Introduction to Physical Layer

Computer Networks
Term B14

Physical Layer Outline

- Definitions
- Multiplexing
- Transmission Media
- End System Choices
- Residential Configurations

Physical Layer Definitions

- The time required to transmit a character depends on both the encoding method and the signaling speed (i.e., the modulation rate - the number of times/sec the signal changes its voltage).
- baud (D) - the number of changes per second.
- bandwidth (H) - the range of frequencies that is passed by a channel. The transmitted signal is constrained by the transmitter and the nature of the transmission medium in cycles/sec (hertz).
- channel capacity (C) – the rate at which data can be transmitted over a given channel under given conditions.{This is also referred to as data rate (R).}

Modulation Rate

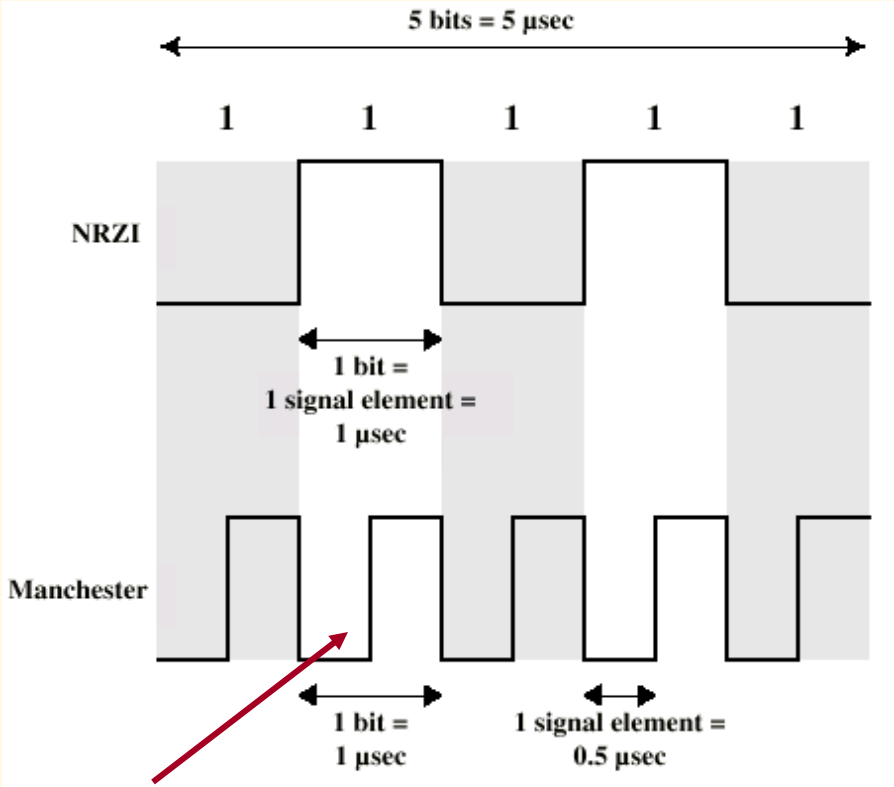

Figure 5.5 A Stream of Binary Ones at 1 Mbps

modulation rate is doubled

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Analog and Digital Signaling

signals:: electric or electromagnetic encoding of data.

signaling:: is the act of propagating the signal along a suitable medium.

Analog signal – a continuously varying electromagnetic wave that may be propagated over a variety of medium depending on the spectrum (e.g., wire, twisted pair, coaxial cable, fiber optic cable and atmosphere or space propagation).

Analog and Digital Signaling

digital signal – a sequence of voltage pulses that may be transmitted over a wire medium.

Note – analog signals to represent analog data and digital signals to represent digital data are not the only possibilities.

There is where modems and codecs come into the picture.

Analog vs Digital (three contexts)

Analog data	Two alternatives: (1) signal occupies the same spectrum as the analog data; (2) analog data are encoded to occupy a different portion of spec-trum.	Analog data are encoded using a codec to produce a digital bit stream. codec
Digital data	Digital data are encoded using a modem to produce analog signal. modem	Two alternatives: (1) signal consists of two voltage levels to represent the two binary values; (2) digital data are encoded to produce a digital signal with desired properties.

(a) Data and signals

	Analog transmission	Digital transmission
Analog signal	Is propagated through amplifiers; same treatment whether signal is used to represent analog data or digital data.	Assumes that the analog signal repre-sents digital data. Signal is propa-gated through repeaters; at each repeater, digital data are recovered from inbound signal and used to gen-eratea new analog outbound signal.
Digital signal	Not used	Digital signal represents a stream of 1s and 0s, which may represent digital data or may be an encoding of analog data. Signal is propagated through repeaters; at each repeater, stream of 1s and 0s is recovered from inbound singal and used to generate a new digital outbound signal.

