDGE to around 384 Kbps
  - 2. Voice traffic
    - But, at a lower quality than analog.
  - 3. Other features:
    - Call forwarding, caller id, etc…
      - Meaning, we need to connect to the SS7 network

GSM Architecture

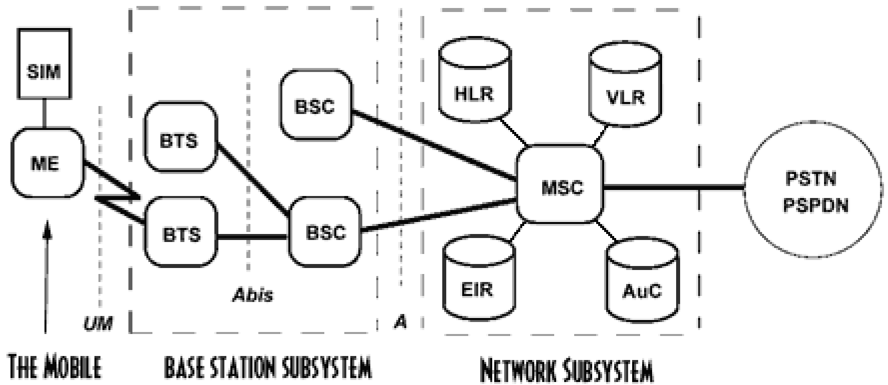
- Very similar to the analog architecture.
- 3 parts:
  - Mobile Phone
    - Digitizes and sends your voice.
  - Cell phone tower / Base Station
    - Controls the radio link.
  - Network switching system
    - The brains in the system.

GSM Architecture



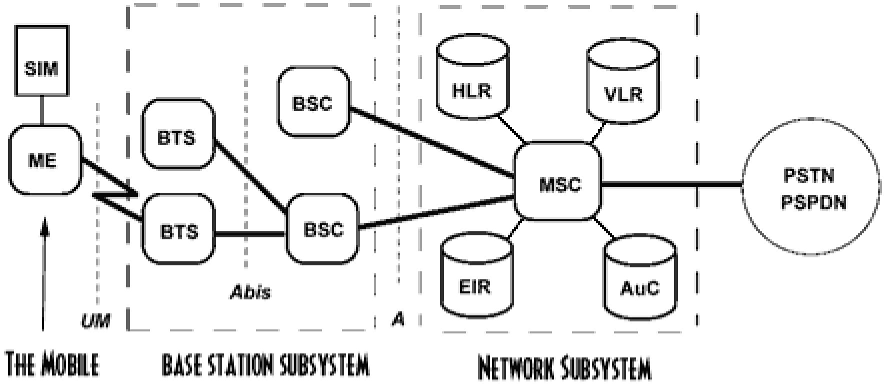
- SIM – Subscriber Identity Module.
  - Allows you to switch phones.
  - Stores your phonebook and ringtones.
- ME – Mobile Equipment.
  - Your cellphone
- UM – User Mobile Frequency
  - The actual radio frequency you are using.

GSM Architecture



Siemens BSC

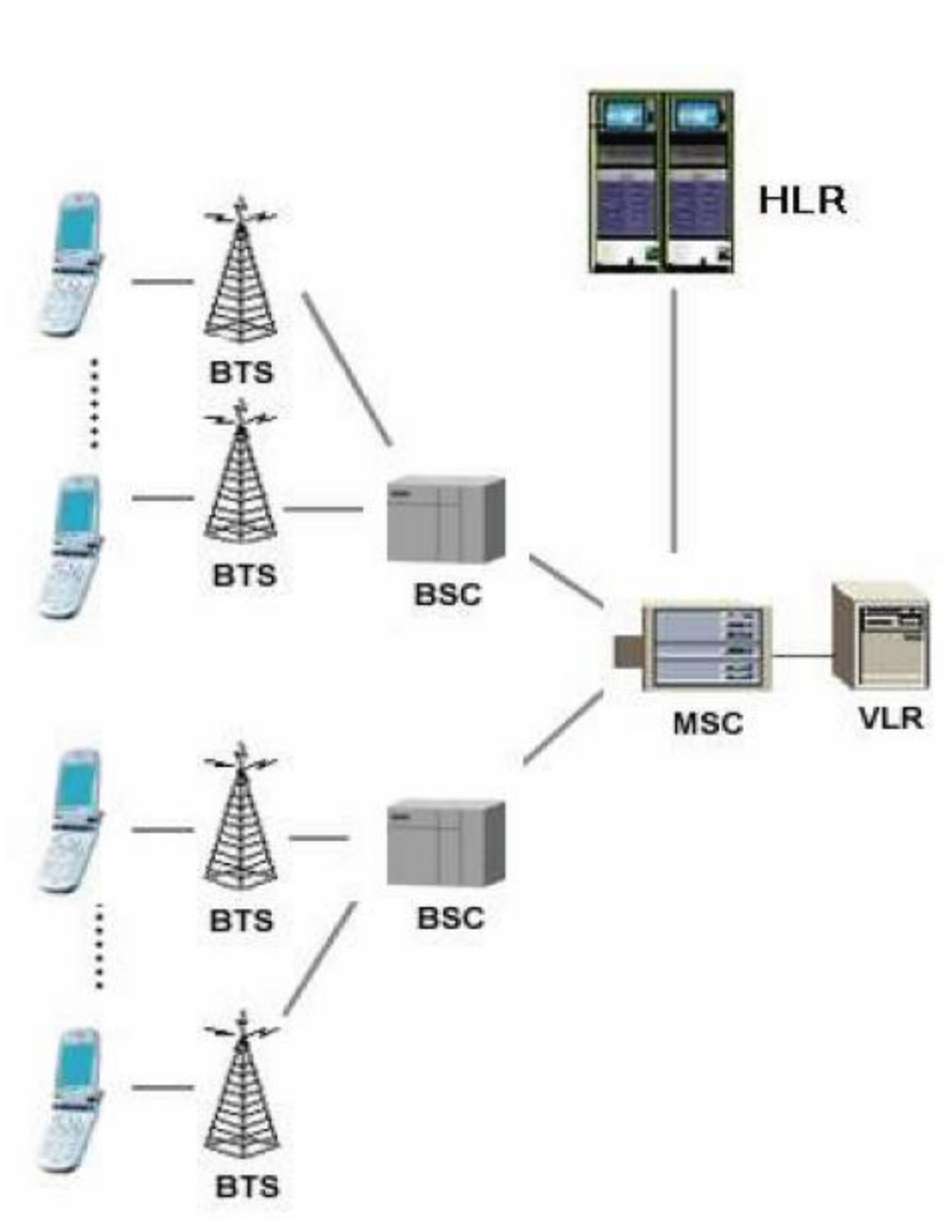
- BTS – Base Transceiver Stations.
  - The radio antennas.
  - In GSM, 1 sends and 1 receives.
    - Only 2 are necessary.
- BSC – Base Station Controller.
  - Packages up all the radio signals and sends them to the switch.
  - Handles handoffs and some other low-level functionality.
  - Manages up to 50 or so radio antennas
    - Provides better network segmentation.
- Abis – Typically a T1 SS7 connection using ISUP



GSM Architecture

- MSC – Mobile Switching Center
  - Has several databases that perform call validation, call routing to the PSTN, and roaming validation.
  - Some of the databases:
    - HLR: Home Location Register
      - Main customer database
      - Motorola only has 60 HLRs in the United States.
    - VLR: Visitor Location Register
      - Works in tandem with the HLR. Roamer database.
    - EIR: Equipment Identity Register
      - Deny stolen mobile phones service. Has all valid serials.
    - AuC: Authentication Center
      - Stores encryption keys necessary for secure communications.

GSM Architecture



Radio Frequencies

- Operates in the 1850 MHz band and from:
  - 1850 to 1910 MHz Mobile to Base
  - 1930 – 1990 MHz Base to Mobile
    - There are 300 forward/reverse channels in this band.
- Each channel is 200 KHz
- GSM uses TDMA to fit 8 conversations on a channel.
- So, technically, GSM is TDMA and FDMA based.

GSM Burst Periods

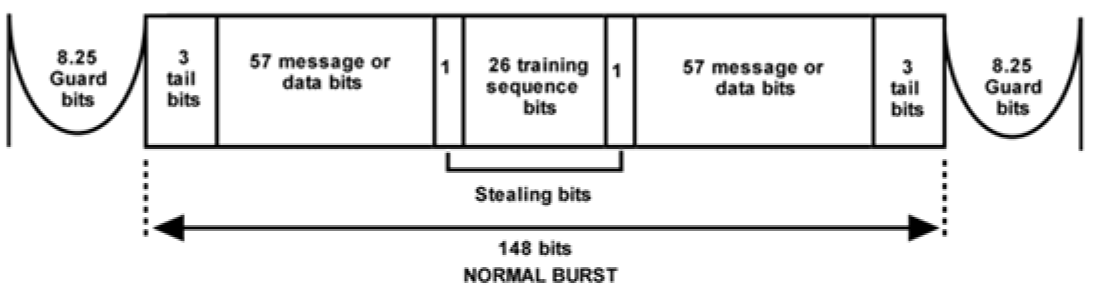
- Since GSM is TDMA based, it uses burst periods to make up a frame.
  - 8 burst periods make up one frame.
  - A burst is like a slot in the train.
  - A burst period is where a phone gets to send digital information.
    - Phones send around 14 bits of information in every burst.
  - However, a burst period only lasts .577 ms.
    - Phones are only bursting information at around 1700 times a second, much less than the 8000 times a second a landline phone samples at.

