CENG460
Computer Communication Networks

Physical Layer
Internet Access

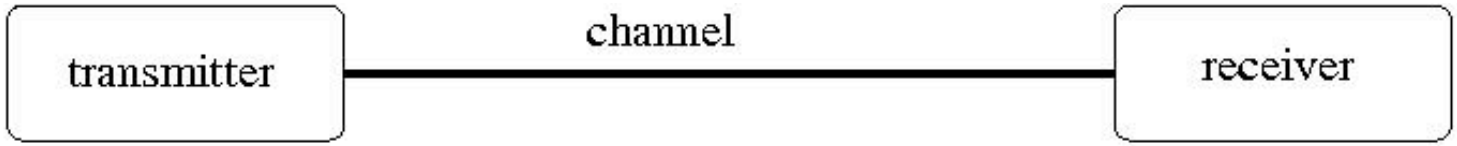
Communications Basics

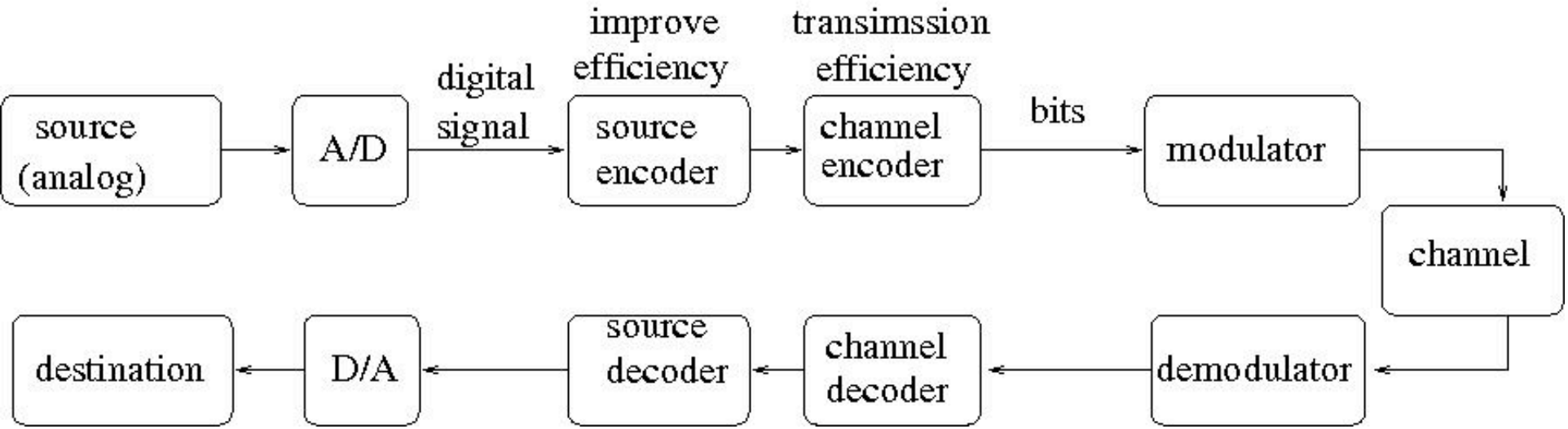
- Analog communication: the information in the form of an analog signal
- Digital communication: the message signal is in the digital form (e.g., binary sequences)

Why Digital?

- All digitized information sources “look” the same
- Control information such as address/routing can be easily accommodated
- Accurate and rapid storage and retrieval
- Encyption relatively easy
- Efficient regeneration of the coded signal along the transmission path
- Digital signal processing hardware circuits are easy to be implemented

