

DIRECT LINK COMMUNICATION II: 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
- 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

- boundary between local and wide area wireless blurring
 - cellular: long-distance vs. WLAN: local
 - 802.16 (WiMax): designed to compete with cellular
- also very short distances (“wireless personal area networks”)
 - bluetooth, UWB, Zigbee: in general, 802.15
 - multi-use: cordless phones, WLANs, etc.
 - 2.4 and 5 GHz spectra: very busy

Integral part of the Internet: where it’s happening

- good news and bad news
- good old #\$\$%&? radio technology

Basics of Wireless Communication

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

—→ NIC: air interface

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

—→ mainly: microwaves

—→ e.g., 2–66 GHz

Key differences with wired communication:

- increased exposure to interference and noise
 - lack of physical shielding
- same frequency spectrum must be shared among all users
- inter-user interference cannot be localized at switch
 - cannot use buffering
 - problem for QoS (e.g., VoIP)

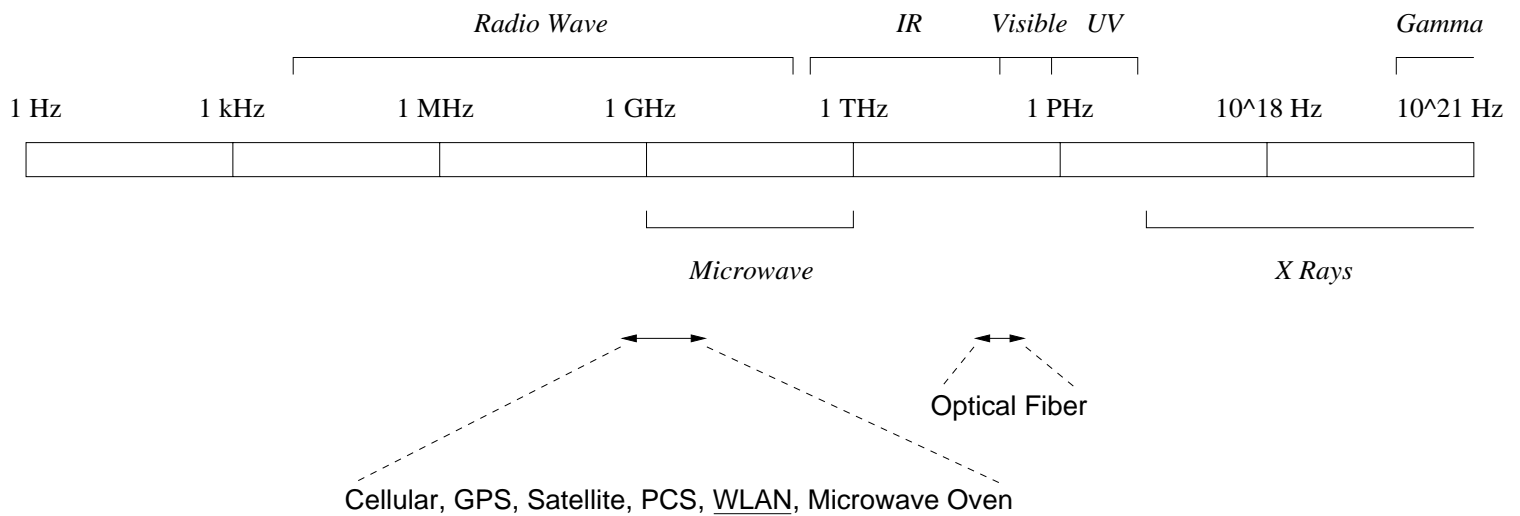
 - information is inherently exposed
 - bad for networking
 - bad for security
 - good for convenient access

- signal propagation and variation is more complex
 - attenuation
 - refraction, absorption, reflection, diffraction
 - multi-path fading
 - mobility

Network bandwidth: two extremes

- high and low bandwidth coexist
- e.g., 10 Gbps and 11 Mbps
- here to stay
- speed mismatch: makes things interesting

Electromagnetic spectrum (logarithmic scale):



