Computer Networks

CMP2205

Lecture 4

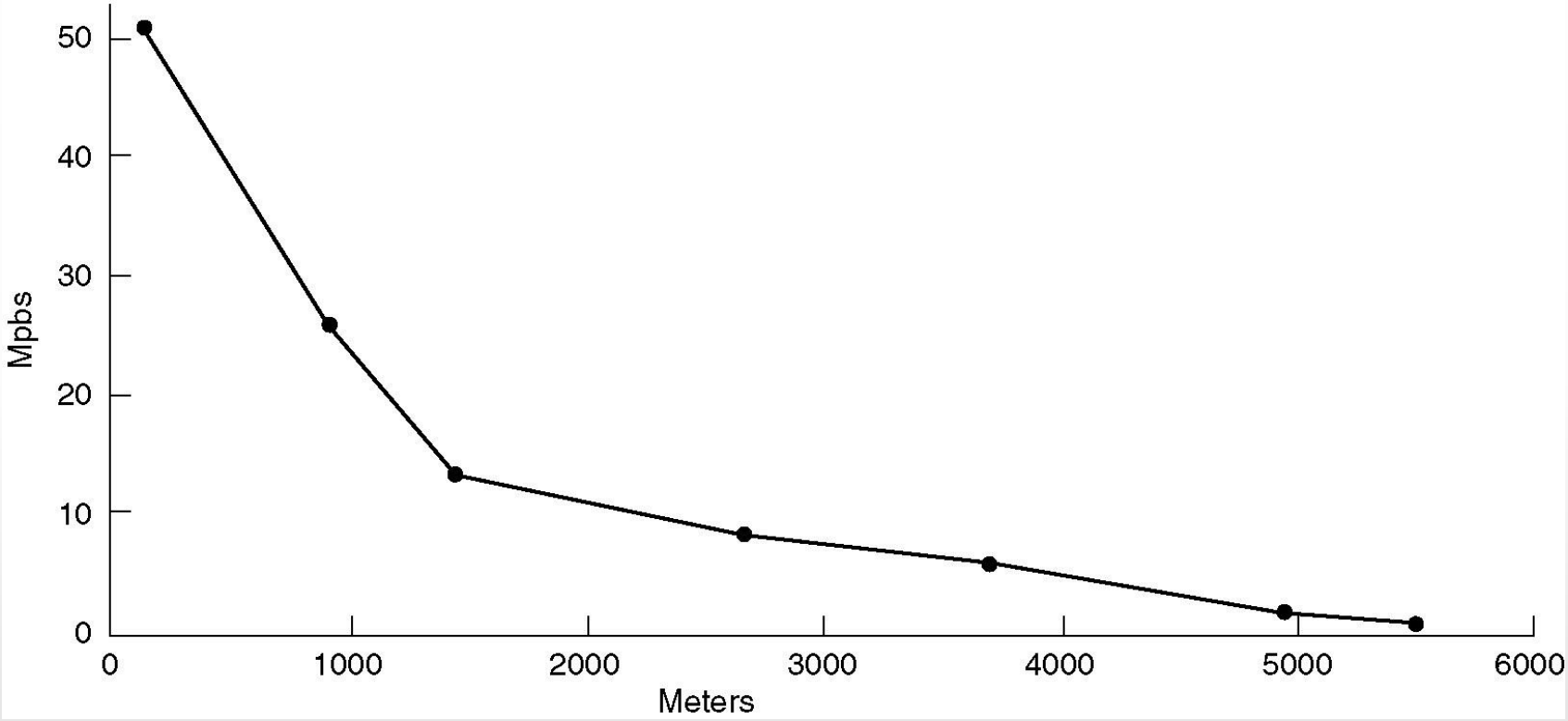
Full Duplex, Half Duplex, Simplex

- *Full duplex: traffic in both directions simultaneously.*
- *Half duplex: traffic in both directions but 1 direction at a time.*
- *Simplex: traffic allowed only one way.*
- *Examples?*

What's next?

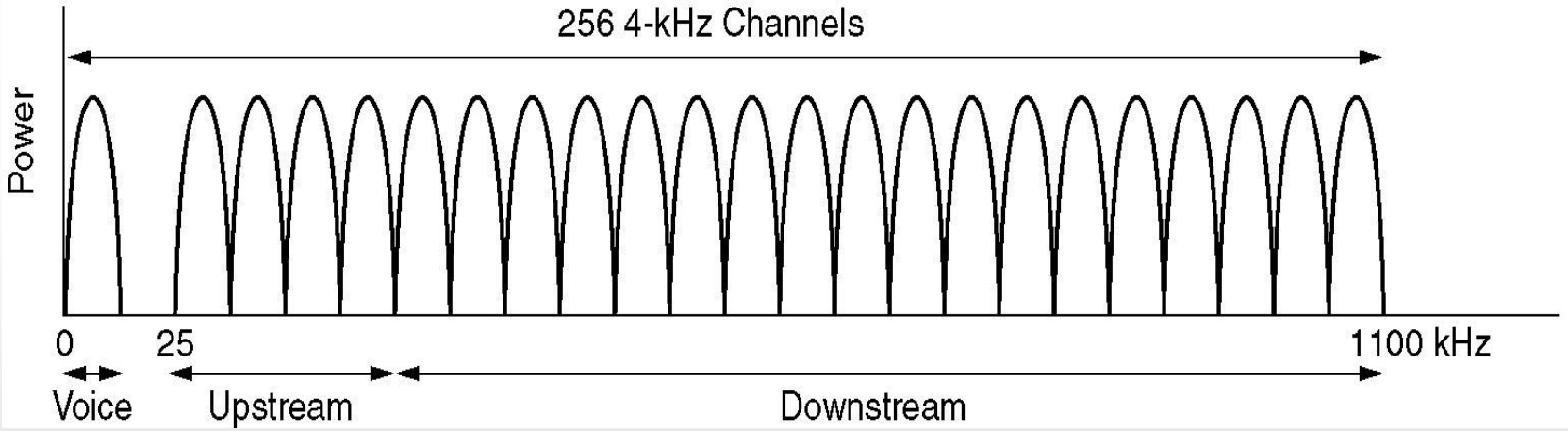
- *Modems were getting faster, e.g., 56Kbps.*
- *But, demand for faster access was growing!*
- *CATV and satellite as competitors.*
- *Phone company's response: DSL.*
  - *"Broadband" access.*
  - *ADSL: asymmetric digital subscriber line.*
  - *When you subscribe to DSL service, you are connected to the local office without the filter to frequencies below 300Hz and above 3400Hz.*
  - *Physical limitation still exists and depends on thickness, length, etc.*

Digital Subscriber Lines



Digital Subscriber Lines (2)