Digital Communication System





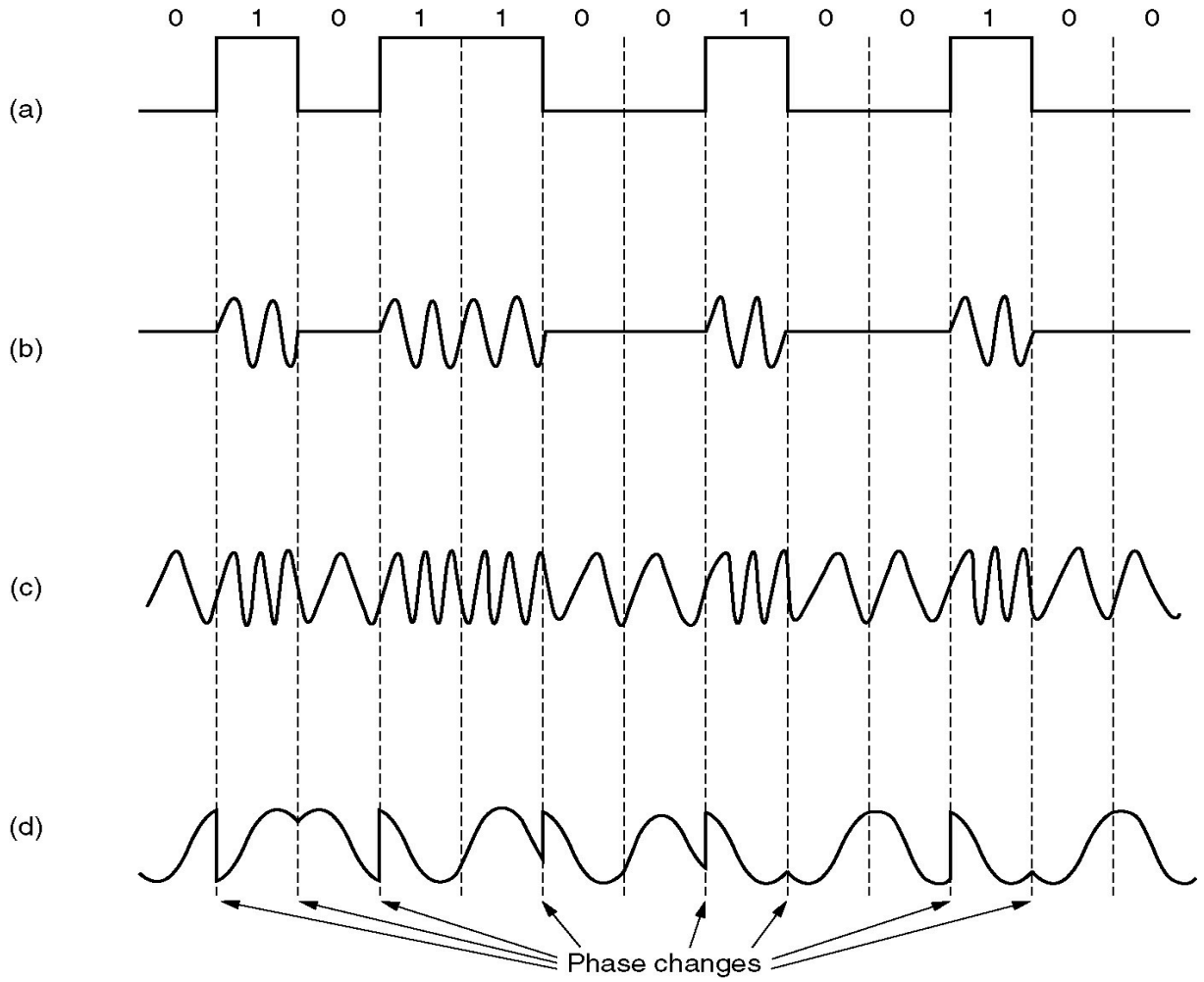
Why Modem?

- Signal in frequency domain
  - Fourier Analysis: any periodic function can be constructed as the sum of a number of sines and consines
  - Baseband DC (digital) signal has infinite harmonics

https://en.wikipedia.org/wiki/Fourier_transform#/media/File:Fourier_transform_time_and_frequency_domains_(small).gif

- Channel bandwidth: defined as the frequency between the highest and the lowest frequency that the channel can reliably transfer (without strong attenuation)
  - limited