GSM Frames

- 8 burst periods make 1 frame.
- The frame length in time is 4.615 ms
  - .577 ms times 8
- Each frame carries 164 bits
  - 114 are for voice
  - The rest are for synchronization and CRC checks
- Each frame can carry up to 8 voice samples, or, the frame can be dedicated to other necessary information.

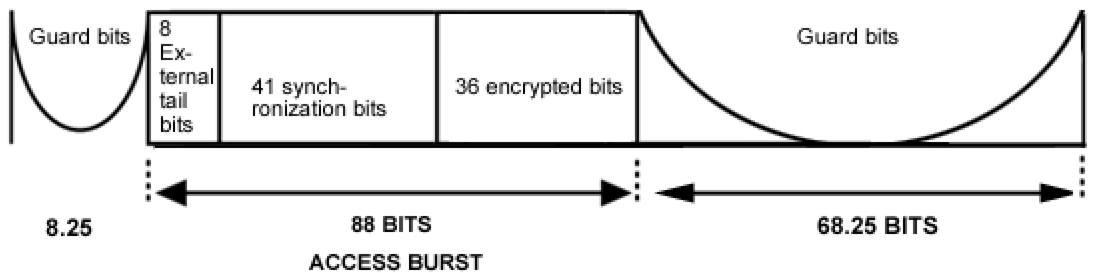
GSM Frames

- Different frames mean different things.
  - For instance, this data structure contains information about the cell site.
    - The cell phone scans for this information when it is turned on.



GSM Frames

- This is the burst that occurs when the mobile transmits its access key back to the base station.



Speech Coding

- GSM uses LPC – Linear Predictive Coding.
  - Uses interpolation.
  - Basically, previous samples, which don't change very quickly, are used to predict current samples.
- So, instead of actually sending the voice sample, the delta in the voice sample is sent.
- Also, silence is not transmitted.
  - This increases throughput by about 40%.
  - This bits can be used for other conversations.

Digital Modulation

- Uses Gaussian minimum shift keying.
- Very complex, uses filters, phase shifts, and frequency shifts to actually send out binary digits.

Power Requirements

- Since GSM is purely digital, it requires a lot less power since it doesn't have to transmit an analog wave.
- The maximum output power of a GSM phone is only 2 watts.
  - And this can be notched down by the controlling cell phone tower.
  - The minimum power is only 20 mW.

GSM Call Processing

- Unlike AMPS, the cell tower can transmit on any of its frequencies.
- The cell phone is actually pre-programmed in the SIM card to have a set of radio frequencies that it should check first.
  - When this fails, it needs to search through all frequencies.
- When it detects the tower identifying itself, call processing begins.

SIM Card Secrets

- The SIM card has a secret serial number that is only known by your cellular provider and the SIM card.
  - You, as the customer, do not know the number.
- This secret number acts as a key, and it is 32 bits in length.

Authentication and Security

- GSM uses a challenge/response public key setup.
- The base station sends a random number to the mobile.
  - This acts as the base station's public key.
- The mobile then uses an algorithm called A3 to encrypt it's secret key using the random public key that it was sent by the base station.
  - A5 is a derivative of DES.
    - Several rounds of shifts and XORs.

Authentication and Security

- This encrypted information is then sent back to the base station.
- The base station performs a reverse operation, and checks to see that the mobile sent the correct secret code.
  - If not, it is denied access.
- A3 has proved to be very difficult to break.
  - Though, given a significant amount of time, it can be broken.

Authentication and Security

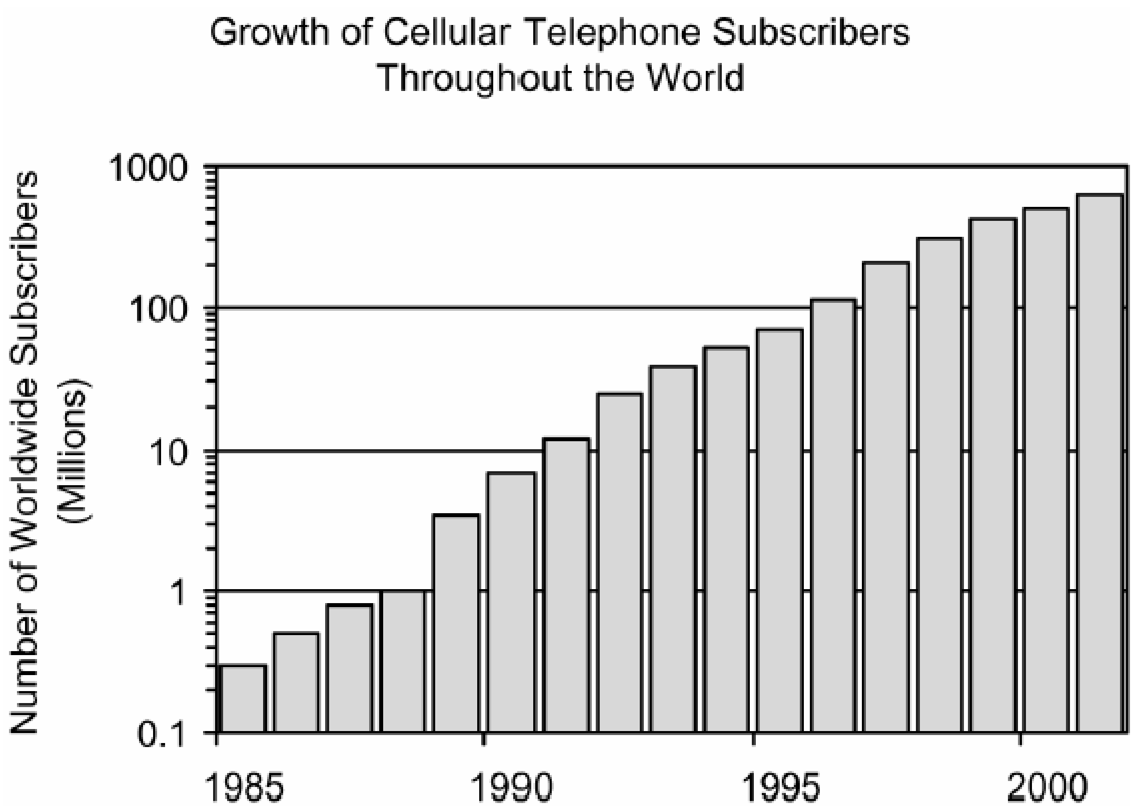
- GSM also uses another database for security.
- This database maintains a list of stolen cell phones, and cell phones that have technical errors.
  - These are also not allowed access to the digital network.

GSM conclusion

- Widely used.
  - Upwards of 70% of phones.
- Uses SIM cards so customers can use any phone and for security.
- Allows more customers than analog.
- Worse voice quality than analog.
- Purely digital.
- Open source, very complex standard.
- Uses TDMA.
- Will be replaced by CDMA in the near future.

CDMA Digital Cellular Standard (IS95) Introduction

- Cellular subscription rates
  - Beyond expectations – note that the below y-axis is on a log scale.



- Many countries see 40% increase per year.
- Projected to reach 2 billion subscribers worldwide by 2006 (30% of world's population).

- Wireless communication is robust.
  - Viable voice transport mechanism
  - Viable data transport mechanism
    - High speed data communications in addition to voice calls.
  - Fixed wireless
    - To replace fiber optic or copper lines between two points.
  - Inside buildings and homes
    - Wireless local area networks (WLANs) to connect between computers.
    - Bluetooth to connect between devices and peripherals.

