Introduction to Mobil/Wireless Communication

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Radio Communication Frequency Bands

• Non Line-of-sight frequency bands
  – VLF - 3 KHz - 30 KHz for long range radio navigation
  – LF - 30 KHz - 300 KHz for long range radio navigation
  – MF - 300 KHz - 3 MHz with 535 KHz to 1.605 MHz for AM radio
  – HF - 3 MHz - 30 MHz with CB radio close to 30 MHz band

• Line-of-sight frequency bands
  – VHF - 30 MHz - 300 MHz with many signal bands
  – UHF - 300 MHz - 3 GHz with many signal bands, including Cellular Phone and Personal Communication Service (PCS)
  – SHF - 3 GHz - 30 GHz for microwave, including and Line-of-Sight (LOS) Microwave Communication and Satellite Communication
  – EHF - 30 GHz - 300 GHz for microwave
Uniqueness about Wireless

- Difficult media
  - Interference and noise
  - Quality varies over space and time
- Mobility, especially for cellular technologies
  - Variation in link reliability and availability
  - Want seamless connectivity; mobility vs portability
- Security
  - No physical boundary
  - Overlapping links and networks

Direct Attenuation

1. Means loss of energy to overcome resistance of the medium. The energy loss of an electromagnetic wave is inversely proportionally to the square of the distance, i.e., $e_{loss} \leftrightarrow 1/d^2$
2. Signals blocked by obstructing objects, such as buildings
Indirect Attenuation

- **Multipath effects:**
  - Rapid changes in signal strength over a small area or time interval
  - Random frequency modulation due to varying Doppler shifts on different multipath signals
  - Time dispersion (echoes) caused by multipath propagation delays

- **Delay Spread**
  - Multipath propagation yields signal paths of different paths with different times of arrival at the receiver
  - Spreads/smears the signal, could cause inter-symbol interference, limits maximum symbol rate
  - Typical values (µs): Open < 0.2, Suburban = 0.5, Urban = 3

Attenuation Examples

- **People moving around:**
  - Additional multipath induced attenuation of 10 dB
- **Buildings with few metal and hard partitions:** delay spread of 30 to 60 ns (several mbps w/o equalization)
- **Buildings with metal/open aisles:** delay spread of up to 300 ns (100s kbps w/o equalization)
- **Between floors:**
  - Concrete/steel flooring yields less attenuation than steel plate flooring
  - Metallic tinted windows yield greater attenuation
  - 15 dB for first floor separation, 6 - 10 dB for next four floors, 1 - 2 dB for each additional floor of separation
Line-of-Sight Microwave (continued)

- Provide a comparative broadband connectivity over a single radio link or a series of links
  - Link connects one radio terminal to another or to a repeater site
  - Link can be up to 30 miles long depending on terrain topology
- On conventional LOS microwave links, length of a link is a function of antenna height
  - The higher the antenna, the further the reach
Line-of-Sight Microwave (continued)

• Major advantages over cabling systems
  − Freedom from land acquisition rights
  − Acquisition of rights to lay cabling, repair cabling, and have permanent access to repeater stations is a major cost in cable communications
  − Use of radio links, that require only acquisition of the transmitter/receiver station, removes this requirement
  − Simplify maintenance and repair the link
  − Ease of communication over difficult terrain. Some terrains make cable laying extremely difficult and expensive, even if land acquisition cost is negligible

Line-of-Sight Microwave (continued)

• Major disadvantages over cabling systems
  − Bandwidth allocation is extremely limited. Unlike cabling systems, that can increase bandwidth by laying more cables, the radio frequency (RF) bandwidth allocation is finite and limited
  − Free-space communication results in susceptibility to weather effects, particularly rain
  − Transmission path needs to be clear because of LOS. Care must be taken in the system design to ensure freedom from obstacles
  − Open to RF interference
  − Cost of design, implementation and maintenance of microwave links is high
Satellite Communication (continued)