- *Operation of ADSL using discrete multitone modulation.*

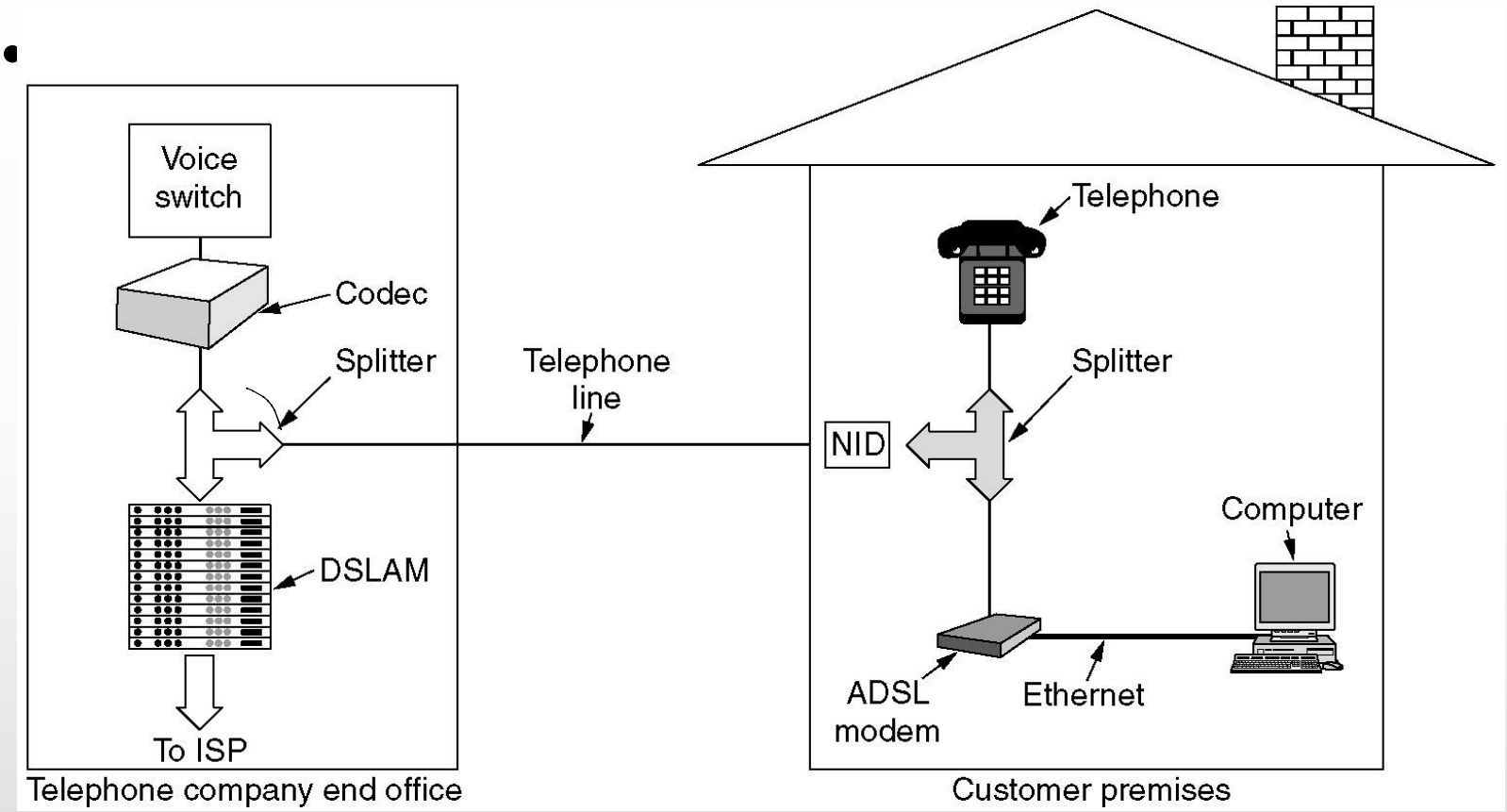


Available 1.1MHz local loop spectrum divided into 256 channels (4.3KHz each).

ADSL

- *Typically, 32 channels for upstream and the rest for downstream traffic.*
- *Usually, 512 Kbps downstream and 64 Kbps upstream (standard) and 1 Mbps downstream and 256 Kbps upstream (premium).*
- *Within each channel, modulation scheme is used (sampling at 4000 baud).*

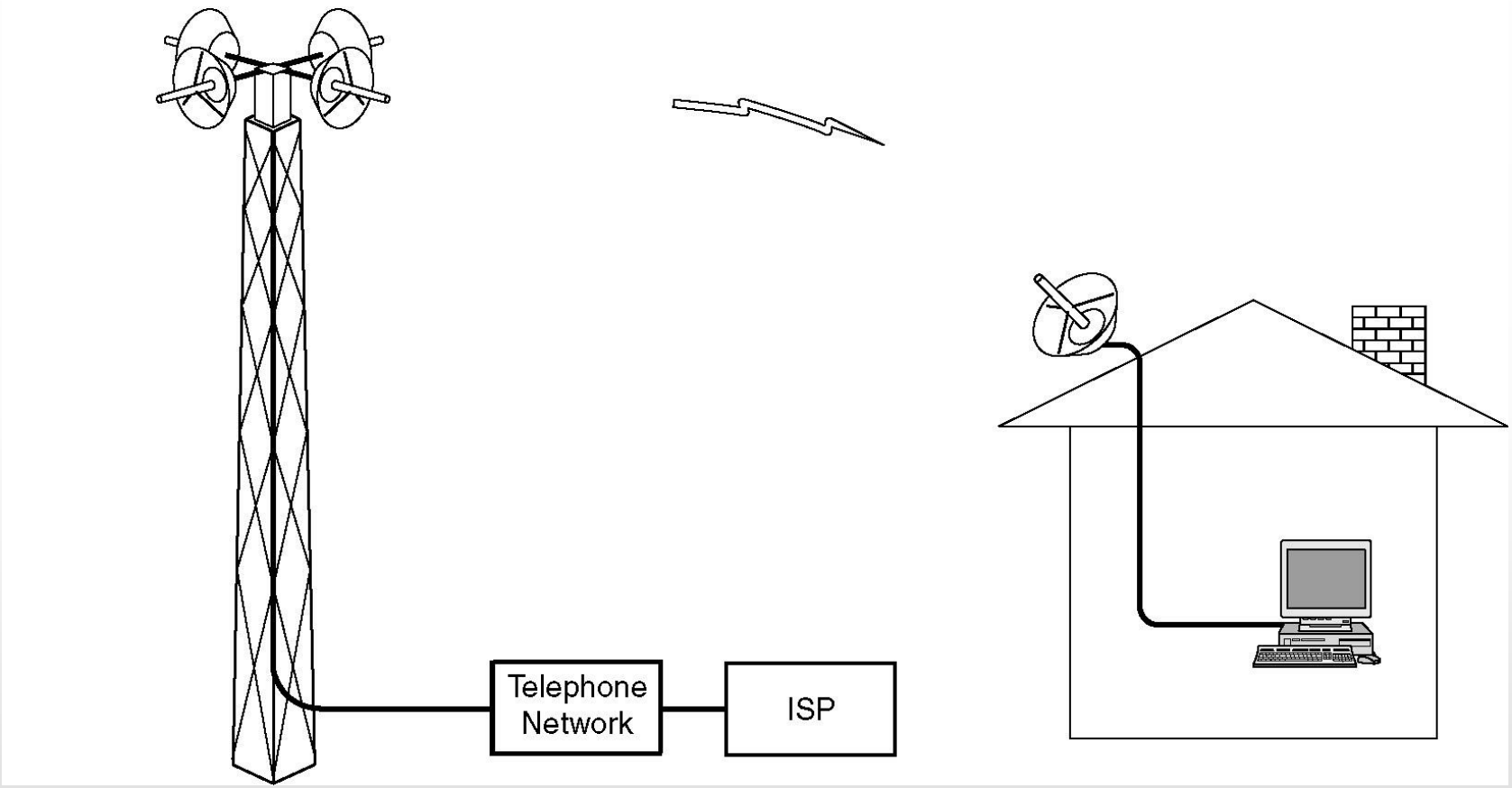
Typical ADSL Setup



Wireless Local Loop

- *Last mile is wireless.*
- *Why?*
- *Historically: local telcos had monopoly for local telephone service.*
  - *In the mid 1990's market open to competition, e.g., long distance carriers.*
  - *Cheaper alternative to stringing cables to customers is using a wireless local loop.*
- *Mobile telephony?*
- *"Fixed" wireless.*