More on Modems



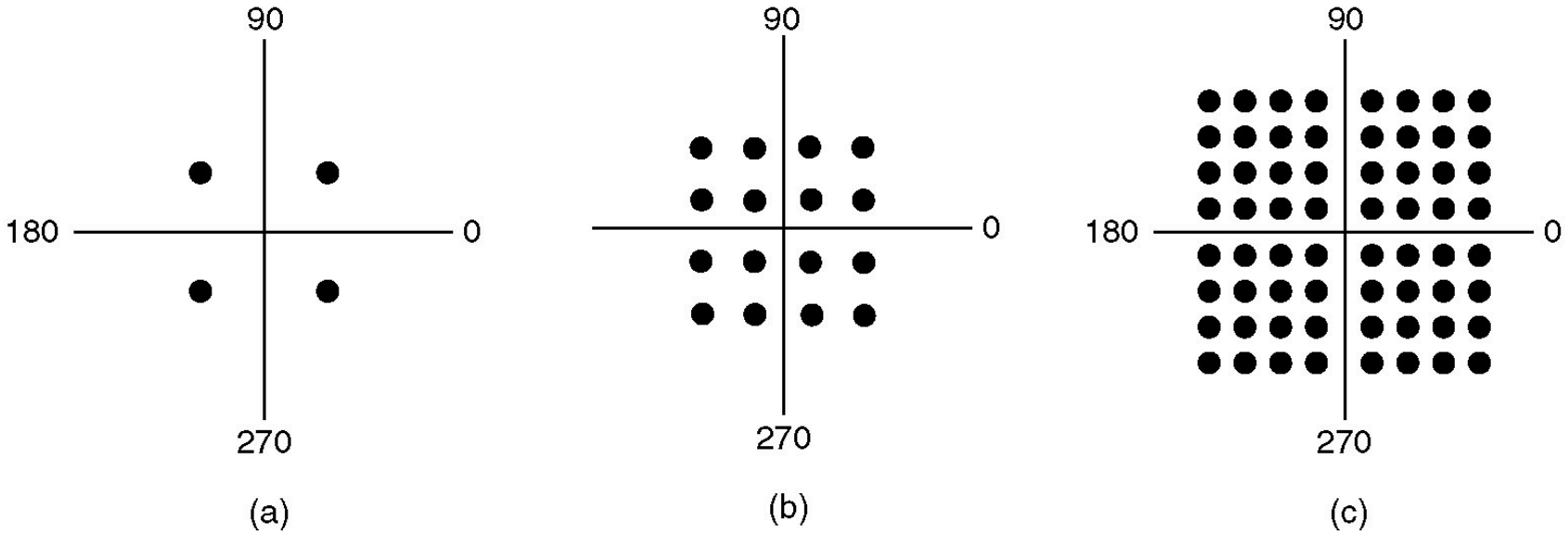
(a) A binary signal

(b) Amplitude modulation

(c) Frequency modulation

(d) Phase modulation

Modems (2)



(a) QPSK.

(b) QAM-16.

(c) QAM-64.

Channel capacity

- Nyquist limit (*noiseless channel*)
  - If an aribitrary signal has been run through a low-pass filter of bandwidth H, the filtered signal can be completely constructed by making only 2H samples per second.
  - $2H \log_2 V$ bps
    - bandwidth (Hz), baud, symbol, bit-per-second

Shannon limit

- Shannon limit (*noisy channel*)
  - $H \log_2 (1+S/N)$ bps
    - telephone local loop: H=3000Hz; S/N=30dB
- Modulation (telephone local loop): amplitude/frequency/phase
  - more bits / symbol * 2.4K symbol / second

