Direct Link Networks: Technology Landscape

Hui Chen

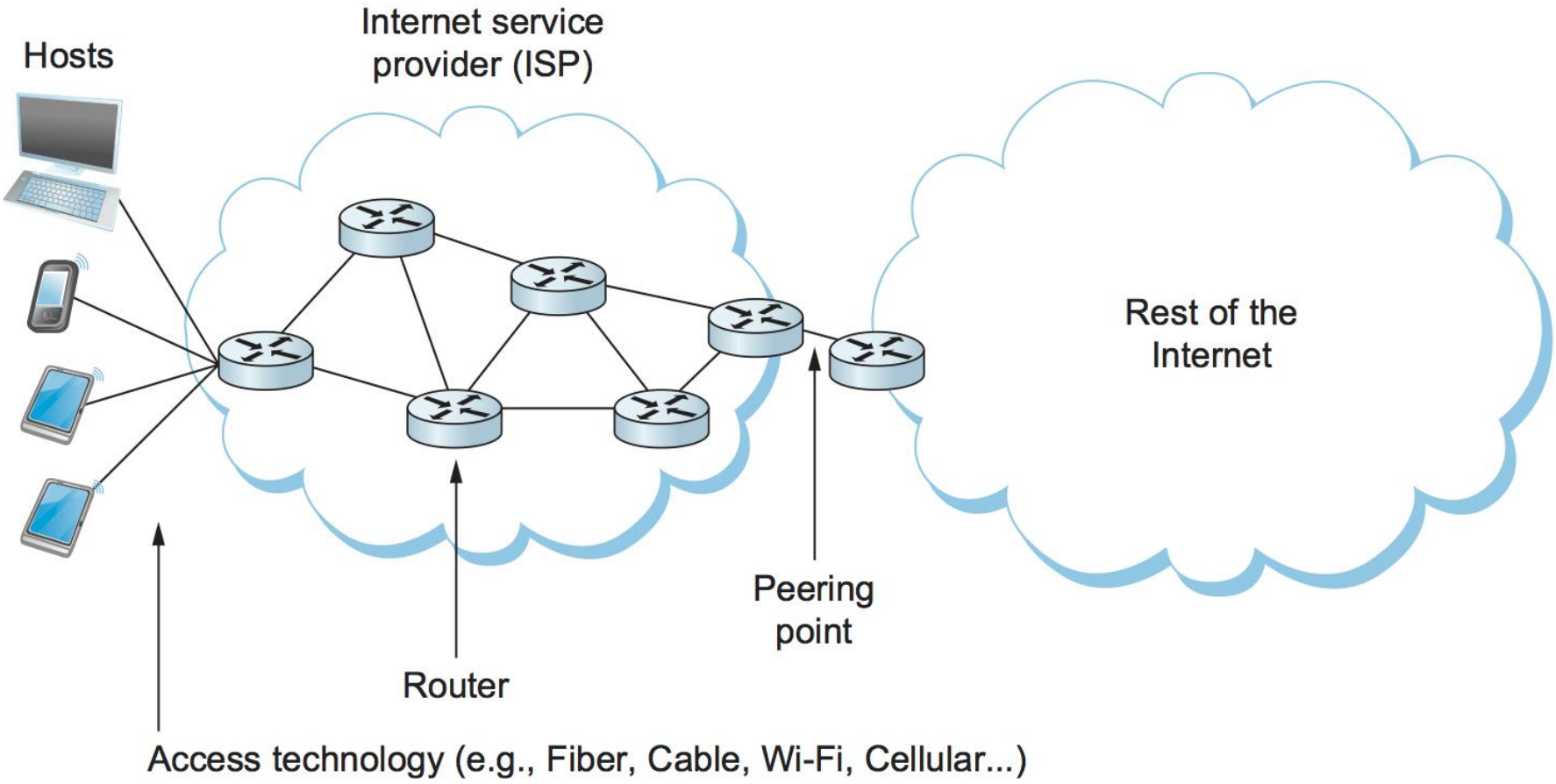
Department of Computer & Information Science

CUNY Brooklyn College

Building Networks

- Global networks
  - must deal with links that span hundreds or thousands of kilometers connecting refrigerator-sized routers.
- Accessing networks (accessing technology)
  - a typical user encounters links mostly as a way to connect a computer to the existing Internet.
  - Examples
    - a wireless (Wi-Fi) link in a coffee shop;
    - an Ethernet link in an office building or university;
    - a smartphone connected to a cellular network;
    - a fiber optic link provided by an ISP; and
    - many others use some sort of copper wire or cable to connect.
  - they can all be made reliable and useful to higher layers in the protocol stack.

An end-user's view of the Internet



Design Objective for Direct Link Networks

- Make all these different types of links look sufficiently alike to end users and routers
  - Must deal with all the physical limitations and shortcomings of links that exist in the real world.