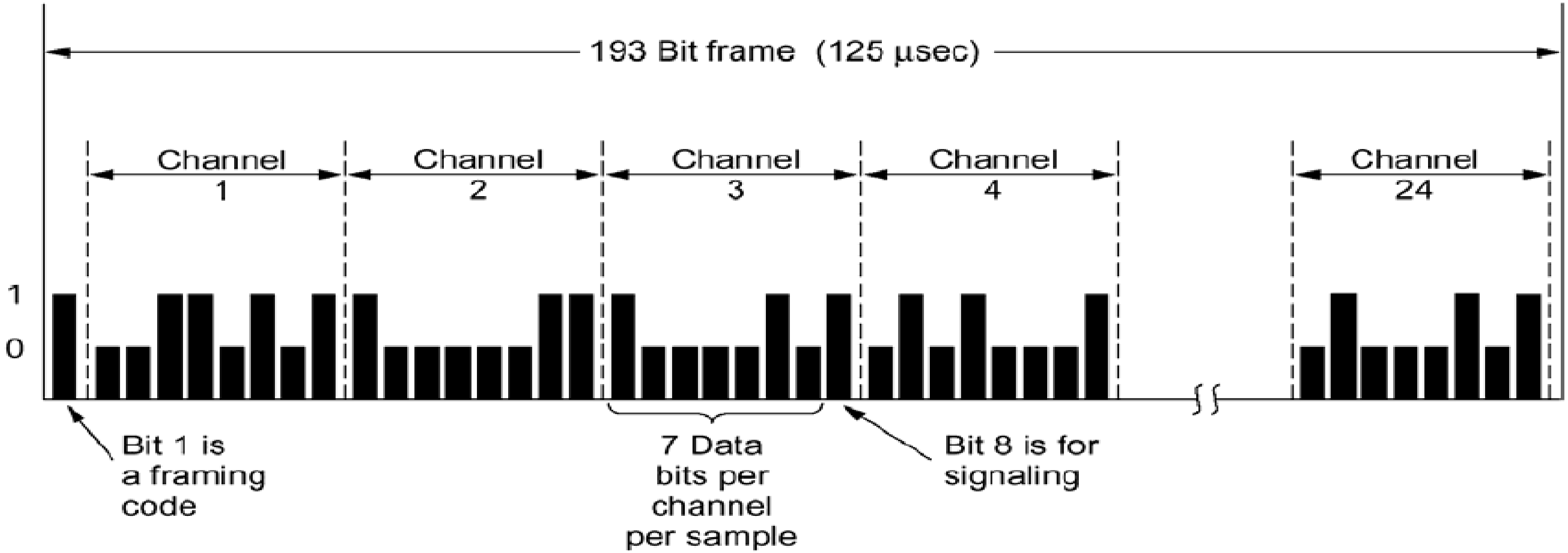
- Possible competition area: Inside buildings
  1. WLANs and Bluetooth
  2. Cellular Carriers

- What ideas do you have of using the benefits of both approaches? Then there would not need to be a choice of one or the other.

II. Second Generation (2G) Cellular Networks

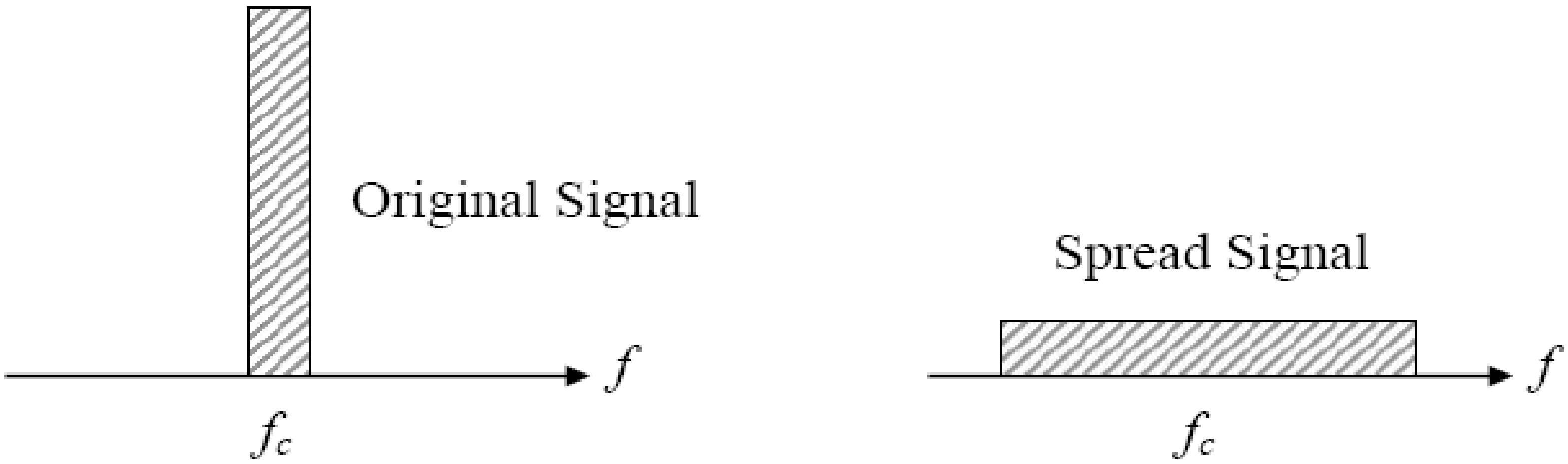
- First Generation
  - Analog
  - Frequency Division Multiple Access (FDMA)
    - Multiple users are provided access to a system by dividing the spectrum up into frequency bands.
    - Different users use different frequency bands.
  - AMPS standard.
    - 30 kHz voice channels

- Second Generation
  - Digital modulation
  - TDMA/FDD or CDMA/FDD
    - Time Division Multiple Access (TDMA) – 3 popular standards use this.
      - Signal is digitized.
      - Users occupy different time slots.
      - Example from wired telephone: Each user needs to send an 8-bit block of digitized voice every 125 microseconds (8000 times per second).
        - ➢ Requirement is for 64 kbps.
        - ➢ One type of channel can support a data rate of 1.544 Mbps (a "T1" telephone circuit).



- So 24*64kbps = 1.536 Mbps, which means 24 users can be supported (with a little bit of bandwidth used for the framing bit).
- As seen in figure above, each user takes a turn each 125 microseconds to send a burst of 8 bits.

- Code Division Multiple Access (CDMA) – one main standard uses this.
  - Instead of using a different time slot or frequency to differentiate users, CDMA uses a different code.
  - These codes are used for *Spread Spectrum Modulation*.
  - The Tx multiplies the signal with a special code and then the signal is transmitted. This expands (spreads) signal BW **many** times. Then the signal is multiplied at the Rx with the same code.
  - This then collapses (despreads) the signal back to its original signal BW.
    - Other signals created with other codes just appear at the Rx as random noise.



- Advantages
  - Resistant to narrowband interference - can only reasonably try to affect part of the signal.
  - Allows multiple users with different codes to share same range of frequencies.
  - The system can operate effectively at lower Signal-to-Noise ratios, so more users can be supported than for a non-CDMA system.

- Signal spreading done by using a pseudo-noise (PN) code or sequence
  - Pseudo-noise means it looks like noise to all except those who know how to recreate the sequence.
  - Others cannot decode the signal
  - They cannot even recognize the signal because it just looks like noise

- Two types of SSM

1) Direct Sequence (DS)

- Multiply baseband data by a high rate signal created with the PN code.
- New signal has much higher rate.
- This spreads the baseband spectrum over a wide range of frequencies.

2) Frequency Hopping (FH)

- Randomly change channel frequency with time, following the PN code.
- Spread the frequency values that are used over a wide range.
- In effect, this signal stays narrowband but moves around a lot to use a wide band of frequencies over time.

- TDMA/FDD versus CDMA/FDD
  - Use TDMA or CDMA to separate users
  - Use different frequencies for forward and reverse voice channels (FDD).

- 4 popular standards for 2G
  1. Global System for Mobile (GSM)
     - Eight time-slotted users for each 200 kHz radio channel.
     - Deployed widely in Europe, Asia, Australia, South America, and some parts of the U.S. in the PCS band of spectrum.
     - GSM uses SIM (Subscriber Identity Module) cards that can be transferred from phone-to-phone. Phones for other types of technologies must be programmed.
     - T-Mobile, AT&T, and Cingular in the U.S.

2. Interim Standard 136 (IS-136)
   - Also called North American Digital Cellular (NADC)
   - Three time-slotted users per 30 kHz channel
   - Popular in North America, South America, and Australia.
   - Cingular and AT&T in the U.S. Both companies have larger areas for their TDMA networks

3. Pacific Digital Cellular (PDC)

- Japanese standard
- Similar to IS-136

4. Interim Standard 95 (IS-95)

- CDMA
- Also known as cdmaOne
- 64 users in a 1.25 MHz channel.
- Can be used in 800 MHz and 1900 MHz bands.
- Sprint and Verizon in the U.S.