Wireless Local Loops

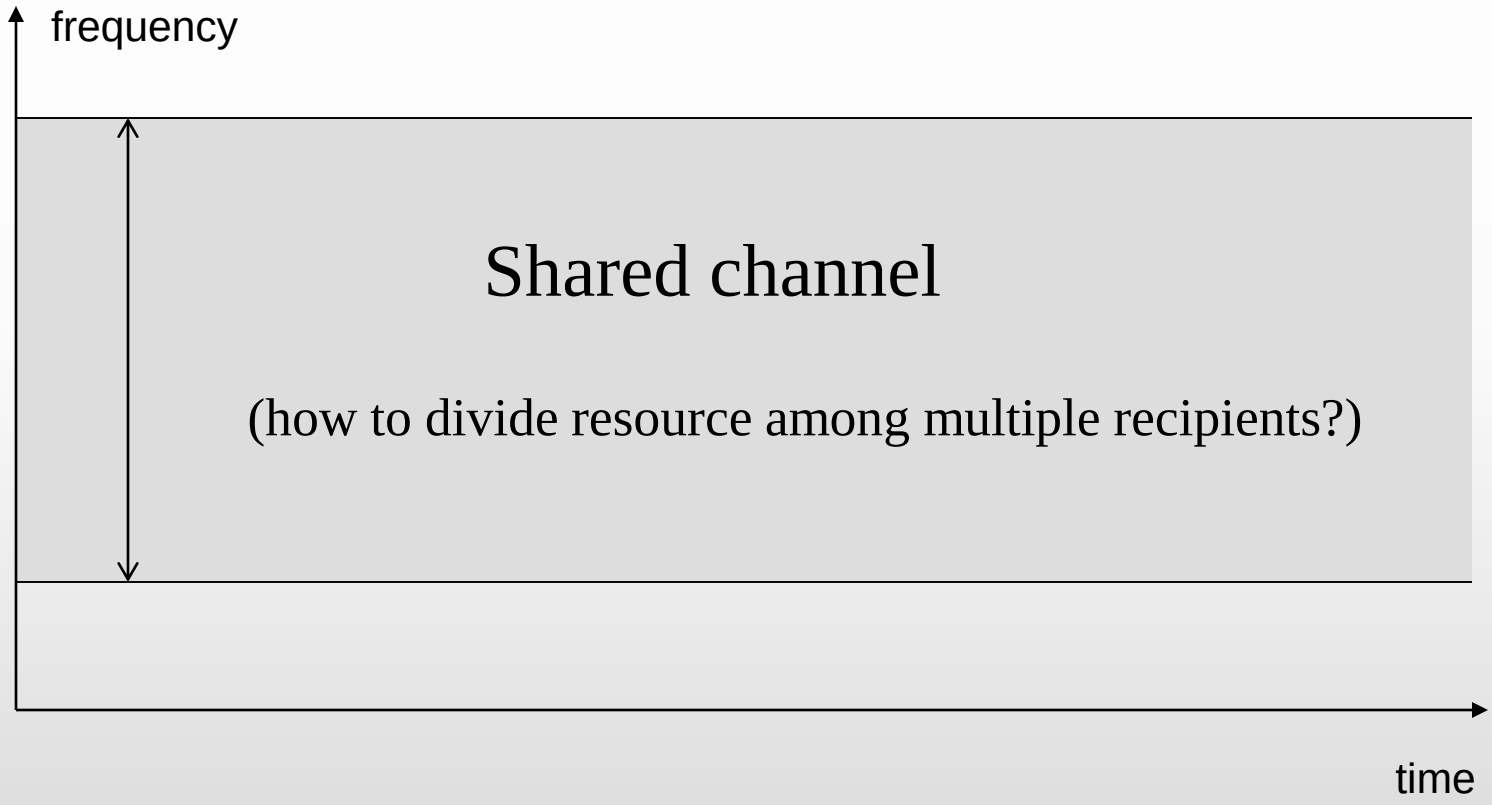


Tower with multiple highly directional antennae; but small range (2-5Km).

Trunking

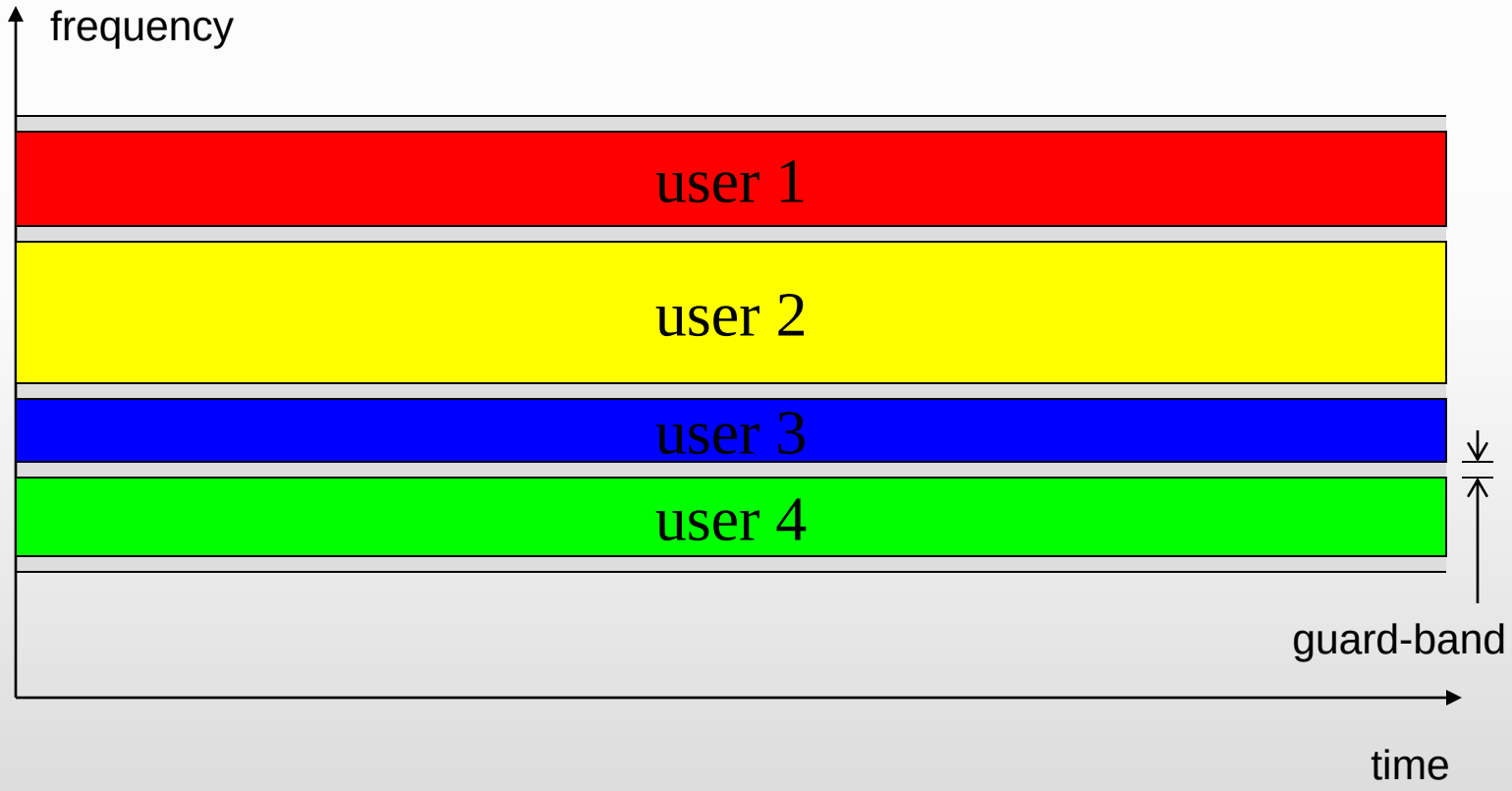
- *Deployment of high-bandwidth pipes.*
  - *Current and future demand.*
  - *Switching offices higher in the PSTN hierarchy.*
- *Multiplexing: ability to send a number of conversations simultaneously over the same pipe.*
- *Multiplexing schemes:*
  - *Frequency Division Multiplexing (FDM).*
  - *Time Division Multiplexing (TDM).*