- Became a possibility when a satellite is orbiting at a distance of 22000 miles above the Earth as a Geostationary Satellite
  - Have an angular orbital velocity equal to the Earth's own orbital velocity, a consequence of Kepler's law that period of rotation $T$ of a satellite around the Earth is given by:
    \[
    T = \frac{2\pi r^{3/2}}{\sqrt[3]{gR^2}}
    \]  \hspace{1cm} (57)

  where $r$ is the orbit radius, $R$ is the Earth's radius and $g = 9.81$ ms$^{-2}$ is the acceleration due to gravity at the Earth's surface
Geostationary Satellites for Global Coverage

In principle, three geostationary satellites correctly placed can provide complete coverage of the Earth's surface.

Satellite Communication Advantages

- The laying and maintenance of intercontinental cable is difficult and expensive.
- The heavy usage of intercontinental traffic makes the satellite commercially attractive.
- Satellites can cover large areas of the Earth. This is particularly useful for sparsely populated areas.
Satellite Communication Disadvantages

- Technological limitations preventing the deployment of large, high gain antennas on the satellite platform.
- Over-crowding of available bandwidths due to low antenna gains
- The high investment cost and insurance cost associated with significant probability of failure
- High atmospheric losses above 30GHz limit carrier frequencies

Must-have accessory for new century?

- Cell phone, of course!
  - From bespectacled power brokers to ripped-jeans-wearing college kids, wireless has been the way to go
  - Today, there are more than 60 million wireless customers, according to the Cellular Telecommunications Industry Assoc. (CTIA)
- However, it is difficult to imagine that cellular service was invented about 50 years ago
  - Wireless business started as some 25 years ago in selected markets
  - Grew steadily from a $3 million market to one that now takes in close to $30 billion in annual revenues
Cellular Technology

• Cellular’s name stems from each geographic region of coverage is broken up into cells
  – Within each of these cells is both a radio transmitter as well as control equipment
  – First cellular services operating at 800 MHz, used analog signals
  – Analog sends signals using a continuous stream or wave
• When a cellular phone customer turns on his phone
  – A signal is sent to identify him as a customer
  – Make sure he is a paying customer
  – Then searches out a free channel to fit his call

Cellular Technology (continued)
Cellular Technology (continued)

- Within each cell, user communicates with a transmitter within the cell
- As the mobile user approaches a cell boundary, the signal strength fades, and the user is passed on to a transmitter from the new cell
- There are only a limited and fixed number channels per cell
- Each cell reuses the same channels based on the concept of radio frequency attenuation

Cellular Technology Advantages

- Popular in every industry, with every age-group, and in many homes primarily because convenient and save time
  - In business time is money so wireless communications providing both voice and data are a necessity
- Instant information delivery
  - Provide anytime, anywhere communications
- Ease to introduce more channels
  - As demand rises, simply reduce the cell size
  - Then the same number of channels is available in a smaller area, increasing the total number of channels per unit area
  - In a well planned system, the cell density reflects the user density
Cellular Technology Disadvantages

- Complicated technology and difficult to implement
  - Difficult media
  - Bandwidths and channels reuse
  - High cost to implement in rural areas and even not feasible
- Security and privacy are easier to be compromised
- Battery life
- Potential health hazard to human

Cellular Terms

- Cellular
  - Type of wireless communication most familiar to mobile phones users
  - Called 'cellular' because the system uses many base stations to divide a service area into multiple “cells”
  - Cellular calls are transferred from base station to base station as a user travels from cell to cell
- Cell Site
  - The transmission and reception equipment, including the base station antenna, that connects a cellular phone to the network
Cellular Terms (continued)

- **Service Area or (Home) Coverage Area**
  - The geographic area served by a wireless system

- **Roaming**
  - Using a wireless phone in an area outside its coverage area, usually associated with additional charge