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) 1850-1910 MHz (US PCS)	890-915 MHz (Europe) 1850-1910 MHz (US PCS)	800 MHz, 1500 MHz (Japan) 1850-1910 MHz (US PCS)
Downlink Frequencies	869-894 MHz (US Cellular) 1930-1990 MHz (US PCS)	935-960 MHz (Europe) 1930-1990 MHz (US PCS)	869-894 MHz (US Cellular) 1930-1990 MHz (US PCS) 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) (25 kHz for PDC)
Channel Data Rate	1.2288 Mchips/sec	270.833 kbps	48.6 kbps (IS-136) (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

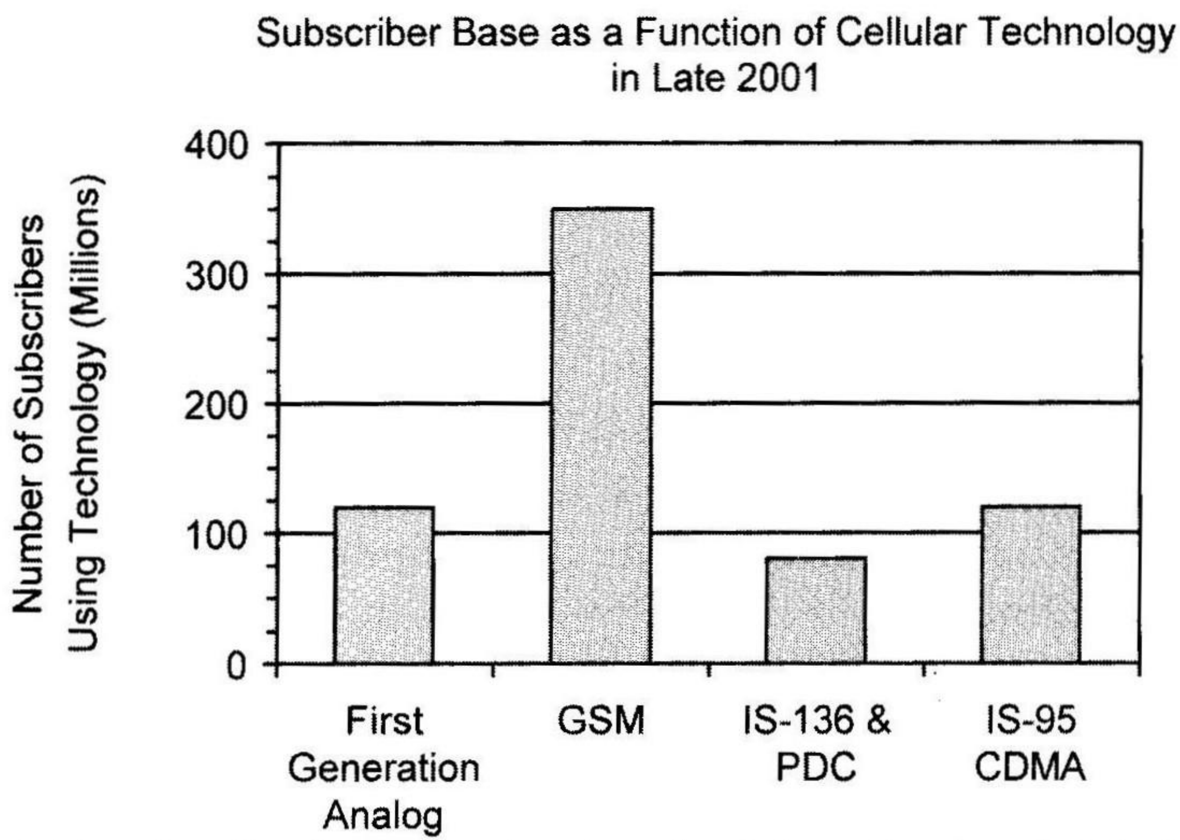


Figure 2.2 Worldwide subscriber base as a function of cellular technology in late 2001.

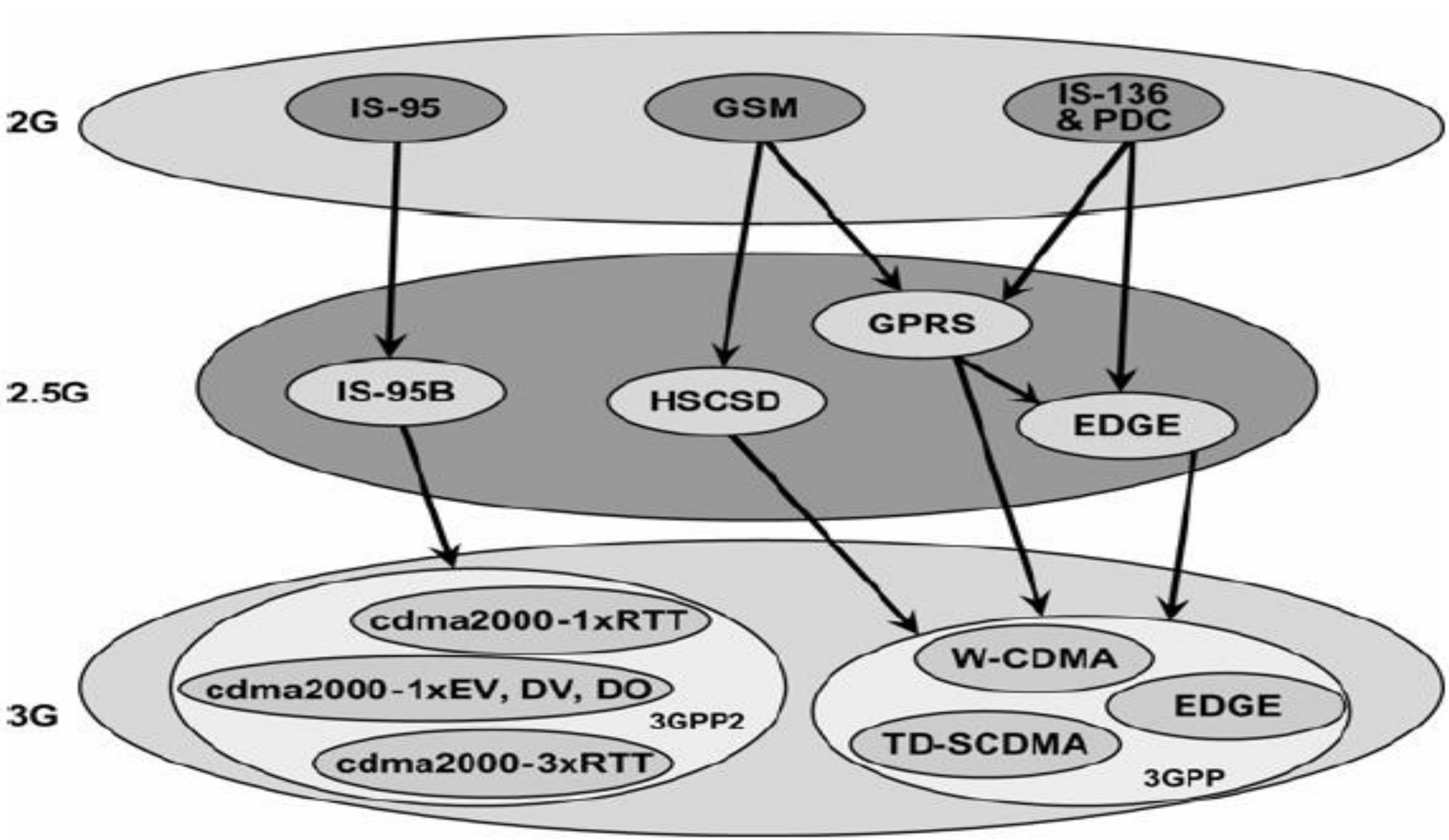
III. Evolution to 2.5G

- 2G Data Transmission Capabilities
  - 2G transmits data over voice circuits
    - Just like a modem
    - Data is sent in place of voice over the same channel bandwidth, just like voice coding rates in the table above.
    - Capabilities around 10 kbps.
  - Applications possible
    - Limited Internet Browsing
    - Short messaging
      - Short messaging service (SMS) in GSM.
      - Can send a short message to another subscriber's phone.
      - Popular in Europe and Japan.

- New standards for data over 2G
  - Called 2.5G technology
  - Allows existing 2G equipment to be modified for higher data-rate transmissions.
  - More advanced applications are possible.
    - Web browsing
      - Wireless Application Protocol (WAP) that allows standard web pages to be viewed in a compressed format.
    - E-mail
    - Mobile commerce
    - Location-based services (maps, directions, etc.)

- Japan: First country to have a successful widespread mobile data service.
  - From NTT DoCoMo
  - I-mode
    - Proprietary data service
    - Games
    - Color graphics
    - Interactive web page browsing at 9.6 kbps.
    - Surprisingly popular: 25 million subscribers

- Upgrade Path
  - A 2.5G technology must match an upgrade path from the 2G technology that is in place.
  - Same air interface
    - Do not want to require wholesale RF equipment changes at the base stations.
  - Only require upgrades to software.
  - Plus addition of more equipment to work with base station equipment.


2G
IS-95
GSM
IS-136
& PDC
2.5G
IS-95B
HSCSD
GPRS
EDGE
3G
cdma2000-1xRTT
cdma2000-1xEV, DV, DO
3GPP2
cdma2000-3xRTT
W-CDMA
EDGE
TD-SCDMA
3GPP

- TDMA upgrades
  - Three upgrade paths for GSM
  - Two are also upgrades for IS-136.

  1. High Speed Circuit Switched Data (HSCSD) for GSM
     - Allows subscriber to use consecutive time slots in TDMA.
     - Up to 57.6 kpbs
       - Four 14.4 kbps channels.
     - Ideal for "voice-like" services.
       - Since it still uses voice channel capabilities.
       - Streaming voice or low quality video
       - Interactive web sessions.
     - Only requires a software change at GSM base stations.