The Multiplexing Problem



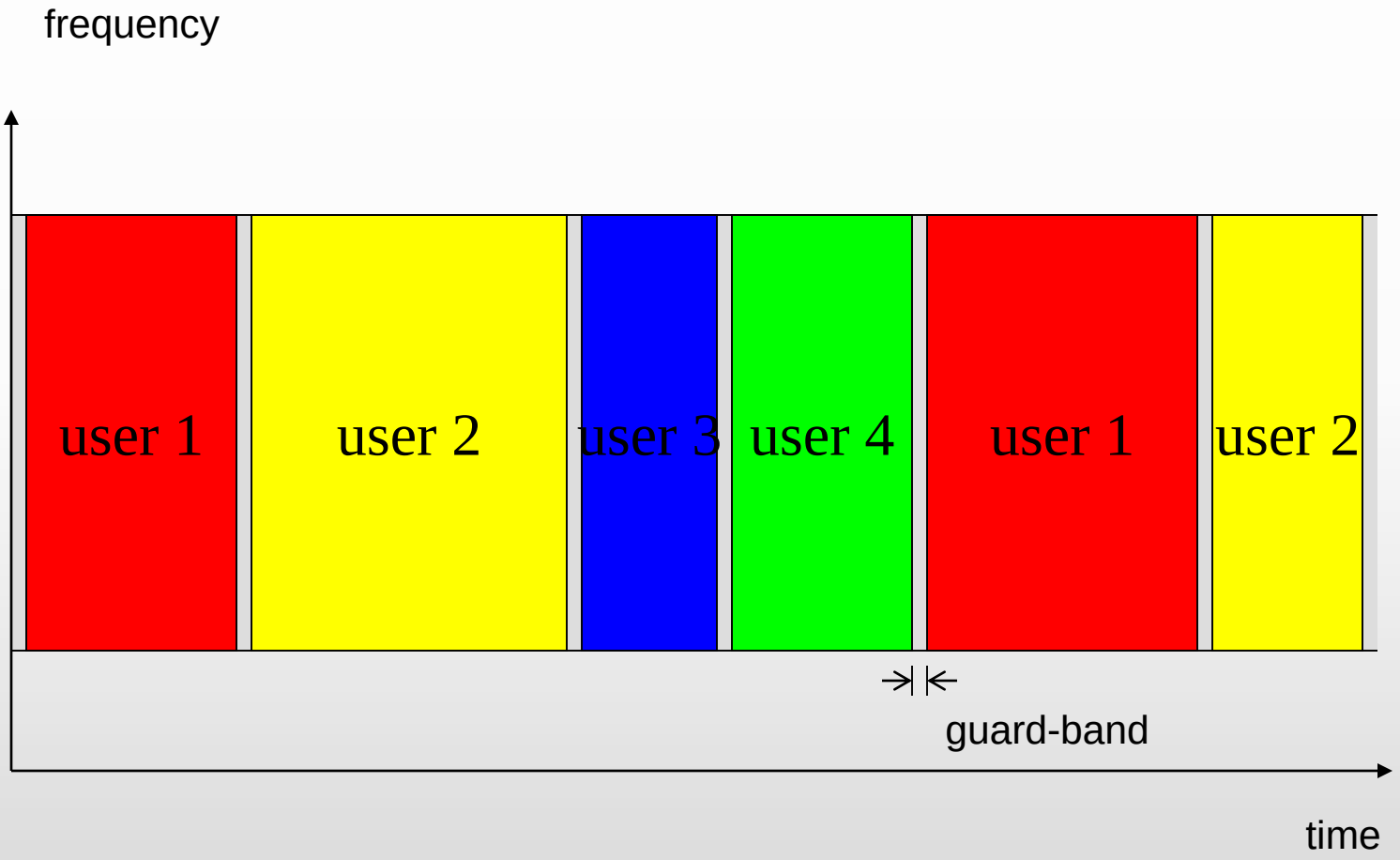
Analogy: a highway shared by many users

Frequency-Division Multiplexing



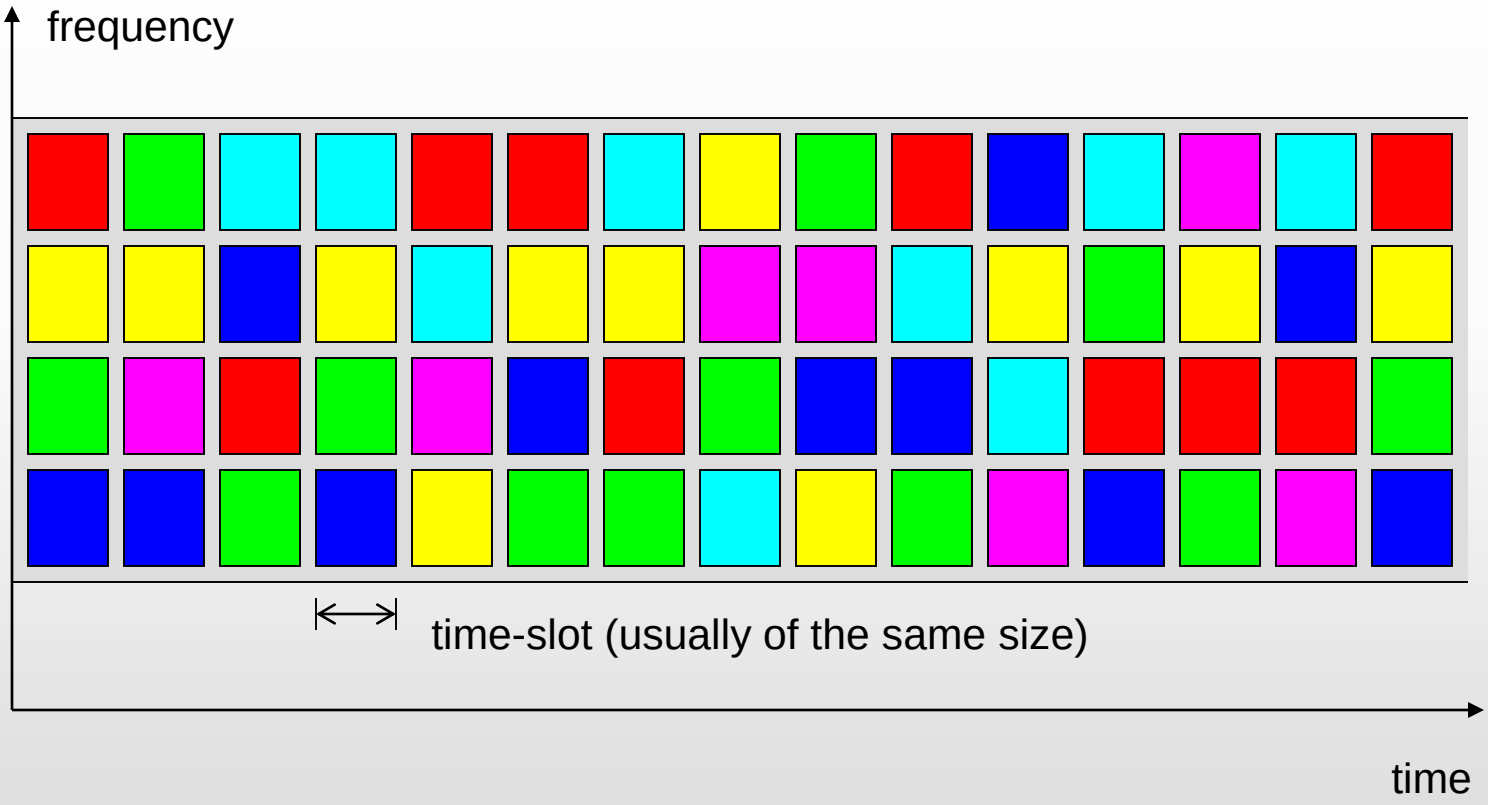
Analogy: a highway has multiple lanes

Time-Division Multiplexing

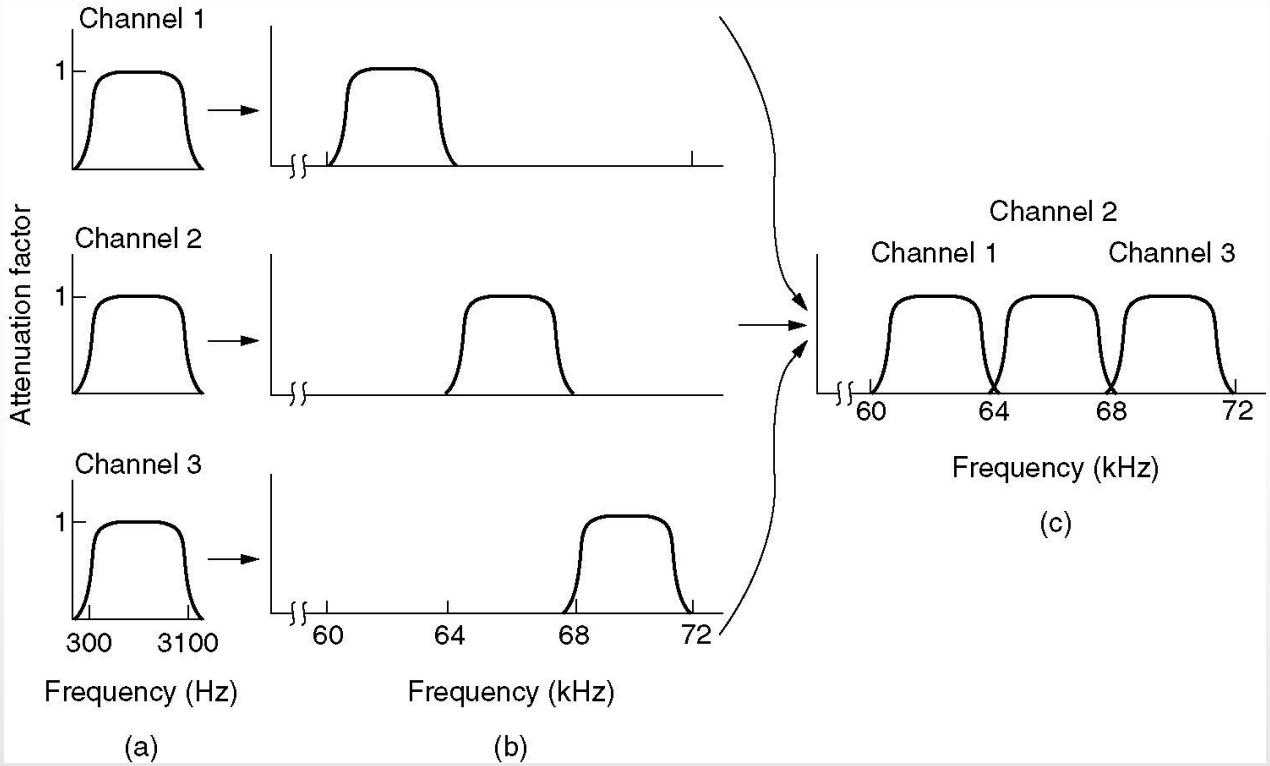


Requirement: precise time coordination

Frequency-Time-Division



Frequency Division Multiplexing

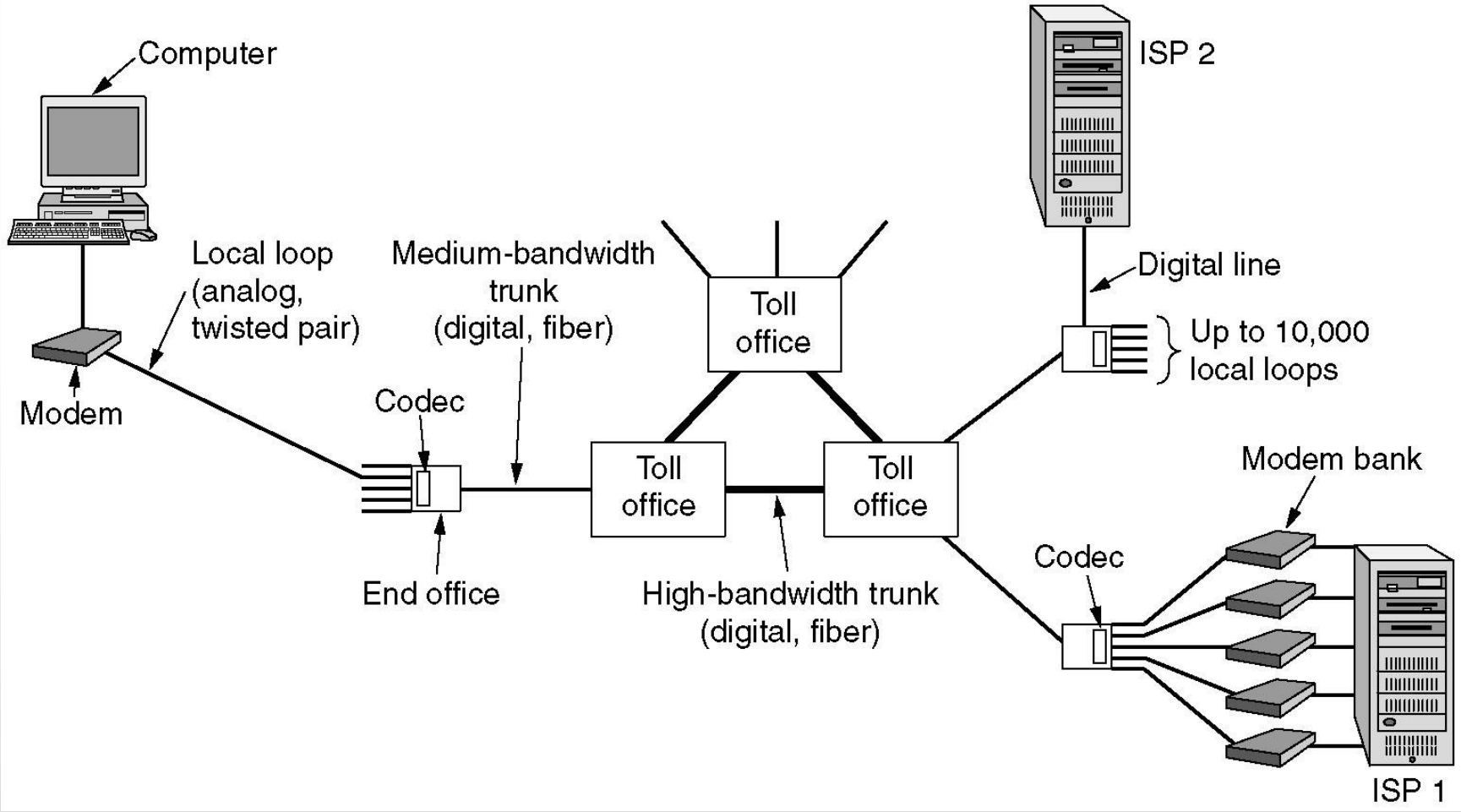


- *(a) The original bandwidths.*
- *(b) The bandwidths raised in frequency.*
- *(c) The multiplexed channel.*

FDM versus TDM

- *FDM requires analog circuitry.*
- *TDM can be done entirely using digital electronics.*
- *But TDM can only be used for digital data.*
  - *Analog signals from local loops need to be digitized (at the local office).*
  - *At end office, all individual local loops arrived, are digitzed, and multiplexed.*

