Link Layer: Wireless Media

Current Trend

- WLAN explosion (also called WiFi)

  → took most by surprise
- cellular telephony: 3G/4G

  → cellular providers, telcos, data in the same mix

  → all-in-one handheld: e.g., Apple iPhone
- self-organization by citizens for local access

  → free WiFi hot spots
- large-scale hot spots: coffee shops, airport lounges, trains, university/enterprise campuses, cities, etc.

  → part of everyday life

  → difficult to turn back clock

- boundary between local and wide area wireless blurring

  → cellular (long-distance) vs. WLAN (short-distance)

  → 802.16 (WiMax): designed to compete with cellular; different version WiBro (Korea)

- also very short distances ("wireless personal area networks")

  → bluetooth, UWB, Zigbee: in general, 802.15

  → 802.11n also in the mix (e.g., Apple TV)

  → 2.4 and 5 GHz spectra: very busy

Integral part of the Internet:

⟶ where it's happening

Wireless Communication: Background

Use electromagnetic waves in wireless media (air/space) to transmit information.

$\longrightarrow$ NIC: also called air interface

- directed signal propagation: e.g., directed antenna or IR (infrared)
- undirected signal propagation: e.g., omni-directional antenna

$\longrightarrow$ mainly: microwaves (2–66 GHz)

$\longrightarrow$ focus: 2–10 GHz

Key differences with wired communication:

- increased exposure to interference and noise

  → lack of physical shielding

- inter-user interference cannot be localized at switch

  → cannot use buffering

  → problem for QoS (e.g., VoIP)

  ⟶ information is inherently exposed

  ⟶ bad for networking

  ⟶ bad for security

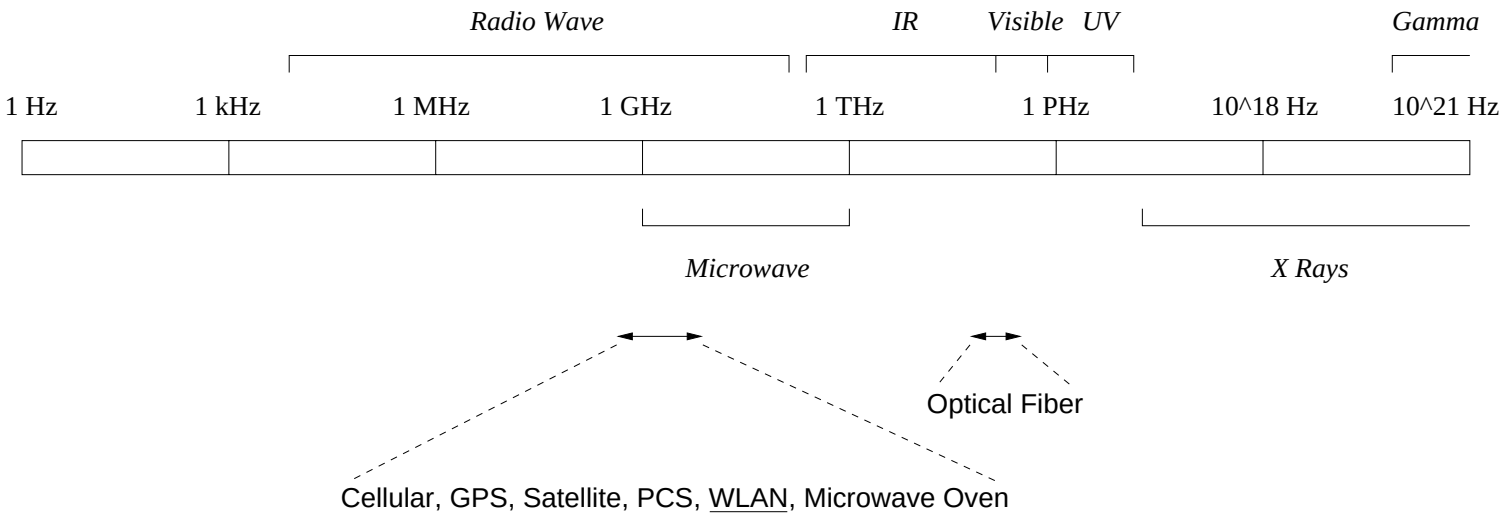
  ⟶ good for convenient access (trumps others)

- signal propagation and variation is more complex
  - ⟶ attenuation (also in wired)
  - ⟶ refraction, absorption, reflection, diffraction
  - ⟶ multi-path fading
  - ⟶ mobility (extreme: bullet train)

Network bandwidth: polarized

- ⟶ high and low bandwidth coexist
- ⟶ e.g., 10 Gbps and 11 Mbps
- ⟶ shrinking (e.g., 802.11n) but slowly
- ⟶ speed mismatch: makes things challenging
- ⟶ i.e., weakest link

Electromagnetic spectrum (logarithmic scale):



$\longrightarrow$ RF: 9 kHz–300 GHz

$\longrightarrow$ Microwave: 1 GHz–1 THz

$\longrightarrow$ Wireless: concentration $\sim$0.8 GHz–6 GHz

$\longrightarrow$ Optical fiber: $\sim$200 THz; 25 THz bandwidth

Miscellaneous spectrum allocations (U.S.):

$\longrightarrow$ FCC (Federal Communications Commission)

- AM Radio: 0.535 MHz–1.7 MHz
- FM Radio: 88 MHz–108 MHz
- TV: 174 MHz–216 MHz, 470 MHz–825 MHz

  $\longrightarrow$ audio (FM), video (AM)
- GPS (Global Positioning System): 1.2276 GHz–1.57542 GHz

  $\longrightarrow$ CDMA

  $\longrightarrow$ 24 satellites (DoD), 10900 miles

  $\longrightarrow$ navigation service: trilateration

- Cellular telephone: 824 MHz–849 MHz, 869 MHz–894 MHz

  $\longrightarrow$ AMPS: FDM, analog

  $\longrightarrow$ GSM: TDMA, digital

  $\longrightarrow$ IS-95: CDMA, digital

- PCS: 1.85 GHz–1.99 GHz

  $\longrightarrow$ CDMA, TDMA

E.g., quad-band phone

$\longrightarrow$ works at different frequency bands

$\longrightarrow$ loosely called: 800, 900, 1800, 1900 MHz

- WLAN: IEEE 802.11b 2.4 GHz–2.4835 GHz

  → CSMA/CA

  → same frequency range for 802.11g
- WLAN: Bluetooth 2.4 GHz–2.4835 GHz
- WLAN: IEEE 802.11a 5.725 GHz–5.850 GHz
- WiMax: IEEE 802.16 2 GHz–66 GHz

  → TDMA based

- Satellite: C-band 3.7 GHz–4.2 GHz (downlink), 5.925 GHz–6.425 GHz (uplink)

  → TDMA based

- Satellite: Ku-band 11.7 Ghz–12.2 Ghz (downlink), 14 GHz–14.5 GHz (uplink)

- Many other frequency bands

  → cf. FCC chart

  → www.ntia.doc.gov/osmhome/allochrt.pdf