2. Generalized Packet Radio Service (GPRS) for GSM and IS-136

- Good for data applications
  - E-mail, faxes, web browsing
- Sets aside groups of TDMA channels as shared data channels.
- Assumes users download much more than they upload.
  - Slower data rate upload than download

- Shares individual radio channels and time slots.
  - All data is sent as packets.
  - Can support many more users, since user traffic is usually bursty.
    - Users transmit in short bursts and then are idle.
- Completely redefined air interface to handle packet data.
- GPRS units tune into GPRS radio channels and are "always on" to send data at any time.

- If all 8 time slots are taken by one user, can achieve 171.2 kbps.
  - 8 times 21.4 kbps (rate with error coding)
  - Applications must provide their own error correction bits.
    - Add additional bits (like CRC codes) to be able to detect errors.
    - As part of the carried data payload in GPRS.
  - Also cannot achieve 171.2 kbps when other users are also sending data, since users share the channel.

- Upgrade requirements
  - Need connections of base stations into a data network through routers and Internet gateways.
    - New software in base station.
    - No change to RF hardware.
  - Originally designed for GSM but upgraded to also support IS-136.

3. Enhanced Data Rates for GSM Evolution (EDGE) for GSM and IS-136

- More advanced upgrade to GSM than GPRS.
  - Additional new hardware and software at base stations.
  - Supports a technology path to 3G.
  - Uses new modulation schemes (8-PSK) that is used in addition to GSM’s standard (GMSK).
- Adaptive modulation uses the best modulation for instantaneous conditions of the network.

- Much higher data rates – from the new modulation schemes and the adaptation.
  - Practical raw data rates up to 384 kbps.
    - For a single user taking a full 200 kHz GSM channel.
  - Can achieve several megabits per second by using multiple GSM channels.
- Although your textbook considers this a 2.5G service, some service providers call EDGE 3G.
  - Carriers who offer this service (for example, Cingular/AT&T) say it offers rates up to 135 kbps.

- Upgrade path from IS-95A to IS-95B for 2.5G CDMA
  - Only one upgrade path for IS-95
  - Users can use up to 8 CDMA codes simultaneously.
    - 14.4 kpbs * 8 = 115.2 kbps
    - Practical throughput is 64 kbps that can actually be achieved.
  - Also changes the method of handoff between base stations.

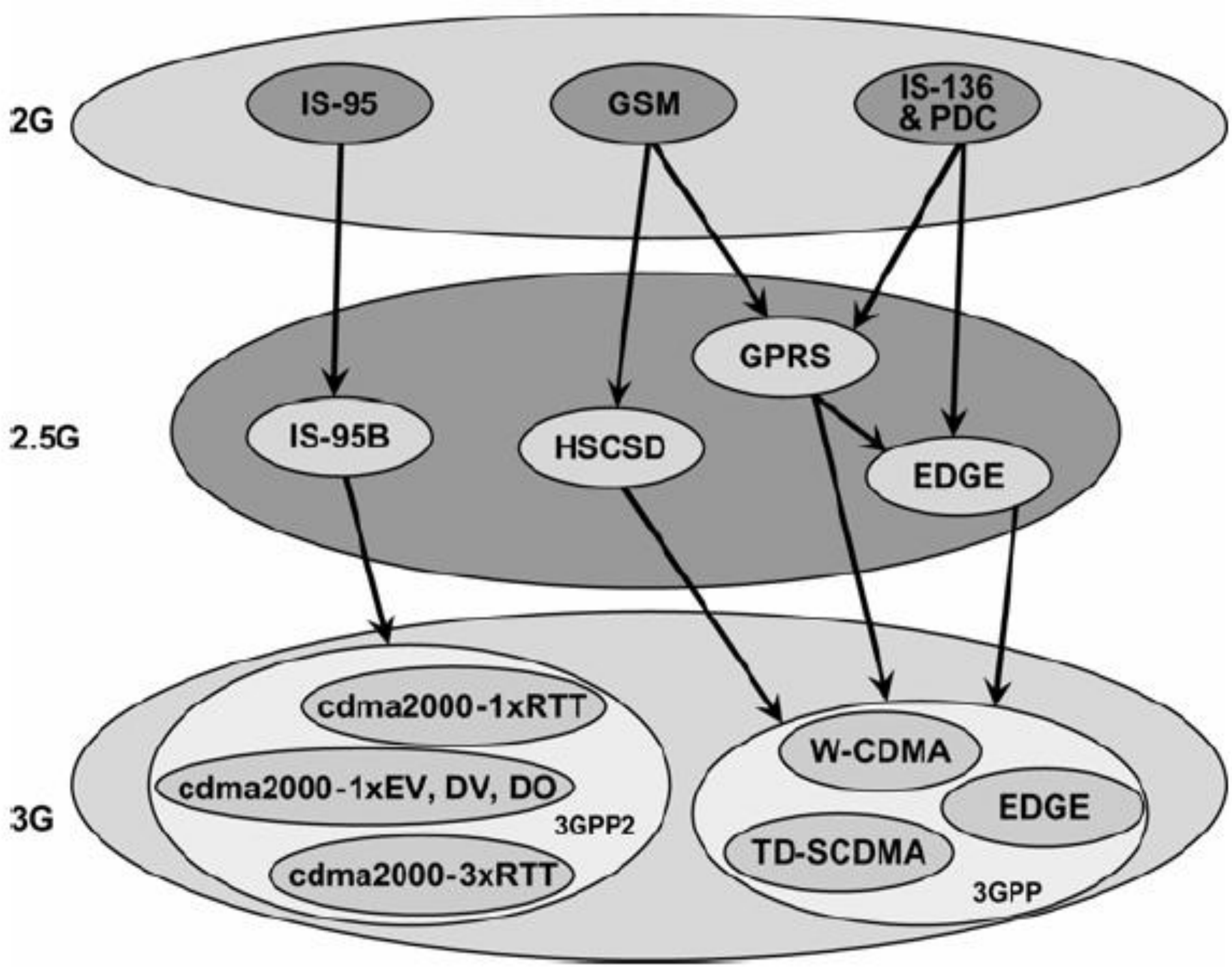
- What summarizes the difference between 2G and 2.5G?

V. Third Generation (3G) Wireless Networks

- Unparalleled new capabilities
  - Multi-megabit Internet access
  - Voice communication over Internet protocols
  - Voice-activated calls
  - "Always on" access
  - Receiving live music
  - Videoconferencing
  - Virtual home entertainment
  - Broadcasting
  - Games
  - Interactive video

- For which of these applications do you believe a great market exists and why?

- New spectrum allocations are being considered for 3G.
- Two major competing camps
  - Based on what 2G technology is used already by each camp.
  - From GSM/IS-136/PDC (by the 3G Partnership Project for **Wideband CDMA – 3GPP**) versus coming from IS-95/IS-95B (by the 3G Partnership Project for **cdma2000 – 3GPP2**).
  - Recall the following figure.


2G
IS-95
GSM
IS-136
& PDC
2.5G
GPRS
IS-95B
HSCSD
EDGE
3G
cdma2000-1xRTT
cdma2000-1xEV, DV, DO
3GPP2
cdma2000-3xRTT
W-CDMA
EDGE
TD-SCDMA
3GPP

1. Wideband-CDMA (W-CDMA) or the Universal Mobile Telecommunications System (UMTS)
   - From GSM/IS-136/PDC.
   - Evolved since 1996.
   - From European Telecommunications Standards Institute (ETSI)
   - Backwards compatible with GSM, IS-136, PDC, HSCSD, GPRS, and EDGE
     - Equipment for the previous technologies will work in UMTS.
     - Network structure same as GSM.

- Up to 2.048 Mbps per user.
  - If user is stationary.
  - Up to 8 Mbps in the future.
- Needs a minimum spectrum allocation of 5 MHz
  - Instead of 200 kHz for GSM
  - Requires complete change of RF equipment at each base station.
  - 6 times more efficient use of spectrum than GSM
  - Uses CDMA

2. cdma2000

- From IS-95/IS-95B
- Works within original 2G CDMA channel bandwidth of 1.25 MHz.
- Allows wireless carriers to introduce 3G in a gradual manner.
  - Can introduce 3G capabilities at each cell
  - Do not have to change out entire base stations
  - Do not have to use different spectrum.

- First air interface: cdma2000 1xRTT
  - 1X = one times the original IS-95 (cdmaOne) channel bandwidth.
  - RTT = Radio Transmission Technology
  - Commonly just referred to as cdma2000 1X.
  - Instantaneous data rate of 307 kbps.
    - Typical rates up to 144 kbps
    - Depends on number of users.
    - Depends on velocity of the user.
    - Depends on the propagation conditions.
  - Uses rapidly adjusting rates.
  - No additional RF equipment is needed.
    - All changes made in software or with additional hardware.