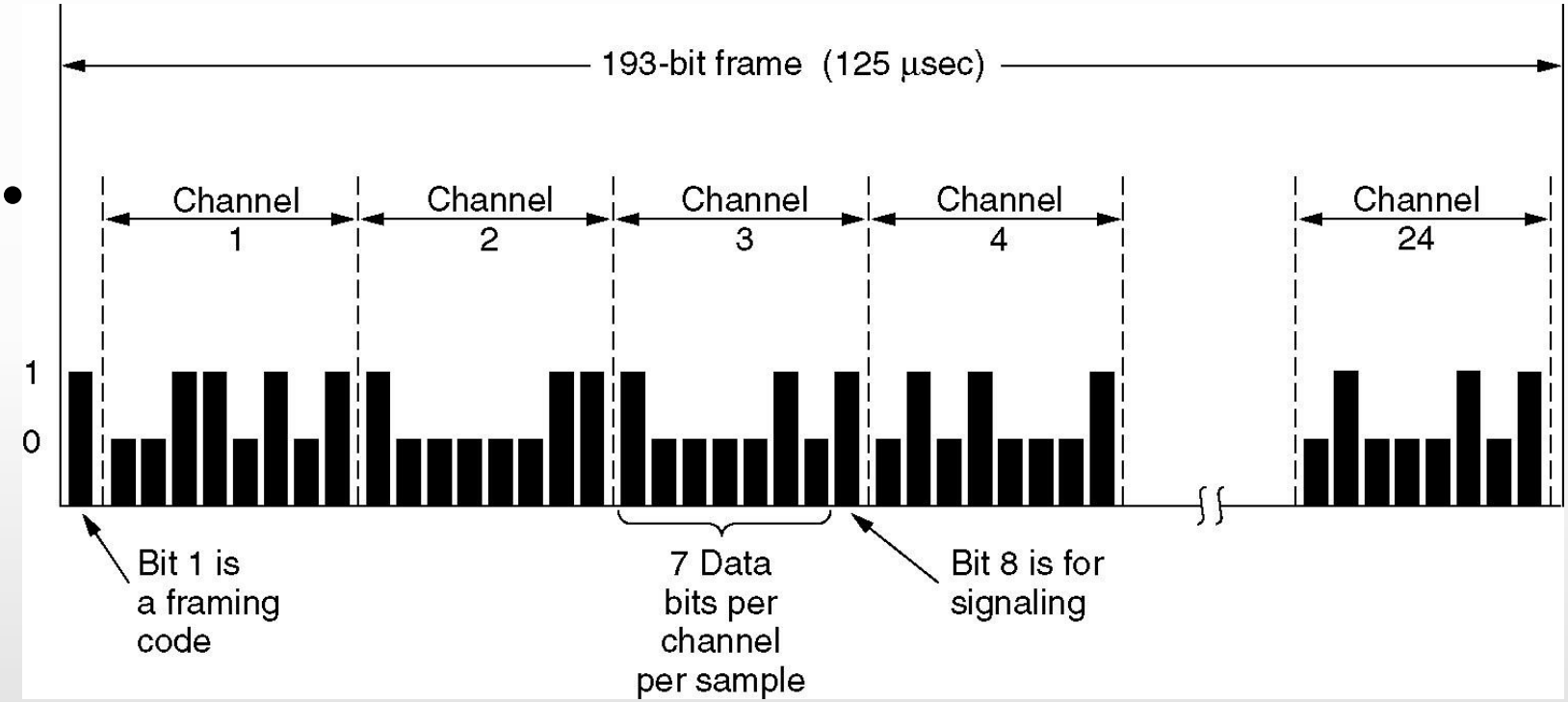
TDM Multiplexing



PCM

- *Pulse Code Modulation:*
  - *Digitization of voice channels.*
  - *Sampling frequency…*
    - *If voice signal peaks at 4KHz, what's the sampling frequency?*
    - *Nyquist: 8000 samples/sec, or 125 microsec/sample.*
    - *Each sample is 8 bits (7 for data and 1 for control).*
    - *Data rate: 7*8000 = 56Kbps of data and 8Kbps of signaling (per channel).*
- *No world-wide standard for PCM.*
- *In the US and Japan: T1 (technically DS1).*

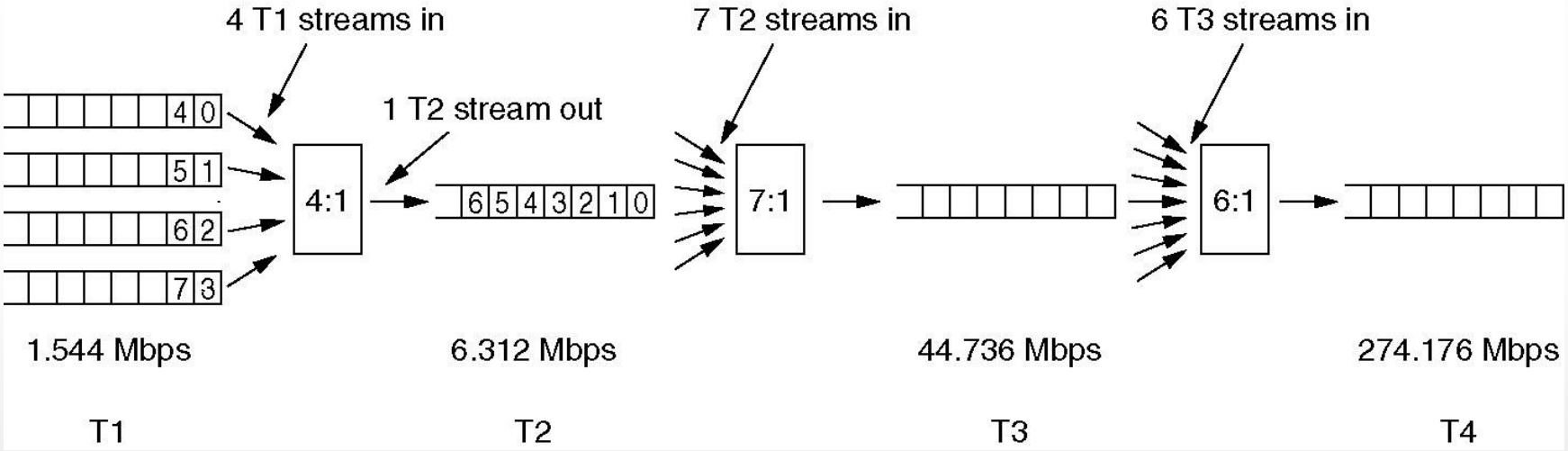
T1



T1: 24 multiplexed voice channels: 1.544 Mbps.