(b) Treatment of signals

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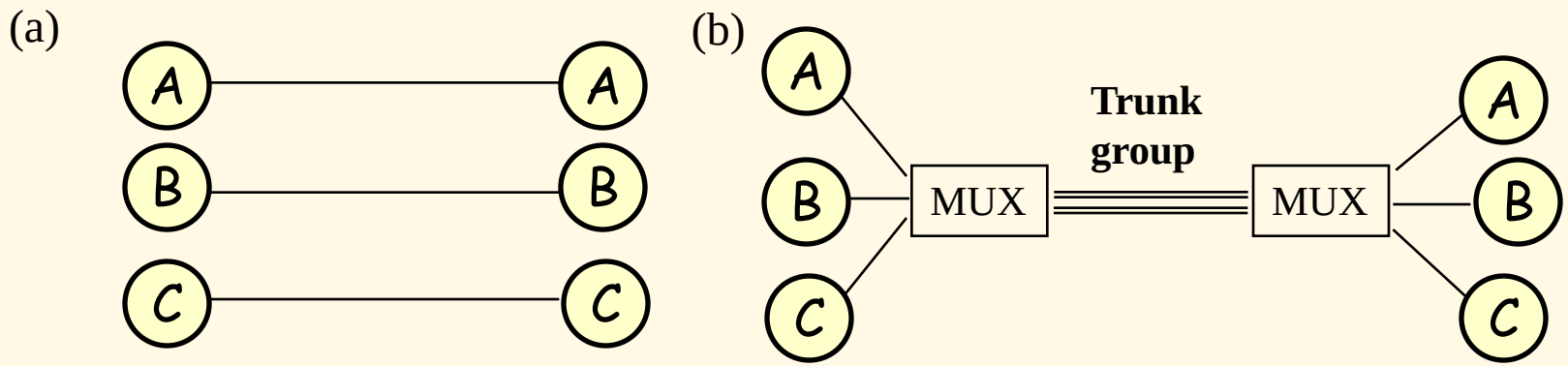
Multiplexing

Multiplexing {general definition} ::

Sharing a resource over time.



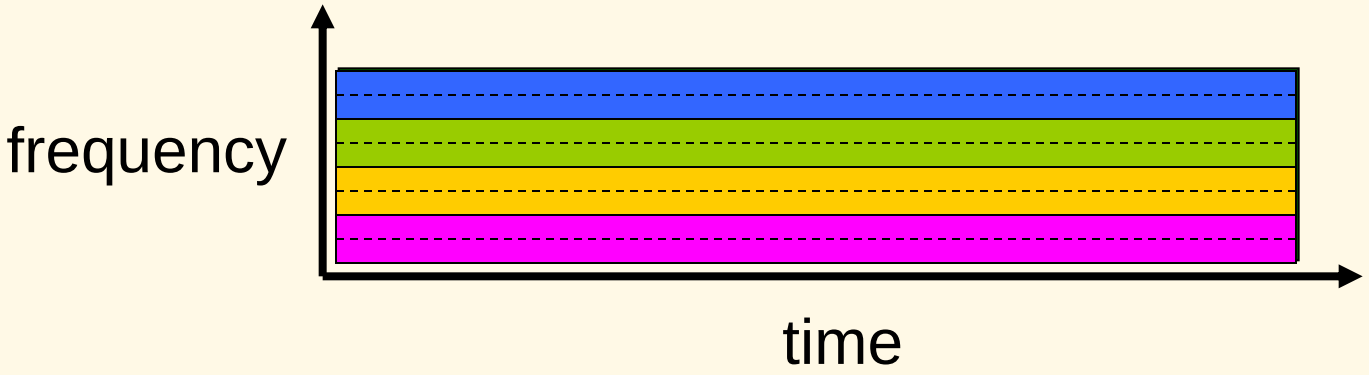
Leon-Garcia & Widjaja: *Communication Networks*

Frequency Division Multiplexing (FDM) vs Time Division Multiplexing (TDM)