- cdma2000 1xEV
  - EV = Evolutionary enhancement
  - High data rate packet standard overlaid on existing IS-95, IS-95B, and cdma2000 networks.
  - 1xEV-DO
    - Data only channel
    - Restricts a shared 1.25 MHz channel strictly to data users.
    - Supports greater than 2.4 Mbps throughput per user.
    - Actual data rates usually much lower.
    - Typical: Several hundred kbps.
    - Highly dependent on number of users, propagation conditions, and velocity of mobile.

- 1xEV-DV
  - Data and voice channel
  - 144 kbps with twice as many voice channels as IS-95B.
- Verizon advertises its EV-DO as having average speeds ranging from 300 kpbs to 1 Mbps.
  - Verizon and Sprint both offering this service and have the highest rates in the industry
  - Highly dependent on number of users, propagation conditions, and velocity of mobile.

- Ultimate 3G CDMA
  - Multicarrier 3x and beyond.
  - 3xRTT uses three adjacent 1.25 MHz channels.
  - Three channels can be operated simultaneously in parallel.

- What summarizes the differences in 2.5G and 3G?

VI. Wireless Local Loop (WLL)

- Rapid growth of demand for Internet connectivity
  - Can use wireless connections where there is inadequate telecommunications infrastructure.
    - Particularly in developing nations.
    - Inexpensive
    - Rapidly deployable
  - One broadband Internet connection could handle all needs for a home or office.
    - Voice, data, cable, Internet, etc.
  - Local loop
    - Old telephone term for a loop of copper to connect a telephone to a telephone central office.
    - Now used to mean a "last-mile" connection to a home or office.

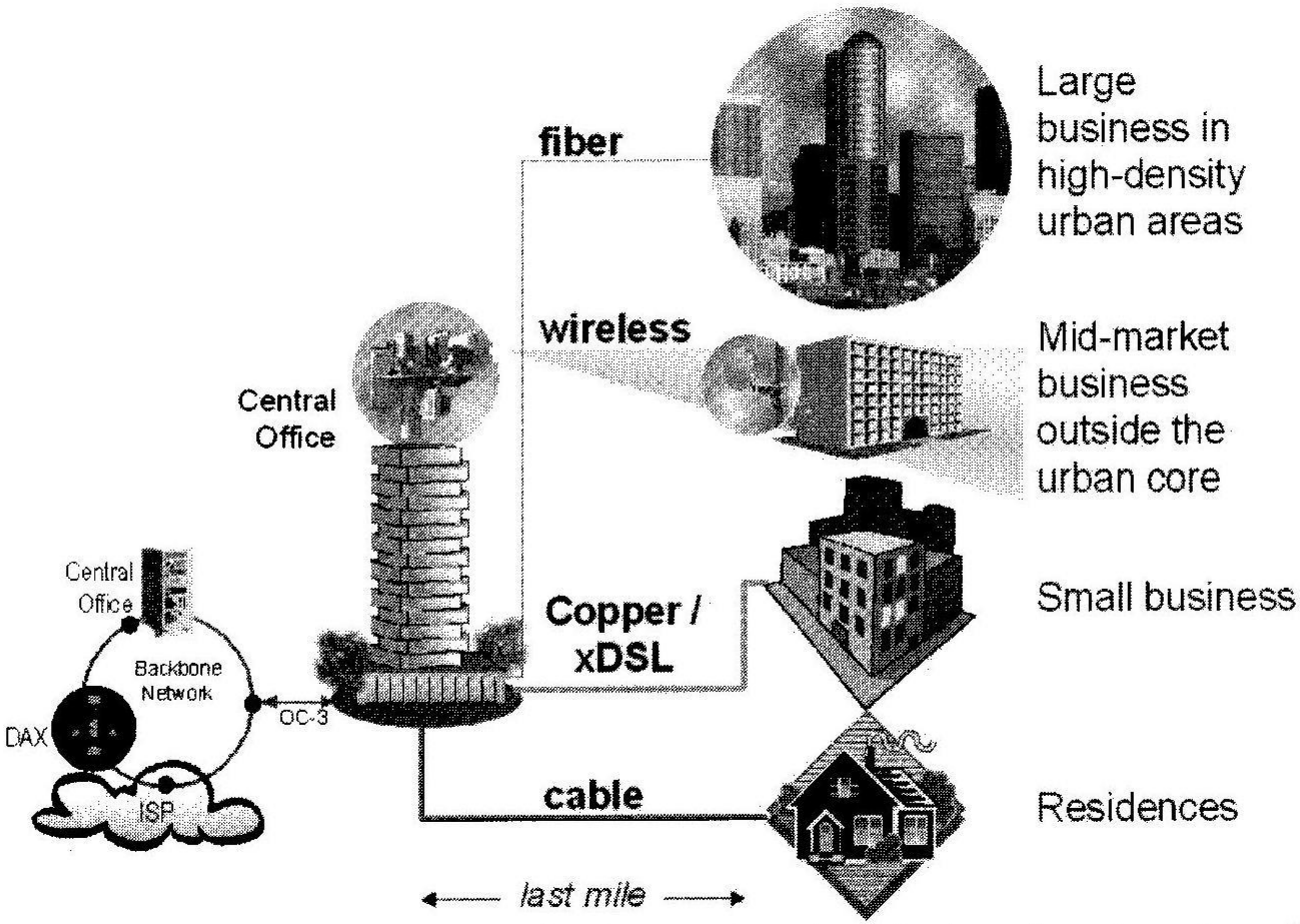


Figure 2.4 Example of the emerging applications and markets for broadband services. (Courtesy of Harris Corporation, ©1999, all rights reserved.)

- Fixed wireless
  - Much more predictable wireless channel.
    - No mobility.
    - Time-invariant
  - Uses high frequencies
    - 28 GHz and higher
    - Allows very high gain directional antennas to be used.
    - Antennas can be of small physical size.
    - Tens or hundreds of megabits per second are possible without distortion.
  - Line-of-sight
    - Much like light.
    - Cannot have any obstructions in between Tx and Rx.
    - Can be affected by weather

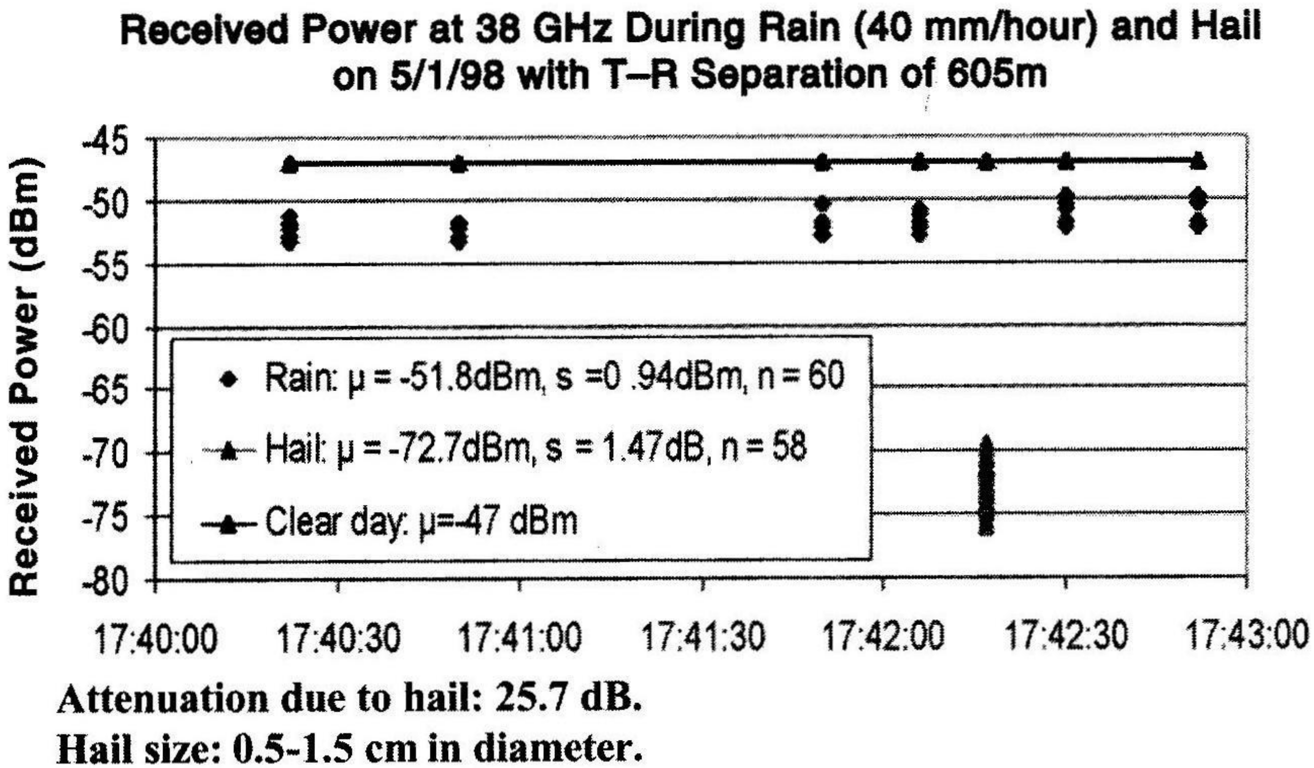


Figure 2.8 Measured received power levels over a 605 m 38 GHz fixed wireless link in clear sky, rain, and hail [from [Xu00], ©IEEE].