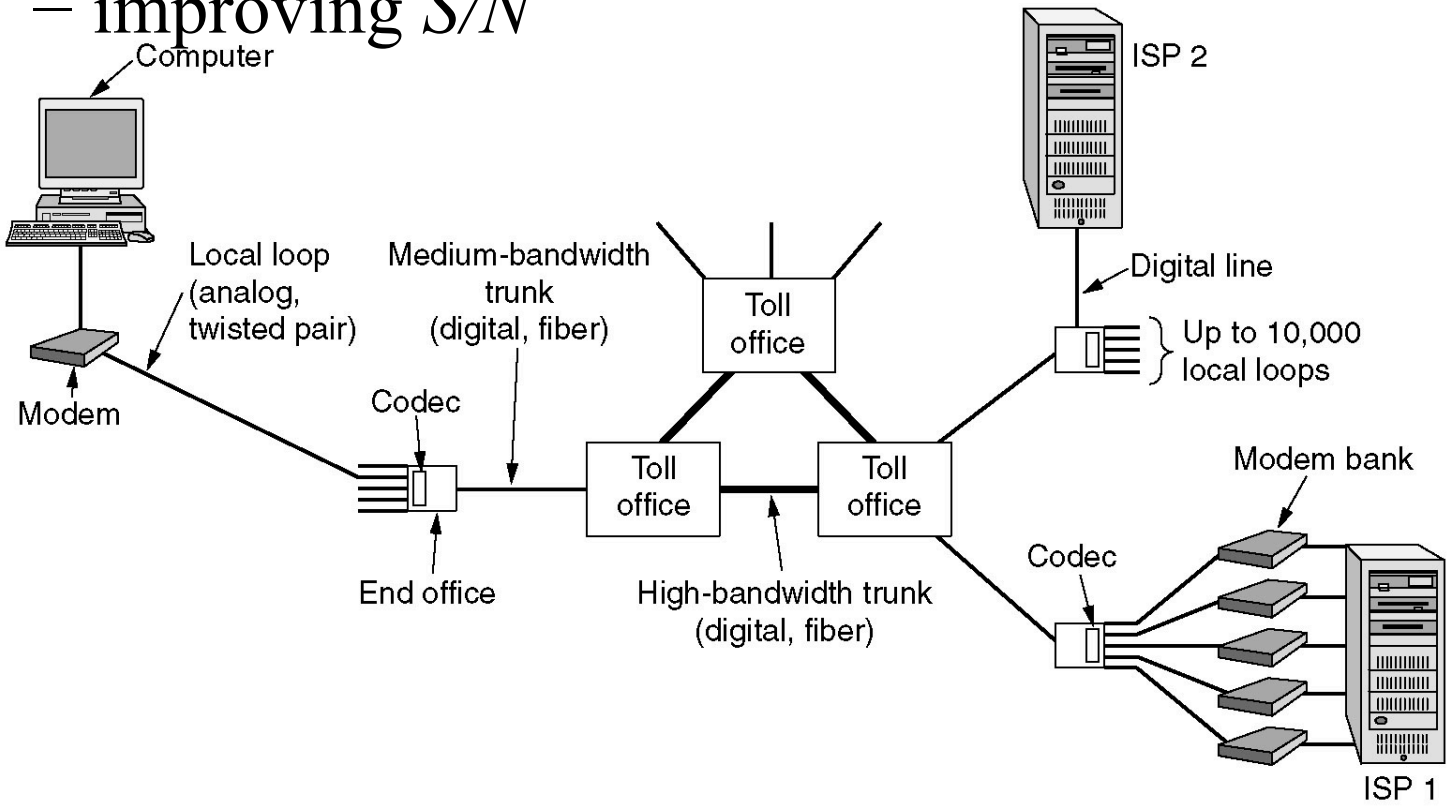
Internet access through phone line

- Analog dialup
  - Modem
  - telephone line
    - unshielded twisted pair (UTP)
  - up to 56Kbps downstream

(a)

