SOME HISTORY

Light, Electromagnetic Waves, TV, WLANs, …
Using Light for Communication

- **Ancient Times:**
  - Smoke signals (150 BC, Greece)
  - Light towers (206 BC, China)

- **Not-so-ancient:**
  - Heliographs, semaphores, navy

- **1794, Claude Chappe**
  - Optical telegraph

Electromagnetic Waves

- **Discovery of electromagnetic waves:**
  - Faraday (1831): demonstrated electromagnetic induction
  - Maxwell (1860s-70s): theory of electromagnetic waves
  - Hertz (1886): demonstrated the wave character of electrical transmission

- **Marconi (1896):**
  - First demonstration of wireless telegraphy
  - Long-wave transmission, high transmission power needed (> 200 kW)

- **1907: Commercial transatlantic connections**
  - Huge base stations (Thirty 100m high antennas)

- **1915: Wireless voice transmission (NY-SFO)**
  - Still needed huge antennas, high transmission power
Small Antennas, Small Power

- 1920: Discovery of short waves (Marconi, again)
  - Get reflected at the ionosphere
  - Enabled sending short radio waves around the world, bouncing at the ionosphere
    - Technique still used today for amateur radio

- 1906: Invention of vacuum tube (DeForest, Leiben)
  - Helped reduce the size of senders and receivers
  - Still used for amplifying sender output in radio stations

- 1920s: Mobile Transmitters
  - First phone in a train (wires parallel to track as antennas)
  - 1927: First commercial car radio
    - 1922: 18-yr Frost (Chicago) integrated radio into a Ford

Rise of Broadcasting: TV & Radio

- 1928: Many TV broadcast trials
  - Baird: TV transmission across Atlantic, Color TV
  - WGY (Schnectady, NY): regular TV broadcasts, TV news

- 1932: CBS started first tele-teaching

- 1933: Frequency modulation (E.H. Armstrong)
  - Much better quality than amplitude modulation
  - Both FM and AM still used for today’s radio broadcasting
    - FM results in better quality

- 1930s:
  - Many radio stations broadcasting all over the world
Analog Mobile Phone Systems

- **1960s**: Bell Labs, US completed *initial* cellular system design
- **1960s-70s**: Several European mobile phone projects
  - **German**: A-Netz (1958), B-Netz (1972)
    - Carrier freq of 160 MHz, no handover
    - connection setup:
      - only from mobile station (A-Netz), fixed network too (B-Netz)
      - 1971: 80% coverage; 11,000 customers
  - **Scandinavian countries**: NMT (1979) – carrier freq 450 MHz
- **1982**: Start of GSM specification
  - Several incompatible analog mobile phone standards
- **1983**: US AMPS system started
  - Advanced Mobile Phone System – 850 MHz
  - Included handoffs
- **1984**: CT1 (cordless home phone standard)
  - 1987: CT2 – carrier freq 864 MHz, channel rate 32 Kbps

Digital Wireless Systems

- **1991**: DECT (Digital European Cordless Telephone)
  - 1880-1900 MHz; 100 – 500 m range; 120 duplex channels
  - 1.2 Mbps data transmission; encryption, authentication
  - Up to several 10000 users/km²; used in 110+ countries
  - Renamed: Digital Enhanced Cordless Telecommunications
- **1992**: Start of GSM (standardized)
  - 900 MHz, 124 duplex channels
  - Full international roaming, automatic location services, authentication, encryption, interoperation with ISDN, relatively high quality audio
  - Includes SMS, fax, data services (9.6 Kbps)
  - Offers compatibility despite provider accounting diversity
    - Currently 400 providers, 190 countries, 70% of world market
  - Renamed: Global System for Mobile Communication
Mobile Communication w/ Satellites

- **1998: Iridium system**
  - 66 satellites in low earth orbit; uses the 1.6 GHz band
  - First small and truly portable mobile satellite phones
    - Including data service

- **1998: UMTS (European)**
  - Universal Mobile Telecommunications System
  - Combines GSM with bandwidth-efficient CDMA solutions

- **IMT-2000: International Mobile Telecommunications**
  - ITU worldwide framework for future mobile communication
  - Service framework, network architecture, radio interface requirements, spectrum considerations, ...
  - Includes strategies for developing countries

WLAN: Wireless Local Area Networks

- **1996: HIPERLAN (European)**
  - High-performance Radio LAN family of standards
  - Type 1 (5.2 GHz, 23.5 Mbps) – Type 4 (17 GHz, 155 Mbps)

- **1997: IEEE 802.11 standard**
  - Uses the License-free Industrial, Science, Medical band
    - 2.4 GHz and infra-red
  - Initially offering 2 Mbps

- **802.11 emerged as winner for LANs**
  - Standards vs. market forces
  - In contrast to GSM vs. US technologies

- **1999: more powerful WLAN standards**
  - IEEE 802.11b: 2.4 GHz, 11 Mbps
  - Bluetooth: 2.4 GHz, < 1 Mbps, short-range, piconets
Third Generation (3G)