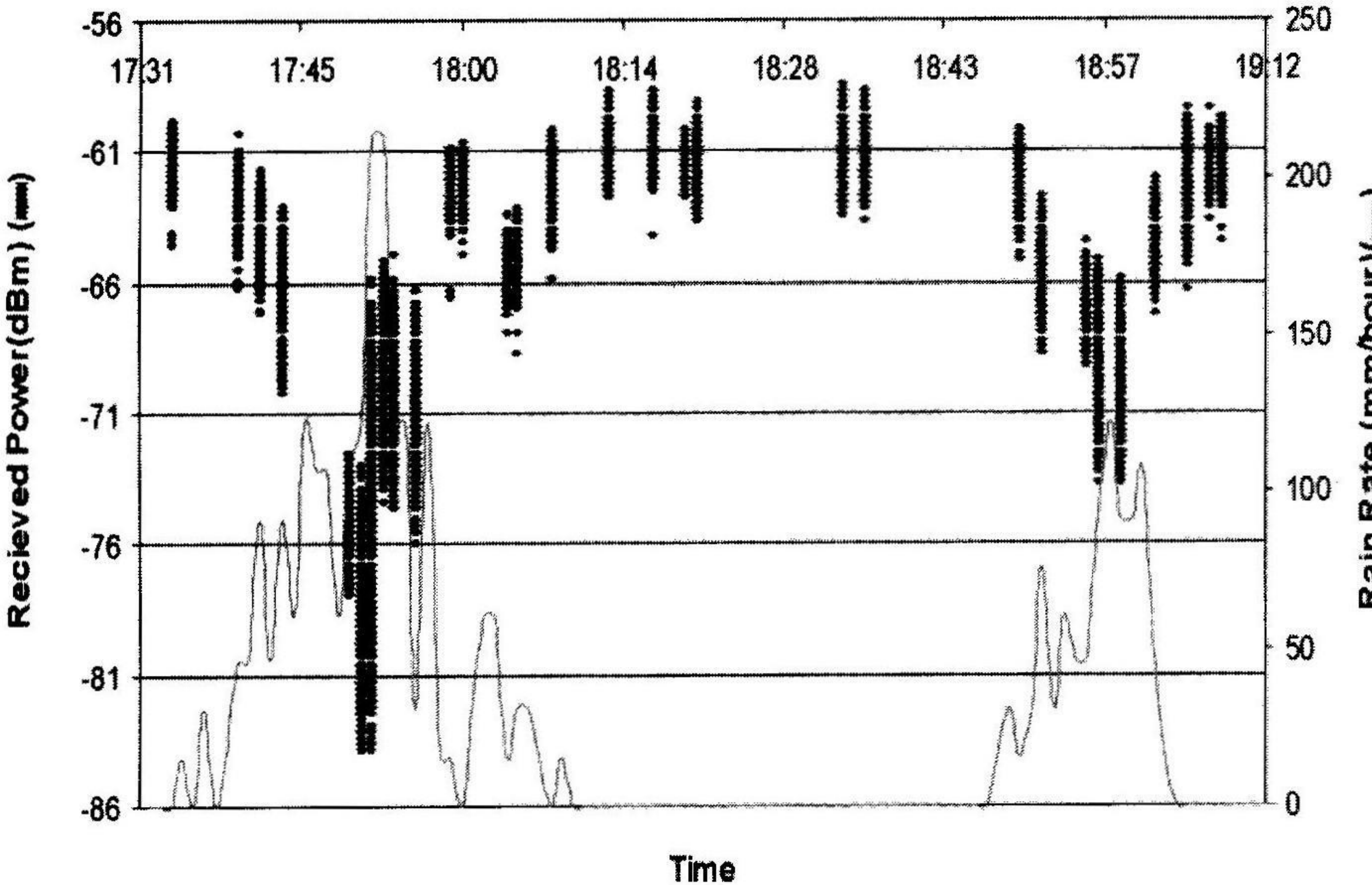


Figure 2.9 Measured received power during rain storm at 38 GHz [from [Xu00], ©IEEE].

- The IEEE 802.16 Standard has recently been developed for WLL
  - Which they call Broadband Wireless Access
  - Also called WirelessMAN for a Wireless Metropolitan Area Network.
  - WiMax 802.16e – Mobility for Data
    - can create city-wide networks, incomparison with WLAN's with ranges of only 100 meters.
  - See http://grouper.ieee.org/groups/802/16/index.html

VII. Wireless Local Area Networks (WLANs)

- Local Area Networks on the order of 100 meters or less in diameter.
- Use unlicensed spectrum
  - So owner does not need a license to set up a WLAN.
  - Unlicensed use has been encouraged through lots of spectrum allocation at several frequency levels .
  - ISM band- 902-928 MHz, 2.4-2.4835 GHz, 5.725-5.825 GHz

- IEEE 802.11
  - Predominant standard in the U.S.
  - Uses CDMA
  - 802.11 – 2 Mbps in 2.4 GHz band
  - 802.11b – 11 Mbps, 5.5 Mbps, in addition to 2 Mbps in 2.4 GHz band
    - Named Wi-Fi by the Wireless Ethernet Compatibility Alliance (www.wi-fi.com)
    - Goal is to promote interoperability between vendors (interoperability between one vendor's wireless card and a different vendor's wireless access point).

- 802.11a – 54 Mbps in 5 GHz band with much shorter range (only about 1/3 the range of 802.11b).
  - Use OFDM
- 802.11g – 54 Mbps at 2.4 GHz
  - Called “Further Higher Data Rate Extension in the 2.4 GHz Band”.
  - Uses OFDM (Orthogonal Frequency Division Multiplexing) to achieve much higher rates.
  - Equipment is less expensive to produce for 2.4 GHz.
  - Much WLAN equipment is now being sold for 802.11g.

- 802.11n – Just started considering proposals for much higher data rates.
  - 802.11b and 802.11g only actually achieve ½ of their raw data rates.
  - Goals are in excess of 100 Mbps.
  - Uses Multiple Input-Multiple Output (MIMO) technology (more than one TX antenna, more than one RX antenna)
  - MIMO Makes use of the concept of diversity (studied later in the semester) to overcome propagation impairments.

  - And 802.11i is addressing an important non-radio issue - security.
  - Also 802.11e (quality of service), 802.11f (roaming) and 802.11x (security keys)!

- HIPERLAN
  - High Performance Radio Local Area Network
  - European standard
  - Current standard: Up to 20 Mbps
  - HIPERLAN/2: Up to 54 Mbps

- Standards might eventually converge to one WLAN standard, or 802.11 may just win.
- WLAN performance depends heavily on how well the WLAN is installed.
  - Needs good placement of equipment.
  - Author discusses tools for easy and effective installation based on a building floor plan.