Dialup ISP

- 56Kbps?
  - improving *S/N*

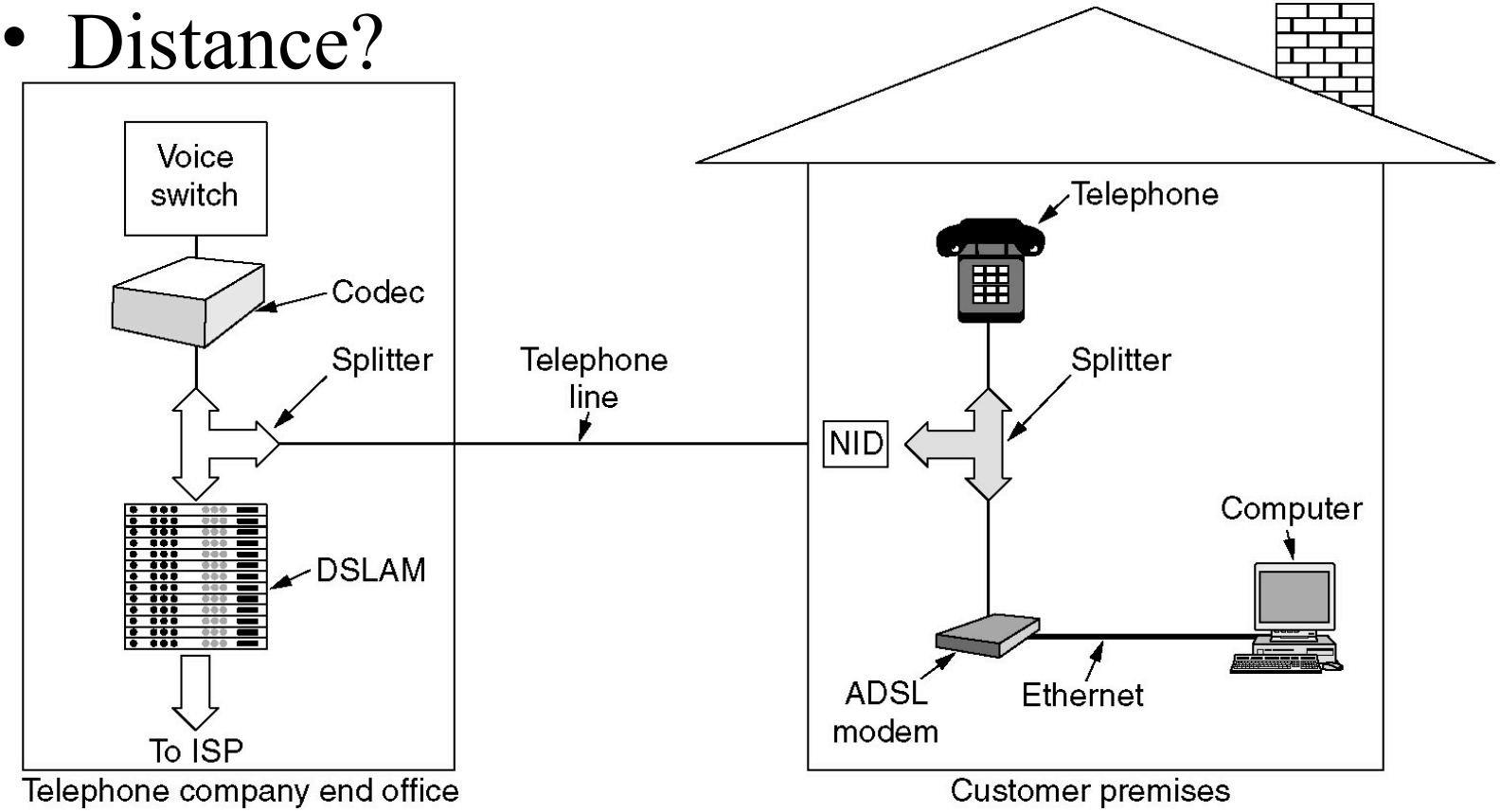


Digital subscriber lines

- Asymmetric DSL (ADSL)
  - free up more *H*
  - frequency division multiplexing (FDM)
    - or discrete multi-tone (DMT)
    - telephone: filter for regular phones
    - upstream: small bandwidth
    - downstream: larger bandwidth
  - DSL modem
    - Ethernet or USB connection to computer/router

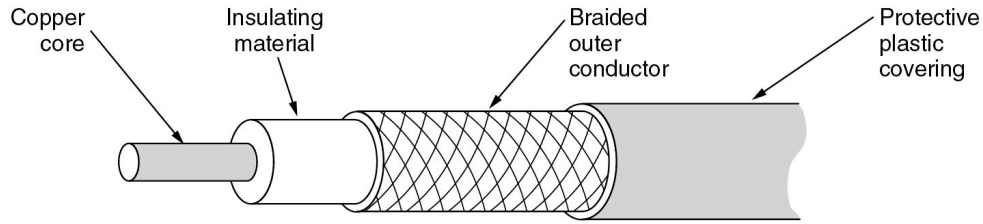
DSL ISP

- Distance?