T2 and Beyond…

- *Multiplexing T1 streams into higher carriers.*



SONET/SDH

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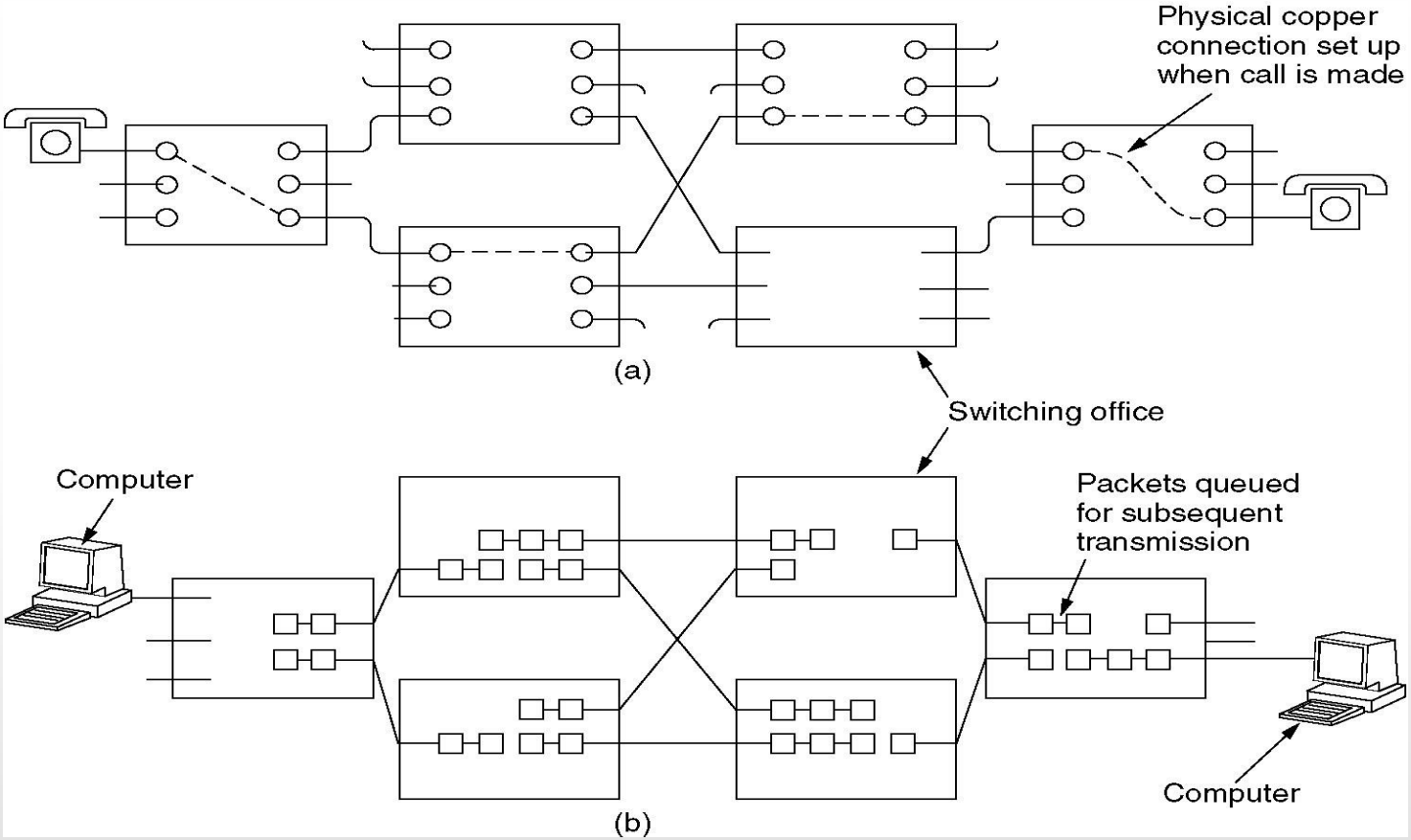
SONET		SDH	Data rate (Mbps)		
Electrical	Optical	Optical	Gross	SPE	User
STS-1	OC-1		51.84	50.112	49.536
STS-3	OC-3	STM-1	155.52	150.336	148.608
STS-9	OC-9	STM-3	466.56	451.008	445.824
STS-12	OC-12	STM-4	622.08	601.344	594.432
STS-18	OC-18	STM-6	933.12	902.016	891.648
STS-24	OC-24	STM-8	1244.16	1202.688	1188.864
STS-36	OC-36	STM-12	1866.24	1804.032	1783.296
STS-48	OC-48	STM-16	2488.32	2405.376	2377.728
STS-192	OC-192	STM-64	9953.28	9621.504	9510.912

SONET: Synchronous Optical NETwork.
SDH: Sync Digital Hierarchy.

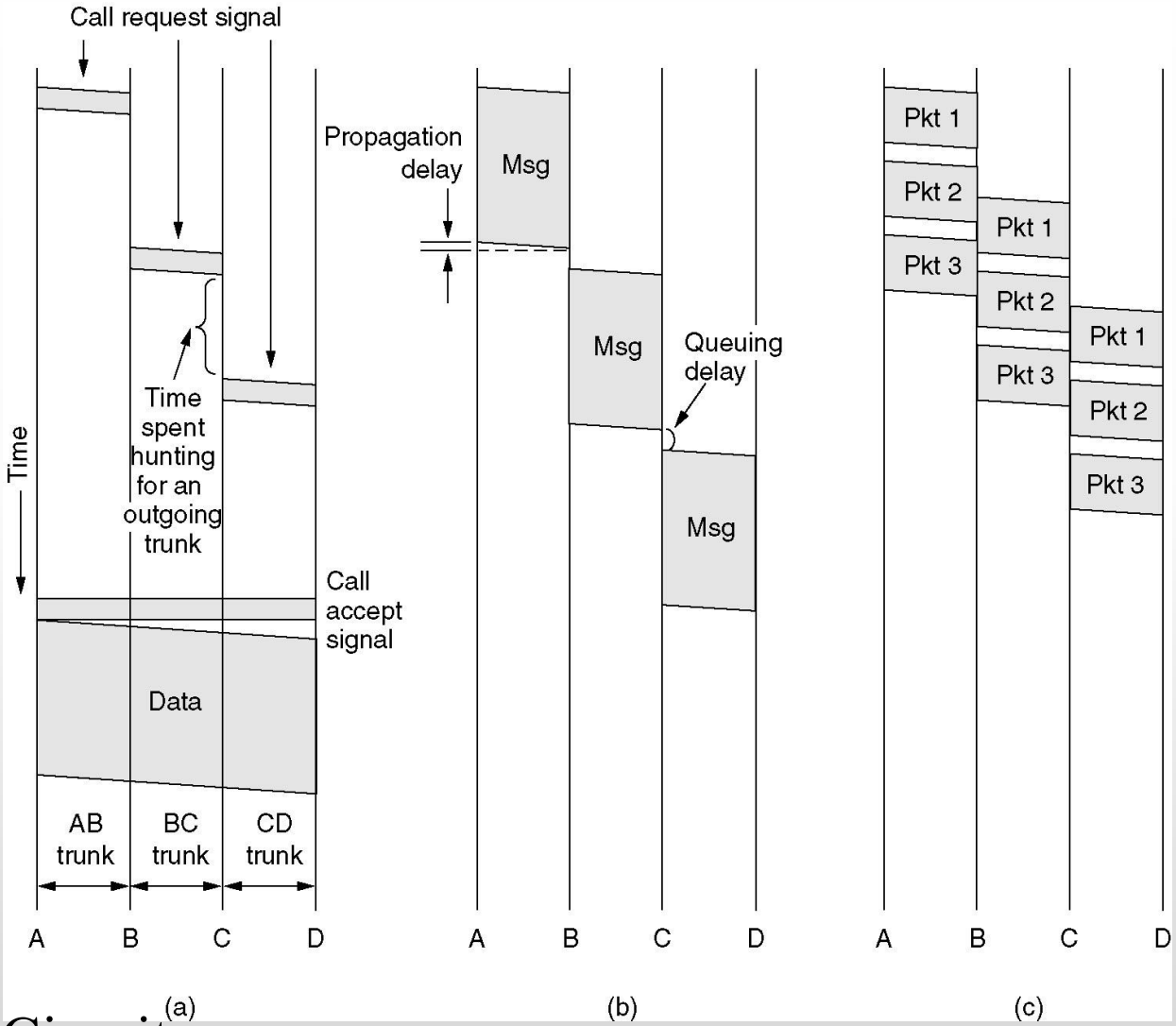
] Optical TDM for fiber transmission

Circuit- and Packet Switching



- *(a) Circuit switching.*
- *(b) Packet switching.*

Switching



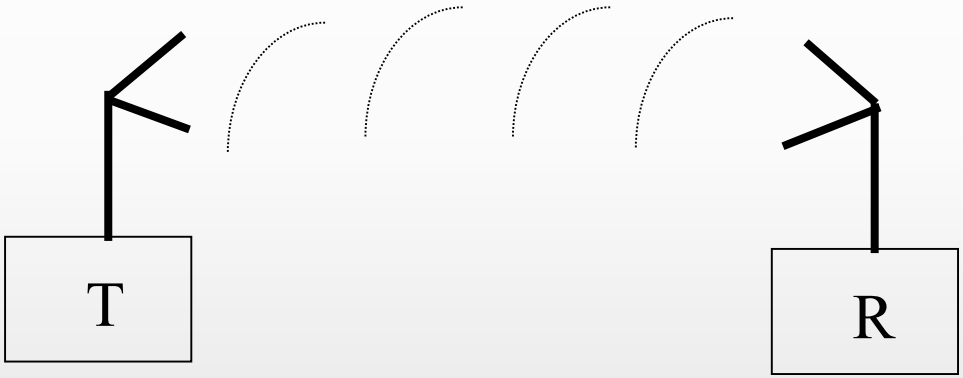
Circuit- Message- Packet Switching

Packet Switching

Item	Circuit-switched	Packet-switched
Call setup	Required	Not needed
Dedicated physical path	Yes	No
Each packet follows the same route	Yes	No
Packets arrive in order	Yes	No
Is a switch crash fatal	Yes	No
Bandwidth available	Fixed	Dynamic
When can congestion occur	At setup time	On every packet
Potentially wasted bandwidth	Yes	No
Store-and-forward transmission	No	Yes
Transparency	Yes	No
Charging	Per minute	Per packet