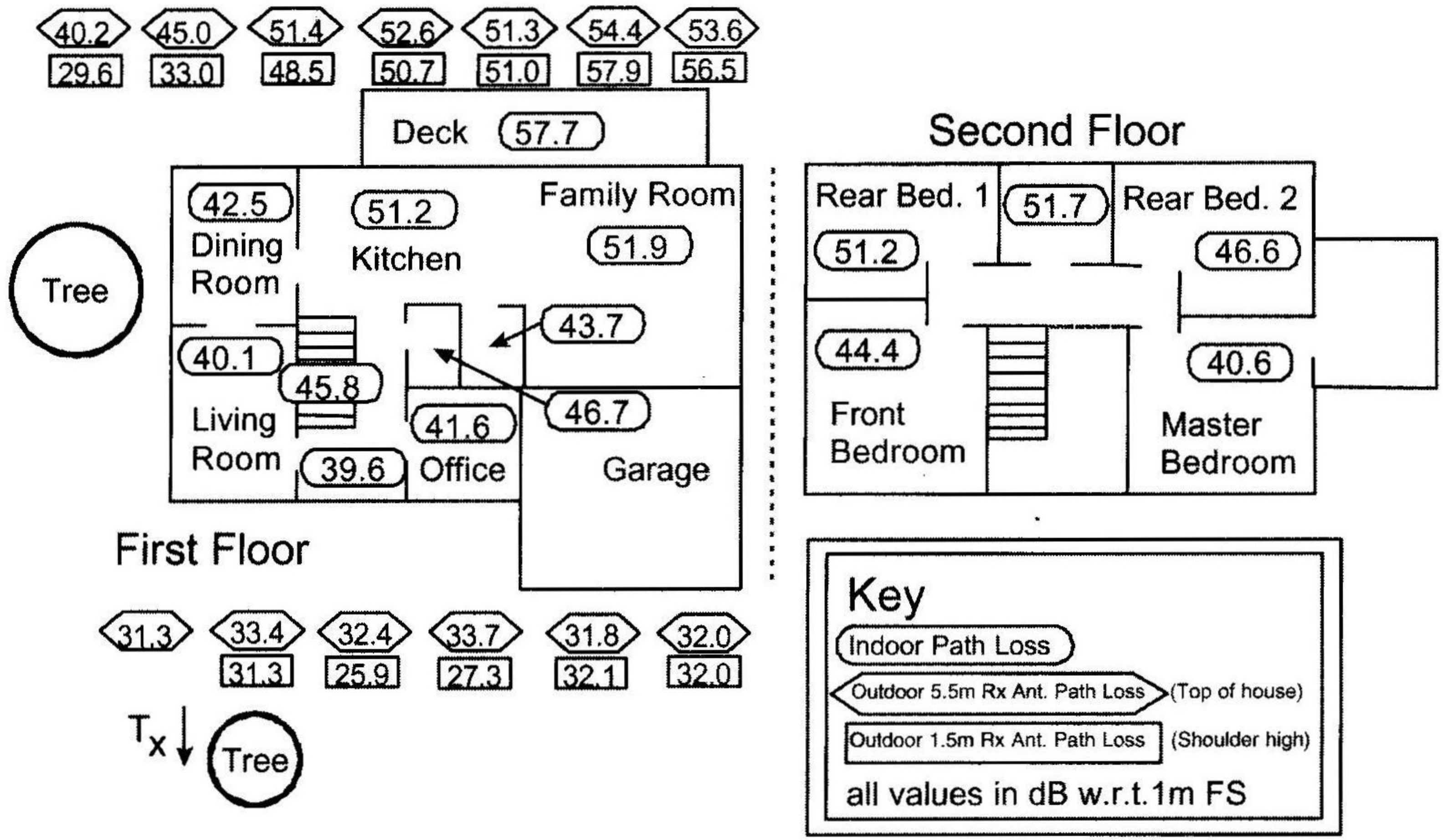


Figure 2.16 Measured values of path loss using a street-mounted lamp-post transmitter at 5.8 GHz, for various types of customer premise antenna [from [Dur98], ©IEEE].

VIII. Bluetooth and Personal Area Networks (PANs)

- Removing the Wire
  - Ability to replace cumbersome cords
    - Printer cables
    - Headphone cables
    - Mouse cables
  - Ability to move equipment throughout an office.
- Bluetooth
  - Open standard
  - Embraced by over 1,000 manufacturers.
  - Uses an **Ad-hoc network approach**
    - Important concept in wireless communication.
      - Seen in WLANs, military applications, etc.

- In "ad hoc networks" devices talk to whatever other devices they can talk to.
  - “Ad hoc” - Formed for or concerned with one specific purpose (usually also considered temporary).
  - Networks of devices that are all peers and talk to whoever is near enough.
  - As devices move, they change their connections with other devices.

  - Why would Bluetooth want to use an ad-hoc approach?

- May have to send data through a sequence of neighbors to reach and end destination.
  - No "base station" concept.
  - Ad hoc networking is a very popular research topic – ad hoc routing, quality of service, sensor networks, power management, etc.
- Bluetooth is named after King Harold Bluetooth, the 10th century Viking who united Denmark and Norway.
  - Goal is to unify the connectivity chores of appliances.

- Within 10 meter range.
- Uses 2.4 GHz ISM unlicensed band
- Uses frequency hopping spread spectrum (1600hops/sec).
- Symbol rate 1Mbps using GFSK modulation

- Wearable computers
  - New opportunities for computers that are worn.
  - PDAs, cell phones, smart cards, position location devices all could be wireless.
    - In a Personal Area Network (PAN)

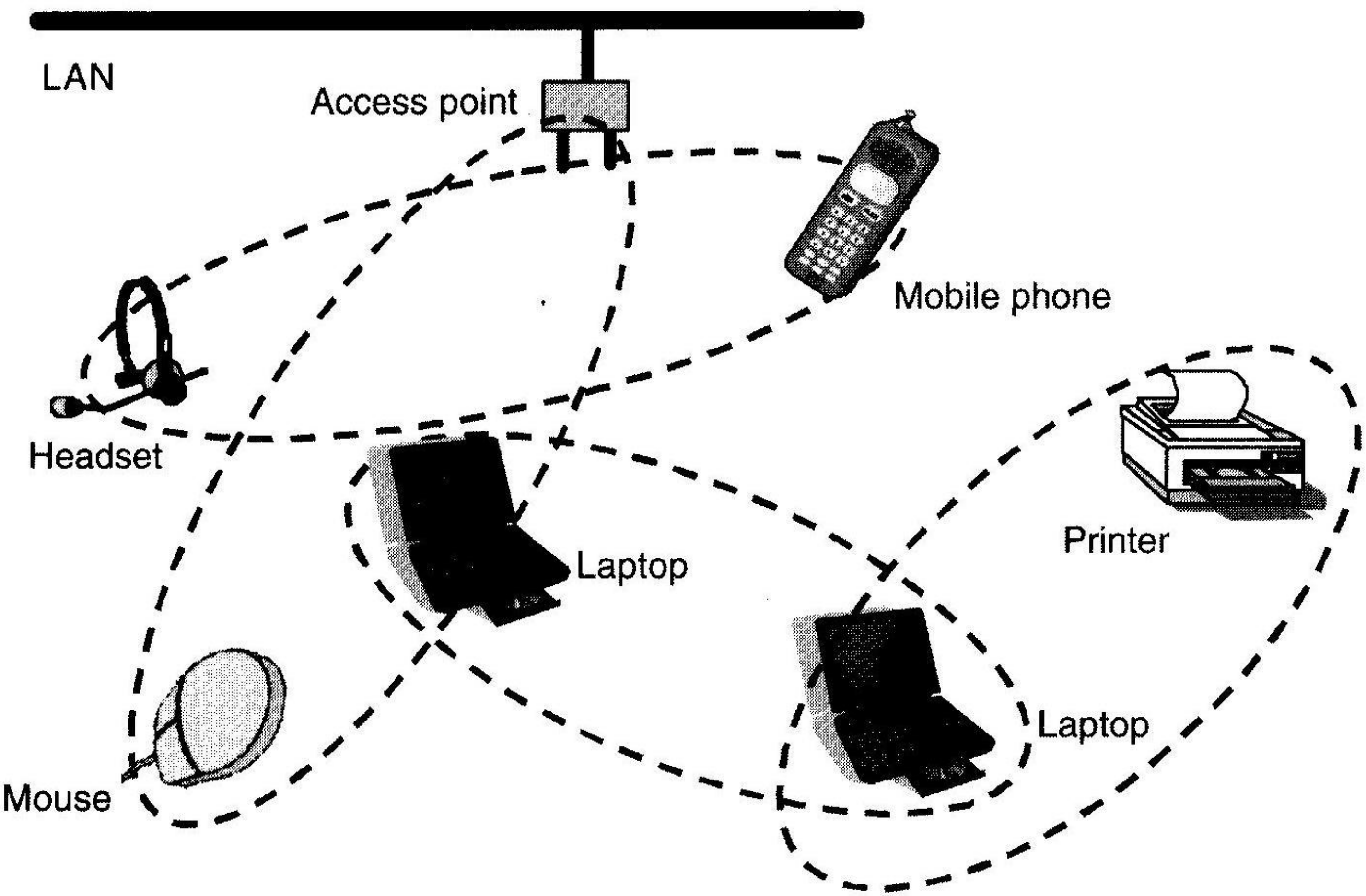


Figure 2.17 Example of a Personal Area Network (PAN) as provided by the Bluetooth standard.

CDMA FORWARD AND REVERSE CHANNELS

Forward Channels

- The Forward CDMA channel is the cell-to-mobile direction of communication or the downlink path.
- It consists of: Pilot Channel is a reference channel which the mobile station uses for acquisition, timing and as a phase reference for coherent demodulation.
- It is transmitted at all times by each base station on each active CDMA frequency. Each mobile station tracks this signal continuously.
- Sync Channel carries a single, repeating message that conveys the timing and system configuration information to the mobile station in the CDMA system.
- Paging Channels' primary purpose is to send out pages, that is, notifications of incoming calls, to the mobile stations.
- The base station uses them to transmit system overhead information and mobile station- specific messages.
- Forward Traffic Channels are code channels used to assign call (usually voice) and signaling traffic to individual users.

Reverse Channels

- The Reverse CDMA channel is the mobile-to-cell direction of communication or the uplink path.
- Access Channels are used by mobile stations to initiate communication with the base station or to respond to Paging Channel messages.
- The Access Channel is used for short signaling message exchanges such as call originations, responses to pages, and registrations.
- Reverse Traffic Channels are used by individual users during their actual calls to transmit traffic from a single mobile station to one or more base stations.