- RF: 9 kHz–300 GHz
- Microwave: 1 GHz–1 THz
- Wireless: concentration \sim 0.8 GHz–6 GHz
- Optical fiber: \sim 200 THz; 25 THz bandwidth

Miscellaneous spectrum allocations (U.S.) & uses:

→ FCC (Federal Communications Commission)

- Voice: 300 Hz–3300 Hz
- AM Radio: 0.535 MHz–1.7 MHz
- FM Radio: 88 MHz–108 MHz
- TV: 174 MHz–216 MHz, 470 MHz–825 MHz
 - audio (FM), video (AM)
- GPS (Global Positioning System): 1.2276 GHz–1.57542 GHz
 - DS-CDMA
 - 24 satellites (DoD), 10900 miles
 - navigation service: trilateration

- Cellular telephone: 824 MHz–849 MHz (upstream),
869 MHz–894 MHz (downstream)
 - AMPS: FDM, analog
 - GSM: TDMA, digital
 - IS-95: CDMA, digital
- PCS: 1.85 GHz–1.99 GHz
 - CDMA, TDMA

- WLAN: IEEE 802.11b 2.4 GHz–2.4835 GHz
 - DSSS or FHSS with CSMA/CA
 - same frequency range for 802.11g
- WLAN: Bluetooth 2.4 GHz–2.4835 GHz
 - FH with TDD
- WLAN: IEEE 802.11a 5.725 GHz–5.850 GHz
 - OFDM with CSMA/CA
- 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)
→ FDMA/TDMA
- Satellite: Ku-band 11.7 GHz–12.2 GHz (downlink), 14 GHz–14.5 GHz (uplink)
- Many other frequency bands
→ cf. FCC chart

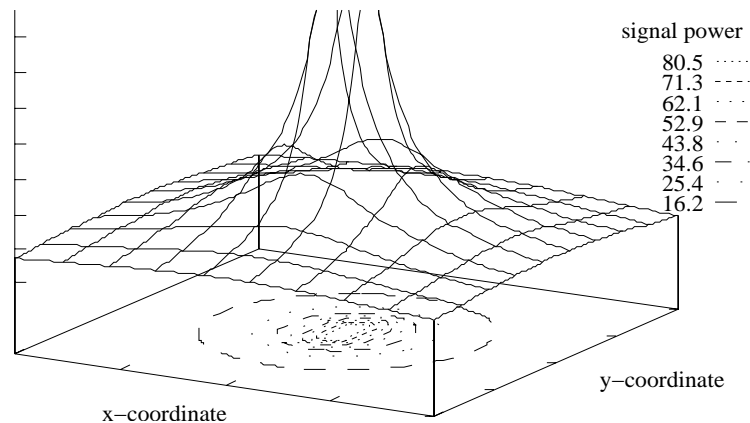
Signal Propagation and Power

Free space loss:

- transmitting antenna: signal power P_{in}
- receiving antenna: signal power P_{out}
- distance: d
- frequency: f

$$P_{\text{out}} \propto P_{\text{in}} \frac{1}{d^2 f^2}$$

→ quadratic decrease in distance & frequency

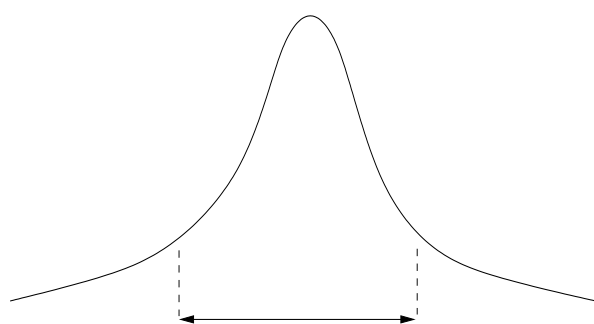


Design implications:

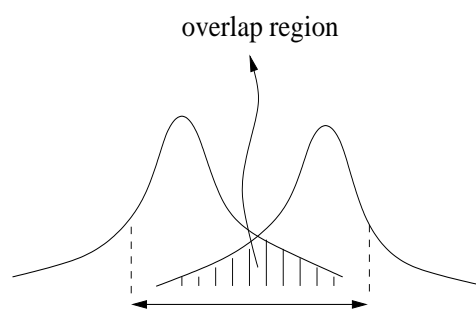
- effective coverage limited by distance

→ SNR: signal-to-noise ratio

→ SIR: signal-to-interference ratio



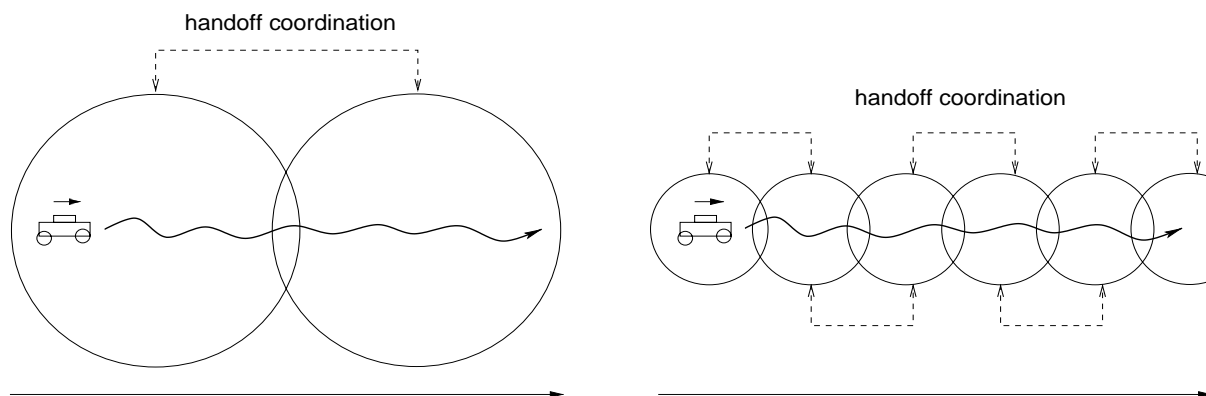
spatial coverage by one high-power antenna



spatial coverage by two low-power antennas

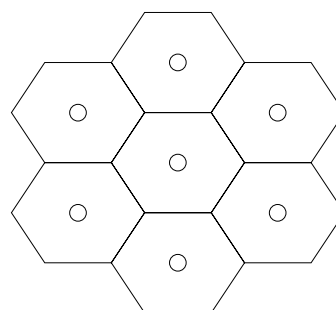
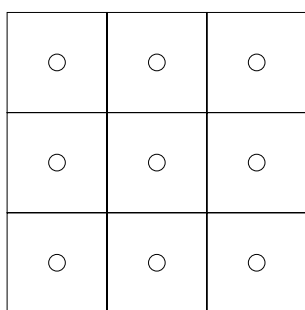
→ pros & cons?

- low power output decreases cell size
 - increased battery life
 - enables frequency reuse
 - more antennas required
 - handoff coordination overhead
 - e.g., I65 from Lafayette to Indy



Cellular Networks

Hexagonal cells:

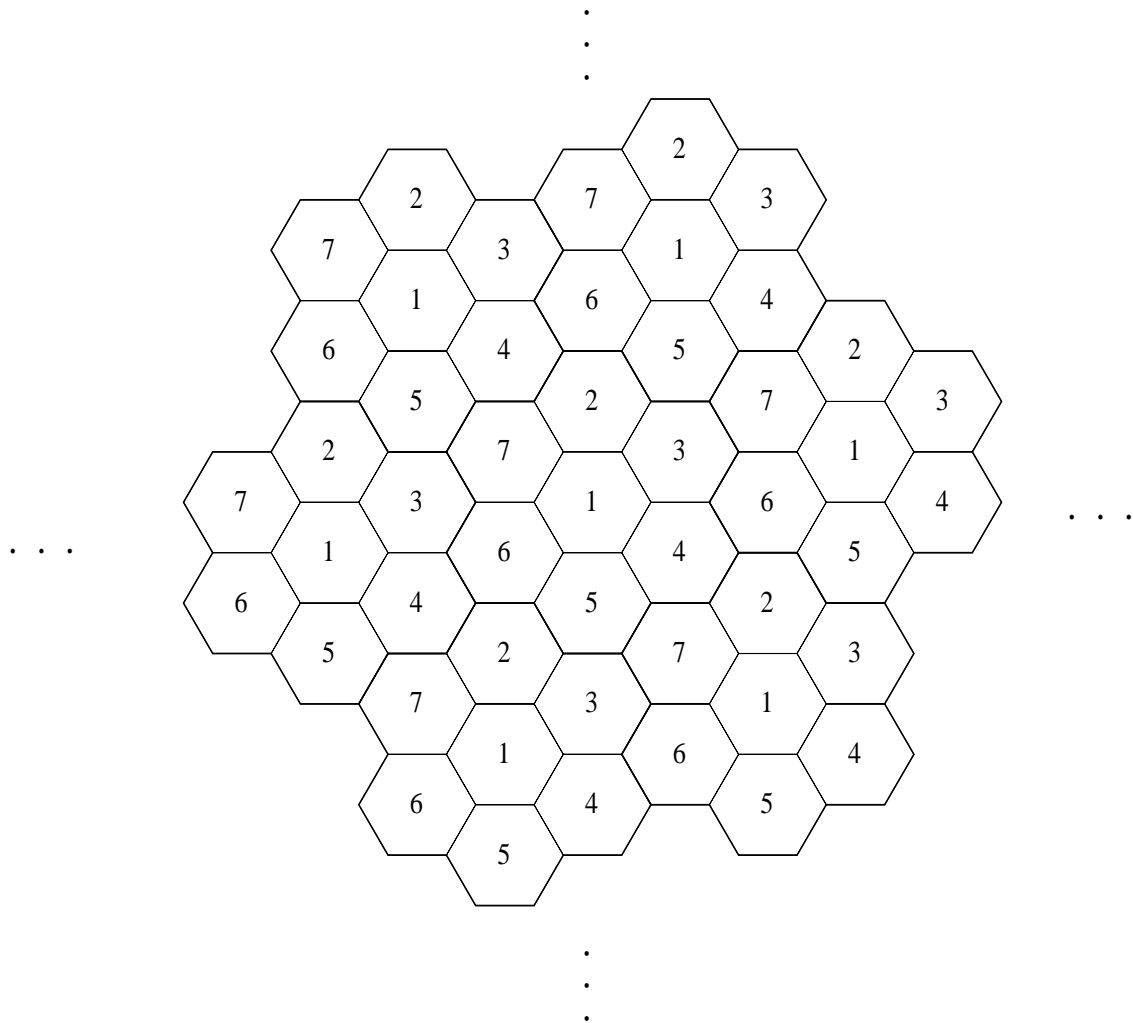


- both affect tiling of the plane
- why hexagonal?

Frequency reuse: adjacent cells do not use common carrier frequency.

- avoid interference
- how many frequencies are required?

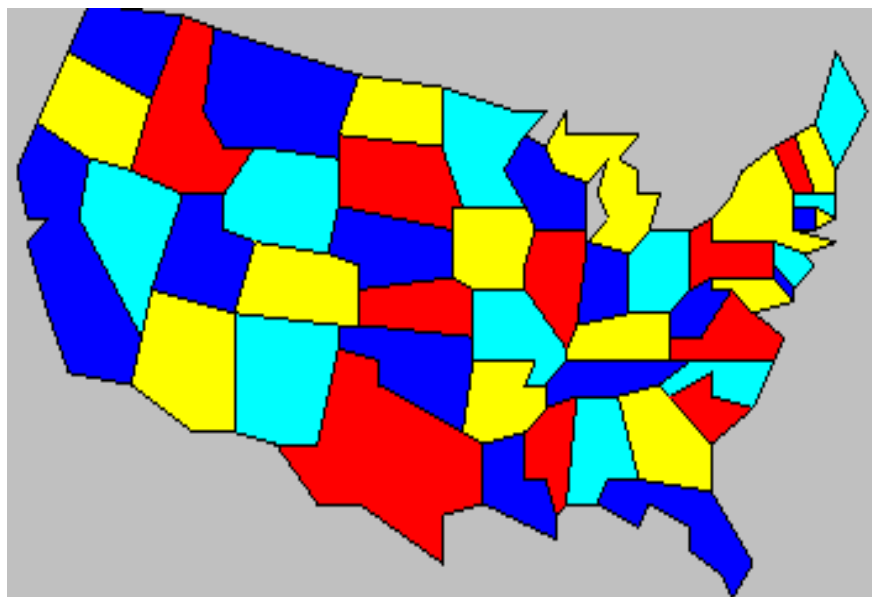
For example, using seven frequencies:



→ why does it work?

→ in general, coloring problem

4-coloring of U.S. map:

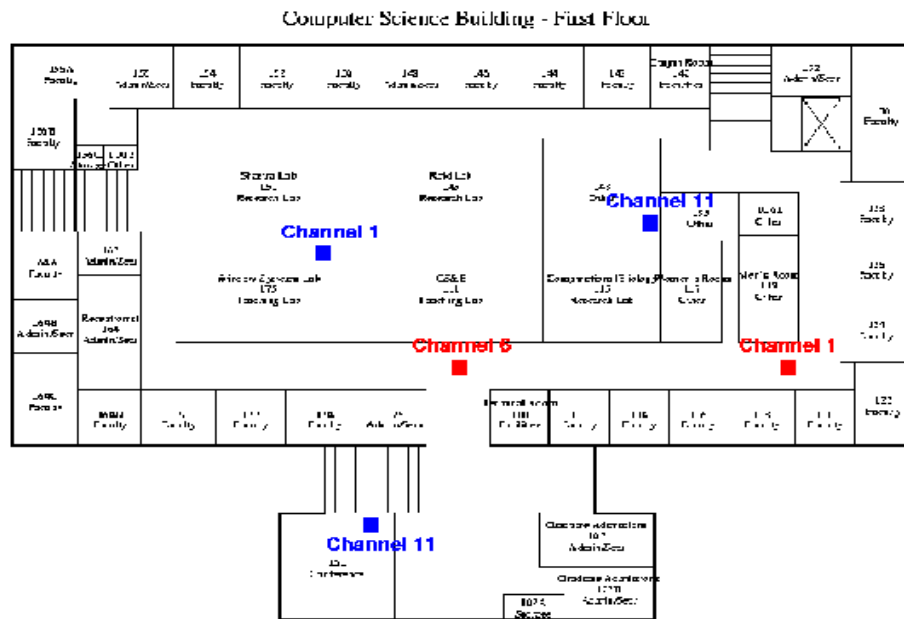


→ Y. Kanada, Y. Sato; Univ. of Tokyo

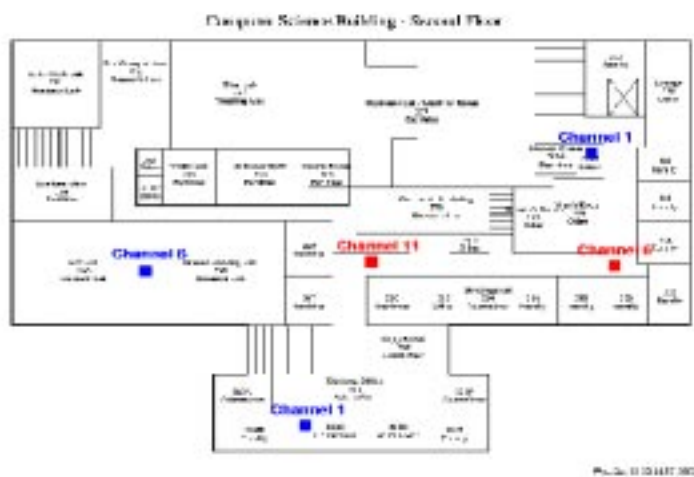
CS Building:



First floor frequency reuse:



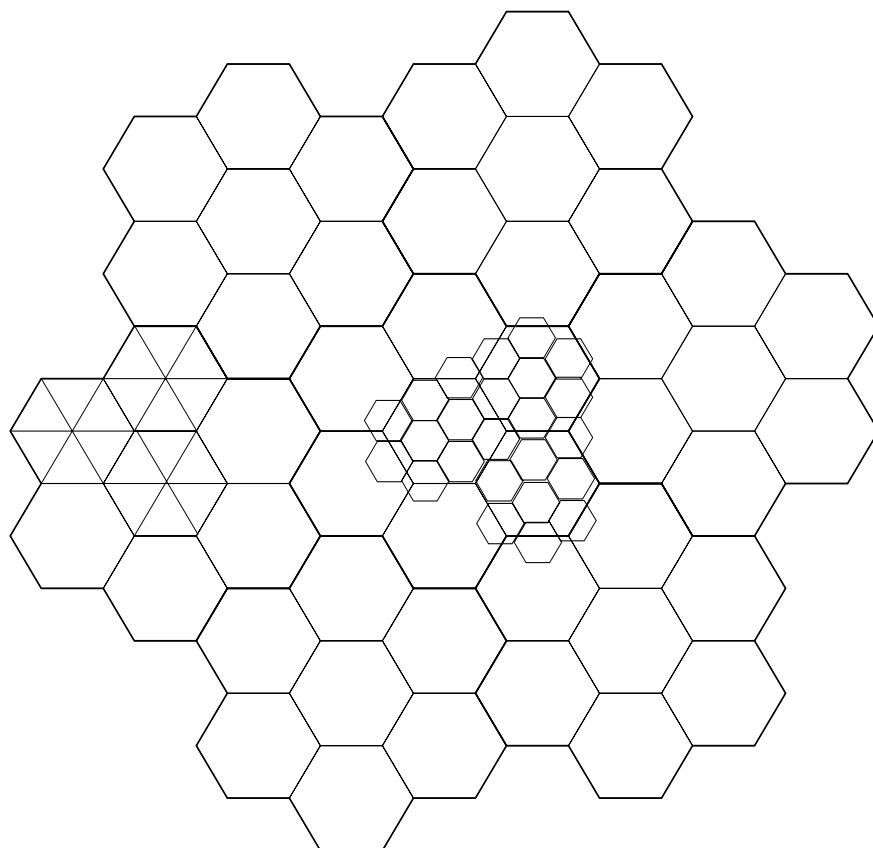
Second floor frequency reuse:



Ground floor frequency reuse:



Non-uniform covering:



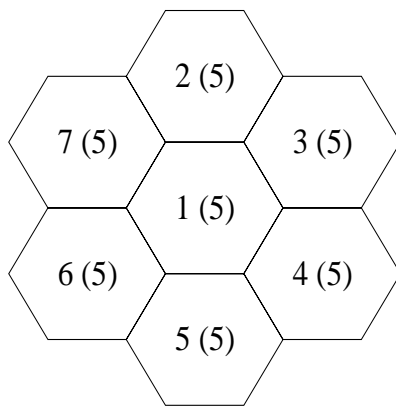
→ directional antenna

→ non-uniform density

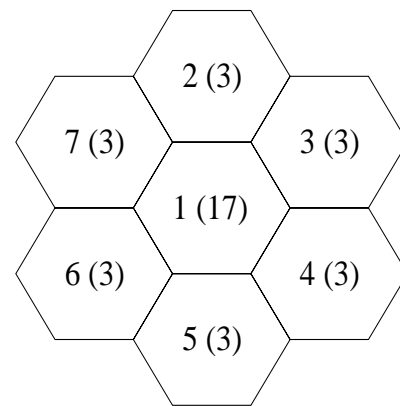
Non-uniform frequency allocation:

→ total carrier frequency budget: 35

→ frequency borrowing



uniform frequency allocation



non-uniform frequency allocation