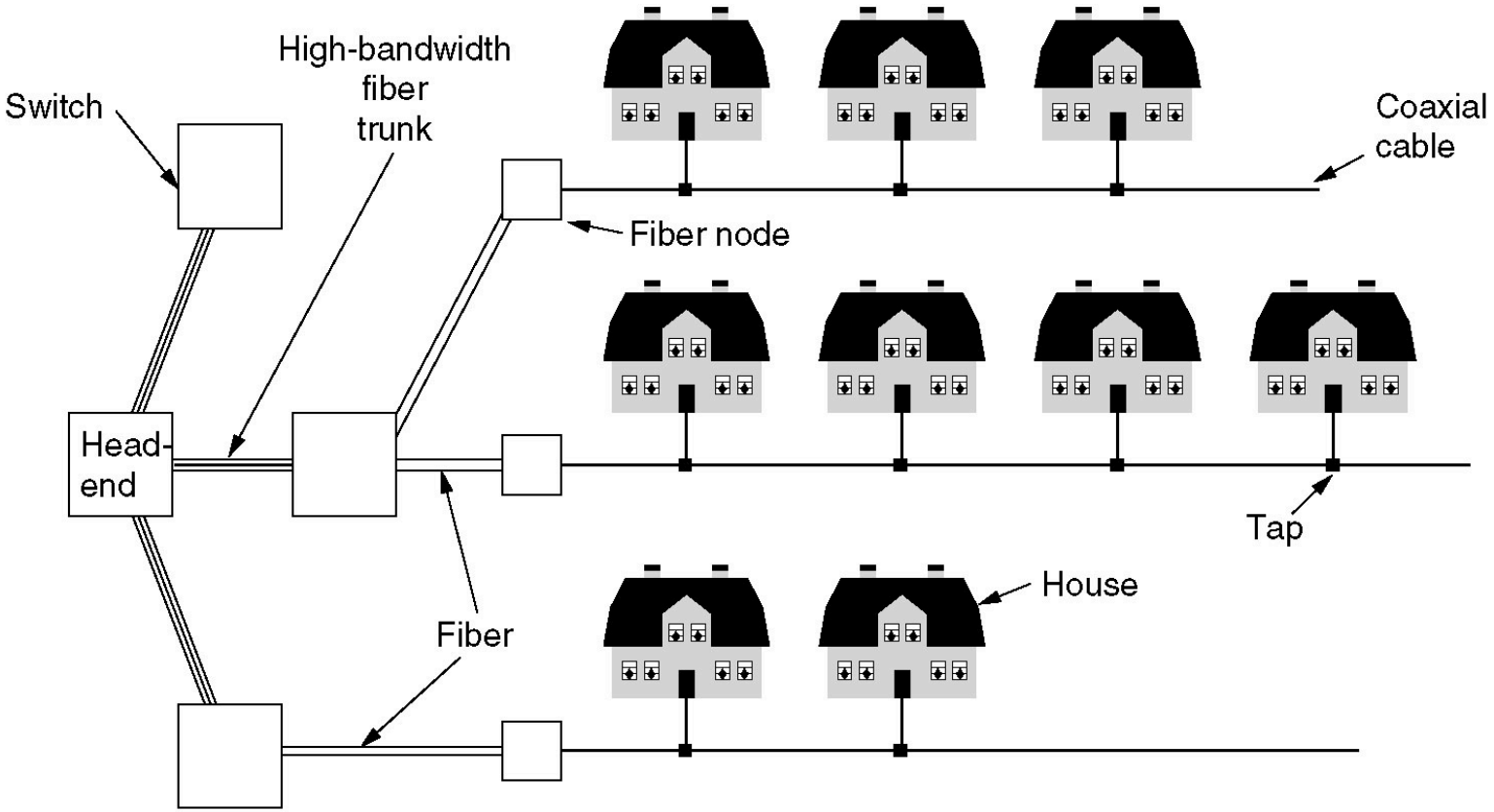
Internet access through cable line

- Traditionally, cable TV is 1-way broadcast
  - one-way amplifier
  - shared coaxial cable