Wireless Transmission

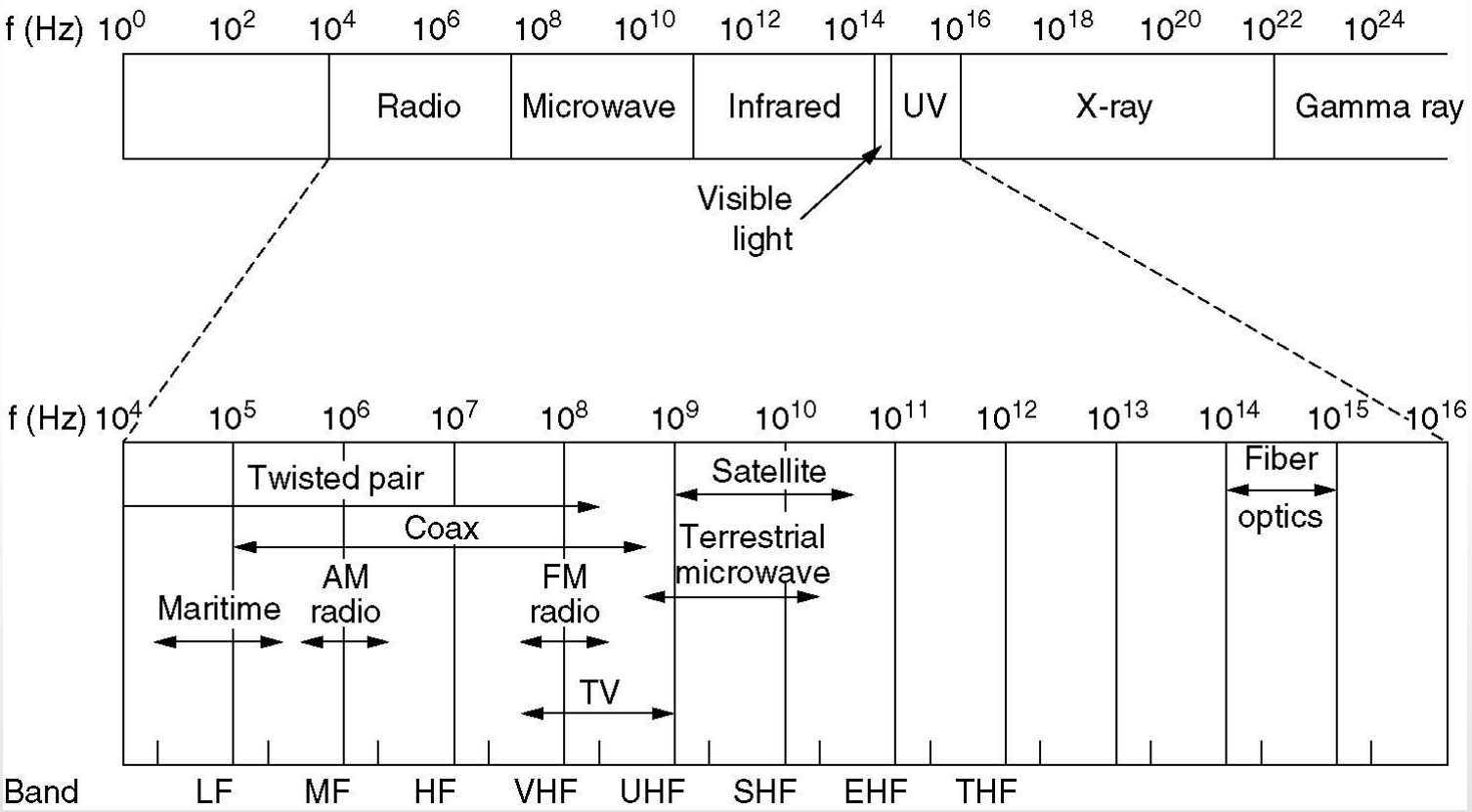
- *Electron movement: electromagnetic waves that propagate through space.*



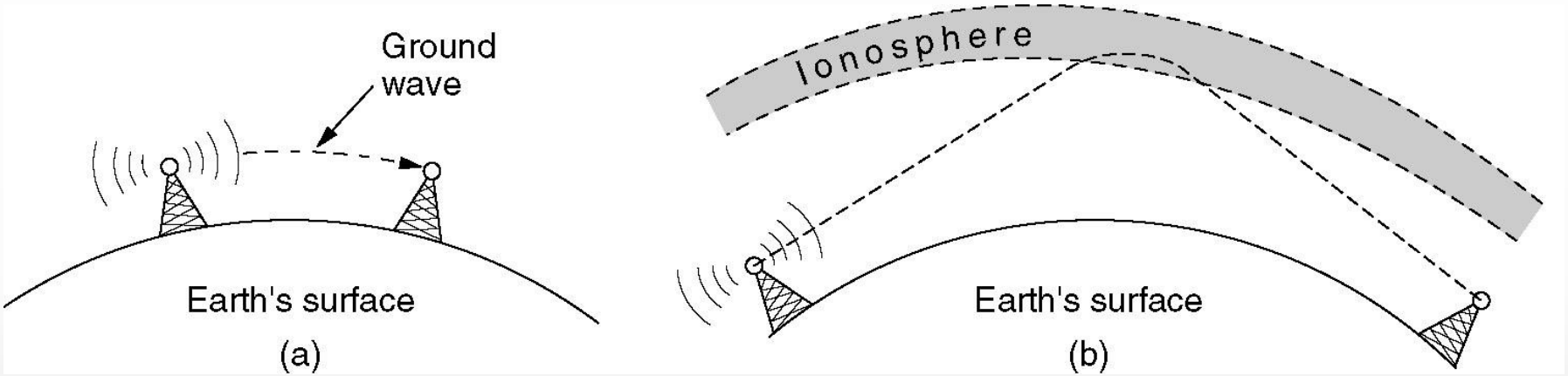
Propagation

- *Maximum speed: speed of light,* **c**, *$3*10^8$ m/s.*
- *In vacuum, all EM waves travel at the same speed* **c**.
- *Otherwise, propagation speed is function of frequency ($c = \lambda * f$), where f is frequency (Hz) and λ is wavelength (m).*

The Electromagnetic Spectrum



Radio Transmission



~1Km

- *(a) In the VLF, LF, and MF bands, radio waves follow the curvature of the earth. E.g., AM radio uses MF.*
- *(b) In the HF and VHF bands, they bounce off the ionosphere. E.g., Hams and military.*

Microwave Transmission

- *Above 100MHz.*
- *Waves travel in straight lines.*
- *Directionality.*
  - *Better quality.*
  - *Space Division Multiple Access.*
  - *But, antennas need to be aligned, do not go through buildings, multi-path fading, etc.*
- *Before fiber, microwave transmission dominated long-distance telephone transmission.*

Infrared Transmission

- *Short range (e.g., remote controls).*
- *Directional, cheap.*
- *But, do not pass through obstacles.*

Lightwave Transmission

- *E.g., laser communication between two buildings for LAN interconnection.*
- *High bandwidth, low cost.*
- *Unidirectionality.*
- *Weather is a major problem (e.g., rain, convection currents).*