- **2000**: GSM higher data rates (up to 57.6 Kbps)
- **Late 90s**: UMTS spectrum auctions
  - **Hype**: portraying 3G as high-performance mobile Internet
    - UMTS announced as capable of handling interactive video streaming for all users at 2 Mbps
  - **Thus**: auctions for licensing 3G spectrum started
  - **More than 100 Billion pounds paid in Europe alone**
    - Companies that had never run a network before paid billions
    - Most companies now bankrupt
- **2001**: Start of 3G systems
  - **FOMA** (Japan), **UMTS** (Europe) **cdma2000** (Korea)

2000s

- **Early 2000s**: New WLAN developments
  - IEEE 802.11a: 5 GHz, up to 54 Mbps
  - IEEE 802.11g: 2.4 GHz, up to 54 Mbps
  - **New Bluetooth applications**:
    - Headsets, remote controls, wireless keyboards, hot syncing
- **Deployment of 3G infrastructure** (licensing pre-condition)
- **Digital terrestrial TV**: high quality, mobile, small antenna
- **Next generation mobile and wireless systems**:
  - Likely to be widely Internet based (IP protocols/apps)
  - Users will have choice of many different networks
- **2009**: Netbooks, iphones, VoIPoWLAN, …
- **Latest**: 802.11ac, 802.11ad, GigalR, WUSB-UWB, …
CURRENT STATE OF AFFAIRS

Market & Spectrum

Explosion of User Base

Global ICT Developments

Note: *Estimates
Source: ITU World Telecommunication/ICT indicators database.

~ 7 billion current mobile phone service subscriptions ➔ more than 96% of world population!
Spectrum Allocation

- Limited frequency spectrum
  - Must be shared among various applications
  - Typically government regulated

- US spectrum allocation chart:

- More in next lecture-set …

EXAMPLES OF WIRELESS COMMUNICATION SYSTEMS

Paging, Cordless, Cellular
**Some Terminology**

- **Portable (hand-held, walk speed) vs mobile (vehicle speed)**
- **Base stations:** mobiles communicate to **fixed** base stations
  - Connected to power source, and a backbone network
- **Classification:**
  - **Simplex systems:** e.g., paging systems
    - Messages are received, but not acknowledged.
  - **Half-duplex systems:** e.g., walkie-talkies
    - Allow two-way communication, but use same radio channel for both transmission and reception.
    - “push-to-talk”, “release-to-listen”
  - **Full-duplex systems:** e.g., US AMPS standard
    - Allow simultaneous radio transmission and reception
    - Provide two separate channels (frequency division duplex), or adjacent time slot on a single channel (time division duplex)

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**Paging Systems**

- **Service:**
  - Send brief messages to a subscriber
  - Simplex, reliable communication

- **Architecture:**
  - Transmit the page throughout the service area using base stations, which simultaneously broadcast the page on a radio carrier
  - Reliability achieved using large transmission power (~kw) and low data rates (~Kbps)
**Cordless Telephony**

- Full duplex in-home communication system
  - Radio connects portable handset to dedicated base station, which is connected to a dedicated phone line

- 2nd-generation systems cover up to 100s of meters
  - But no coverage outside range

**Cellular Systems**

- Provides wireless connection to the PSTN for any user location within the system range

- Accommodate large number of users (using cells) over a large geographic area (using handoffs), within a limited frequency spectrum

- Base station
  - Several antennas
  - Full duplex
  - Connects to MSC

- MSC:
  - Handles channel allocation in base stations
  - Involved in call initiation, termination, and handoff
ARCHITECTURAL CONTEXT
Layered Reference Model
Internet Structure

- Internet is a “network of networks”
  - A packet passes through many networks

Organizing the Structure

- Networks are diverse and complex
  - Many pieces and many designers
    - Hosts
    - Routers
    - Links of various media
    - Applications
    - Protocols
    - Hardware, software

*Use layering for accommodating diversity and managing complexity*
**Why Layering?**

- Explicit structure allows identification, relationship of complex system's pieces

- Modularization eases maintenance, updating of system
  - Change of implementation of a layer transparent to rest of system

- Standard, well-defined interfaces a must
  - Single, simple IP glues the Internet together

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**Internet Protocol Stack**

- **Application layer**
  - Supporting network applications
    - *ftp*, SMTP, HTTP

- **Transport layer**
  - Host-host data transfer
    - TCP, UDP

- **Network layer**
  - Routing of packets from source to destination
    - IP, routing protocols

- **Link layer**
  - Data transfer between directly connected network elements
    - Ethernet, 802.11, SONET, ...

- **Physical layer**
  - The insertion of individual bits “on the wire”
### Impact of Wireless on Protocol Layers

<table>
<thead>
<tr>
<th>Layer</th>
<th>Impact</th>
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<tbody>
<tr>
<td>Application layer</td>
<td>service location, new/adaptive apps, multimedia</td>
</tr>
<tr>
<td>Transport layer</td>
<td>congestion/flow control, quality of service</td>
</tr>
<tr>
<td>Network layer</td>
<td>addressing, routing, device location, hand-over</td>
</tr>
<tr>
<td>Data link layer</td>
<td>authentication, media access/control, multiplexing, encryption</td>
</tr>
<tr>
<td>Physical layer</td>
<td>modulation, interference, attenuation, frequency</td>
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