Characterizing Physical Links

- By medium
- By frequency
- By usage

Physical Medium

- By the *medium* they use, e.g.,
  - guided media: transmission in “bounded media (wires)”,
    - copper wire in some form
      - twisted pair (some Ethernets and landline phones) ; coaxial (cable)
    - optical fiber
      - used for both fiber-to-the-home and many long-distance links in the Internet’s backbone
  - Unguided media: transmission in “open space (wireless)”
    - air/free space for wireless links.
    - examples: Radio, Sonar

Frequency

- By *frequency (f)*
  - measured in hertz, with which the electromagnetic waves oscillate
  - Some wave oscillation propagates in the medium and carries data
- Concepts
  - Wave length (λ)
  - Propagation speed (v)
    - all electromagnetic waves travel at the speed of light that in turn depends on the medium on which it travels
- Relationship
  - $v = \lambda f$

Example

- Relationship
  - $v = \lambda f$, *or*
  - $\lambda = v / f$
- a 300-Hz wave traveling through copper would have a wavelength of

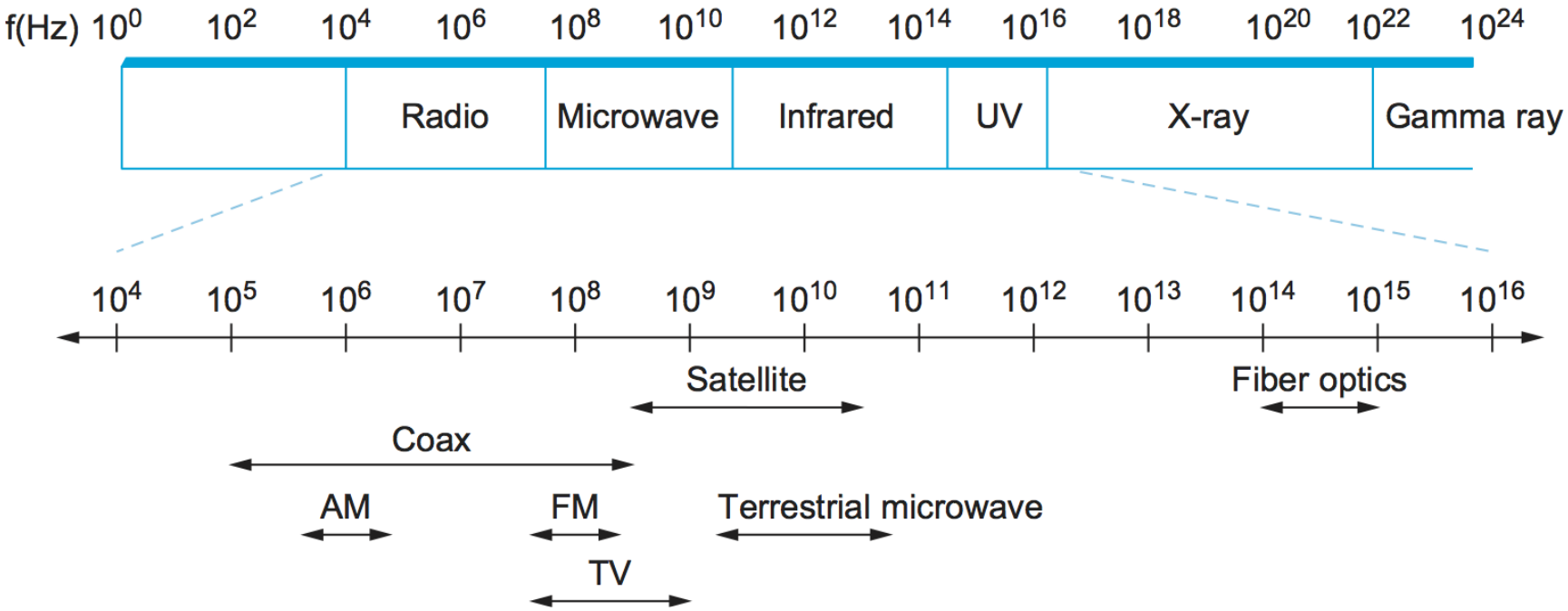
  SpeedOfLightInCopper / Frequency

  $= 2/3 \times 3 \times 10^8 / 300$

  $= 667 \times 10^3$ meters
- Typically, a physical medium carrying signals in the form of electromagnetic waves.

Electromagnetic spectrum

- Typically, a physical medium carrying signals in the form of electromagnetic waves.