- Internet access through HFC (DOCSIS)
  - two-way communication channels
    - small upstream bandwidth
    - larger downstream bandwidth
  - smaller (shared) cable segment
    - security

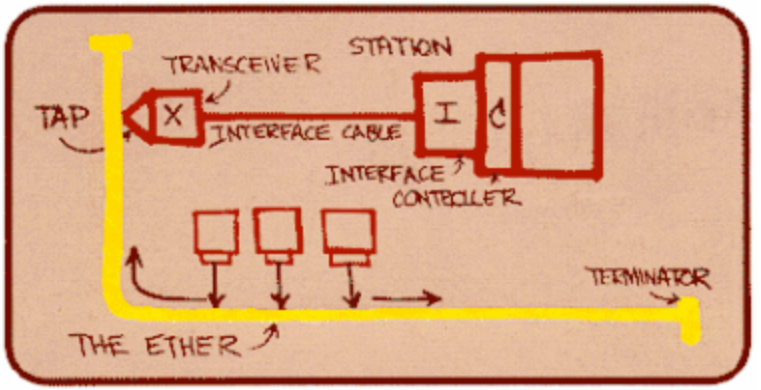
Cable ISP


Switch
High-bandwidth fiber trunk
Coaxial cable
Fiber node
Head-end
Tap
House
Fiber

(a)

Internet access through LAN

- UVicNet: switched Ethernet
  - RJ45 plug
  - UTP Cat3: 10Mbps
  - UTP Cat5: 100Mbps~1Gbps
  - UTP Cat6: 1Gbps~10Gbps
    - more twists per inch
- ResNet: 10Mbps switched
  - was 10Mbps shared



Internet access through WLAN

- WiFi (e.g., UVic AirNet)
  - 802.11b: 2.4GHz, 100ft@11Mbps
    - direct sequence spread spectrum
    - 11 overlapping channels
    - channel 1, 6, 11 independent
  - 802.11a: 5GHz, 54Mbps
    - orthogonal frequency division multiplexing
  - 802.11g: 2.4GHz, 54Mbps (OFDM)
  - 802.11n: 2.4GHz, 200 ~ 540 Mbps (OFDM +MIMO)
- Security

Internet access over the air

- Wireless MAN (metropolitan area network)
  - MMDS: 198MHz@2.5GHz
    - range: 25~50km; 3Mbps downstream 200Kbps up
  - LMDS: 1.3GHz@28~31GHz
    - range: 2~5km, line-of-sight!
    - wireless DSL: 36Gbps downstream 1Mbps up/sector
- IEEE 802.16: WiMax
  - 10~66GHz (802.16a: 2-11GHz NLOS), OFDM

Wireless*AN

- Personal area network
  - range: up to 10m
  - Bluetooth (802.15.1): 1Mbps; headset-to-phone
  - UWB (802.15.3a): 400Mbps; wireless USB
  - Millimeter wave (802.15.3c): 1~ 3Gbps
- Local area network (802.11)
  - range: up to 100m
- Metropolitan area network (802.16)
  - range: up to 50km

Internet access through cellular

- Cellular systems
  - 1st generation (80's): analog voice (9.6Kbps)
    - AMPS: cells, frequency reuse, cell split; FDMA
    - base station, mobile switching center, handoff
  - 2G (90's): digital voice (14.4Kbps)
    - TDMA, GSM, CDMA
    - 2.5G (~100Kbps): GPRS, EDGE, EV-DO, EV-DV
  - 3G: digital voice and data (384Kbps, 2Mbps)
    - WCDMA, CDMA2000, TD-SCDMA
  - 4G: multimedia services
    - Mobile WiMAX (802.16e), LTE
  - 5G: eMBB, URLLC, mMTC

Summary

- Internet access
  - phone line: dialup, DSL
  - cable line
  - LAN: Ethernet
  - wireless: WiFi, WiMax, cellular
- Explore further
  - compare your Internet access with your friend's
  - FTTH: fiber to the home!

Next

- Internet backbone