- **Roaming Agreement**
  - An agreement among wireless carriers allowing users to use their phone on systems other their own home systems
  - May incur Roaming Fee charged for roaming

Cellular Terms (continued)

- **“A” or “B” Carriers**
  - Most areas of US have two cellular carriers, each of which operates on a different frequency band
  - One is designated the “A” carrier and the other is designated the “B” carrier
  - In some markets there may be only one carrier which may be "A" or "B"

- **A/B Switching**
  - Most cellular phones have ability to switch to "A" or "B" frequency bands, especially is useful when roaming outside your home coverage area
Cellular Terms (continued)

• Airtime
  – Total time that a wireless phone is in connected and in use for talking, including use for calls both received and placed

• PSTN (Public Switched Telephone Network)
  – A formal name for the world-wide telephone network

• MTSO (Mobile Telephone Switching Office)
  – An office housing switches and computers to which all cell sites in an area are connected for the purpose of eventual connection to PSTN
  – MTSO handles connection, tracking, status and billing of all wireless call activity in an assigned area

Cellular Terms (continued)

• Standby Time
  – Time a phone is on but not actively transmitting or receiving a call

• Talk Time
  – Time a phone is on and actively transmitting or receiving a call

• Wireless Local Loop (WLL)
  – A wireless system meant to bypass a local landline telephone system
  – A home or businesses phone system is connected to public network by a wireless carrier instead of by the traditional local phone company
Personal Communications Services (PCS)

- Encompass a wide range of wireless mobile technologies
  - Primarily two-way paging and cellular-like calling services that are transmitted at lower power and higher frequencies than cellular services.
- Spectrum is divided to support three major categories of PCS services:
  - Narrowband PCS in the 900-901 Mhz, 930-931 Mhz and 940-941 Mhz bands
  - Broadband PCS in the 1850-1990 Mhz band; and
  - An unlicensed portion of spectrum at 1910-1930 Mhz

Personal Communications Services (PCS)

- Major enhancements beyond traditional cellular technology
  - Combining lightweight phones and advanced features including paging, voice mail, and a variety of others that can be tailored for each individual customer
  - May be integrated as a wireless network device to access wireless local area network (LAN) so that gain access to wide area network (WAN) as well
  - A greater capacity for future growth based upon spectrum allocation and use of efficient digital technology for cleaner voice conversations, less background noise, and fewer dropped calls
  - An advanced digital radio network which uses smaller cell sites (about 1 mile radius) that are less than traditional cellular (4 - 6 miles radius)
  - Better security since encryption/decryption can be applied to digital signal
Wireless LAN

• A flexible data communications system implemented as an extension to, or as an alternative for, a wired LAN
  – Using radio frequency (RF) technology, wireless LANs transmit and receive data over the air, minimizing the need for wired connections
  – Wireless LANs combine data connectivity with user mobility.

• Gained strong popularity in a number of vertical markets, including the health-care, retail, manufacturing, warehousing, and academia
  – These industries have profited from productivity gains of using hand-held terminals and notebook computers to transmit real-time information to centralized hosts for processing

Wireless LAN Advantages

• Mobility
  – Provide LAN users with access to real-time information anywhere in their organization
  – This mobility supports productivity and service opportunities not possible with wired networks

• Installation Speed and Simplicity
  – Installing a wireless LAN system can be fast and easy and can eliminate the need to pull cable through walls and ceilings

• Installation Flexibility
  – Wireless technology allows network to go where wire cannot go
Wireless LAN Advantages (continued)

• Reduced Cost-of-Ownership
  – While the initial investment required for wireless LAN hardware can be higher than the cost of wired LAN hardware, overall installation expenses and life-cycle costs can be significantly lower
  – Long-term cost benefits are greatest in dynamic environments requiring frequent moves and changes

• Scalability
  – Can be configured in a variety of topologies to meet needs of specific applications and installations
  – Configurations are easily changed and range from peer-to-peer networks suitable for a small number of users to full infrastructure networks of thousands of users that enable roaming over a broad area