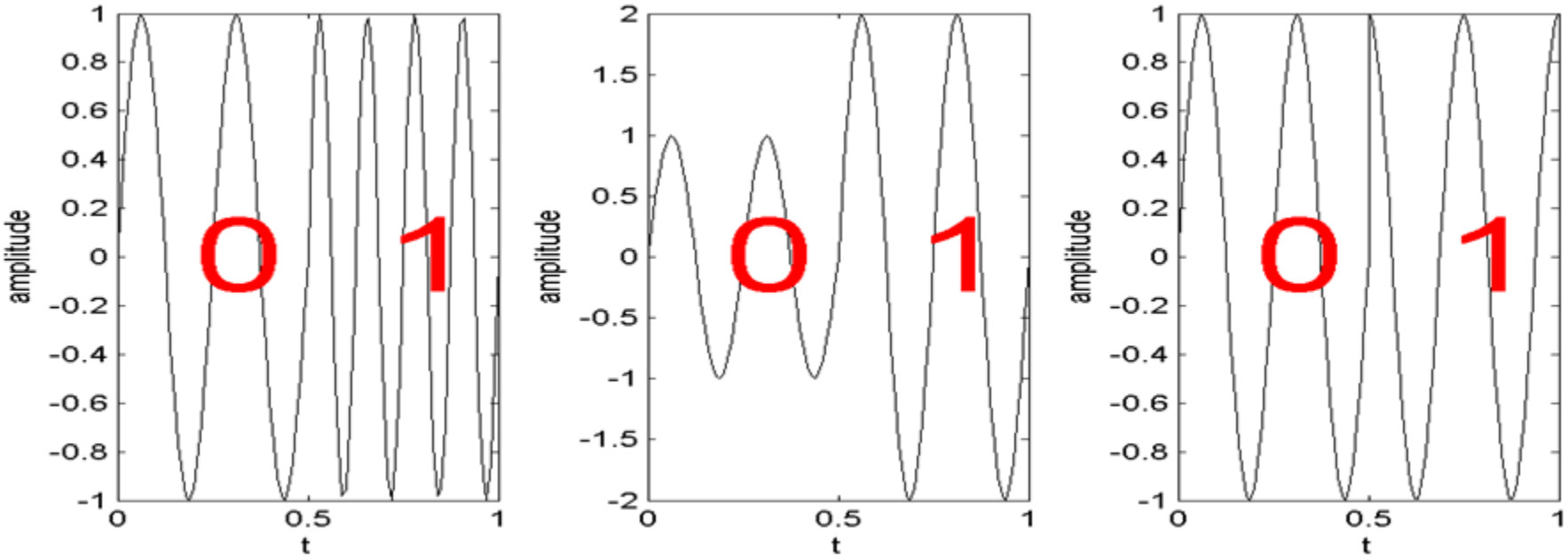
Note that this figure does show where the cellular network fits in.

Modulation and Encoding

- Link: a physical medium carrying signals in the form of electromagnetic waves.
  - Can transmits both analog and digital data
  - Digital data: binary data (1s and 0s).
- Problem: convert digital data to physical signal that is transmitted in a physical medium
- Encoding: the binary data is *encoded* in the signal, a complex topic
  - *Modulation:* varying the frequency, amplitude, or phase of the signal to effect the transmission of data.
    - We can simplify it by assuming with modulation we can transmit a pair of distinguishable signals (e.g., high and low)
  - Encoding binary data onto these two distinguishable signals.

Modulation

- Modulation
  - Varying frequency, amplitude, or phase of carrier signal with a modulating signal that carries information



Usage

- By how the links are used
  - last-mile links (access networks)
  - mobile links
  - backbone links
  - local area network links

Last-mile Links: Examples

- Common services available for the last-mile connection to your home

Service	Bandwidth
DSL (copper)	Up to 100 Mbps
G.fast (copper)	Up to 1 Gbps
PON (optical)	Up to 10 Gbps

Links for Local Area Networks

- Links that you find inside a building or a campus
  - generally referred to as *local area networks* (LANs).
- Example
  - Ethernet
  - Wireless LAN (e.g., WiFi)

Mobile or Cellular Network

- Connecting mobile devices to the Internet
- Evolution
  - 3G → 4G → 5G → …

Backbone Links

- Need some long-distance *backbone* links to interconnect cities.
  - Almost exclusively fiber optics
  - SONET (Synchronous Optical Network)
- Examples
  - https://www.cogentco.com/en/network/network-map
  - https://www.lumen.com/en-us/resources/network-maps.html
  - https://www.gtt.net/us-en/about-us/network/
  - https://www.zayo.com/network/
  - https://www.verizon.com/business/content/dam/business-markets/img/why-verizon/global_networks_map_en_xg.pdf
  - https://www.att.com/Common/files/pdf/GlobalMap11-17.pdf

Summary

- There are a diverse range of network link
- Key problem:
  - How networking protocols present a consistent view of the network to higher layers
    - Considering the diversity, the low-level complexity and economic factors.