Wireless LAN Technologies

• Narrowband technology
  – A narrowband radio system transmits and receives user information on a specific radio frequency
  – Keep radio signal frequency as narrow as possible just to pass the information
  – Undesirable crosstalk between communications channels is avoided by carefully coordinating different users on different channel frequencies
  – A private telephone line is much like a radio frequency
  – However, the end-user must obtain an FCC license for each site where it is employed
Wireless LAN Technologies (continued)

• Spread spectrum technology
  – Used by most wireless LAN systems
  – A wideband radio frequency technique developed by military for reliable, secure, mission-critical communications
  – Designed to trade off bandwidth efficiency for reliability, integrity, and security so that more bandwidth is consumed than narrowband transmission to produce a louder signal and thus easier to detect
  – If a receiver is not tuned to the right frequency, a spread-spectrum signal looks like background noise
  – Two types of spread spectrum radio: frequency hopping and direct sequence

Wireless LAN Technologies (continued)

• Frequency-hopping spread spectrum technology (FHSS)
  – Use a narrowband carrier that changes frequency in a pattern known to both transmitter and receiver
  – Properly synchronized, the net effect is to maintain a single logical channel
  – To an unintended receiver, FHSS appears to be short-duration impulse noise
Wireless LAN Technologies (continued)

• Direct-sequence spread spectrum technology (DSSS)
  – Generate a redundant bit pattern for each bit to be transmitted
  – This bit pattern is called a chip (or chipping code)
  – The longer the chip, the greater the probability that the original data can be recovered (and, of course, the more bandwidth required)
  – Even if one or more bits in the chip are damaged during transmission, statistical techniques embedded in the radio can recover the original data without the need for retransmission
  – To an unintended receiver, DSSS appears as low-power wideband noise and is rejected (ignored) by most narrowband receivers

Wireless LAN Technologies (continued)

• Infrared technology (IR)
  – Little used in commercial wireless LANs and use very high frequencies, just below visible light in the electromagnetic spectrum, to carry data
  – Like light, IR cannot penetrate opaque objects; it is either directed (line-of-sight) or diffuse technology
  – Inexpensive directed systems provide very limited range (3 ft) and typically are used for personal area networks but occasionally are used in specific wireless LAN applications
  – High performance directed IR is impractical for mobile users and is therefore used only to implement fixed sub-networks
  – Diffuse (or reflective) IR wireless LAN systems do not require line-of-sight, but cells are limited to individual rooms
Biological Effects of Radio Radiation

- Thermal effects
  - Blood vessels are dilating and blood flow increases substantially as thermoregulatory mechanism is activated to keep body temperature constant
  - With rising body temperature the metabolic rate rises also, what may lead to Stress-Adaptation-Fatigue Syndrome

- Electrophonic effect
  - Humans can perceive a buzzing or clicking sound in the back of their heads at exposure to power densities as low as 0.1 mW/cm² of pulsed microwave radiation (200-3000 MHz)
  - Absorbed energy produces a thermoelectric expansion of brain tissue causing an acoustic pressure wave sensation strong enough to be perceived in an ambient noise level of 65 dB

Biological Effects of Radio Radiation (continued)

- Accumulation dosage
  - Limits as given in Canadian Safety Code 6 (1991) for occupational exposure to radio wave energy are 1 mW/cm² averaged over one hour period and 25mW/cm² averaged over one minute period
  - With a pulse train, that has a 1:20 on/off ratio, one could be exposed to pulse energies proven to be highly dangerous - e.g. 500 mW/cm² without violation of the Code. Also one could be exposed for a full second to 1.5 W/cm² over a one minute period. Recall from above: 7% of this value causes eye damage!
  - For an 8 hour work shift, an allowable dose of 8 mWh/cm² per day could be established, only valid for a 16 hour recovery period