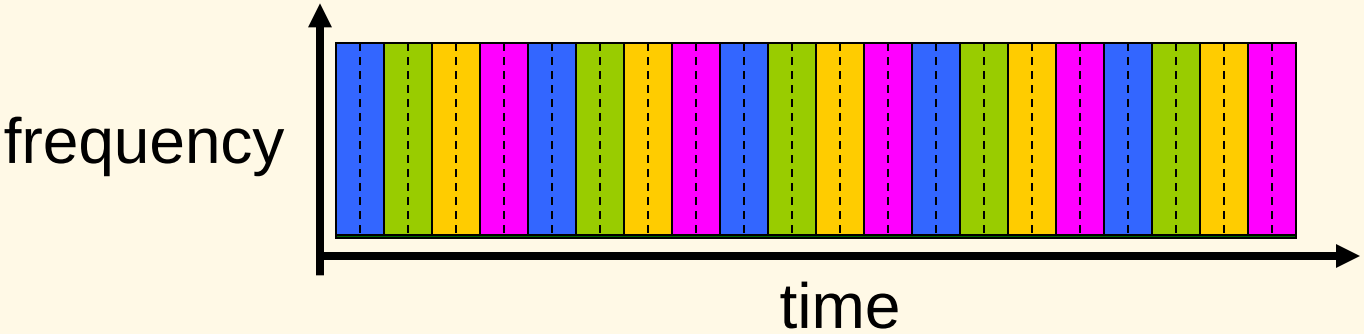
Example:

4 users

FDM



TDM



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Frequency Division Multiplexing

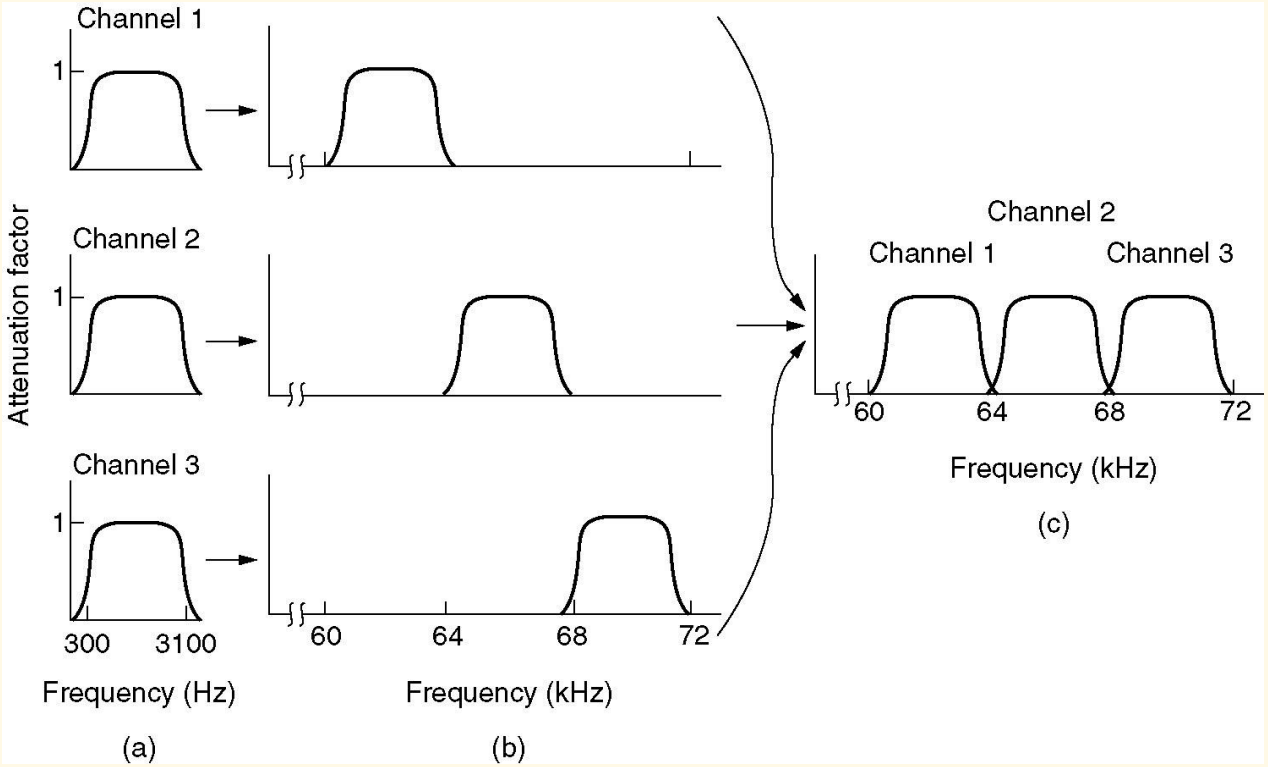

Figure 2-31. (a) The original bandwidths. (b) The bandwidths raised in frequency. (c) The multiplexed channel.

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T1 - TDM Link

TDM:: each host gets a fixed slot in revolving TDM frame

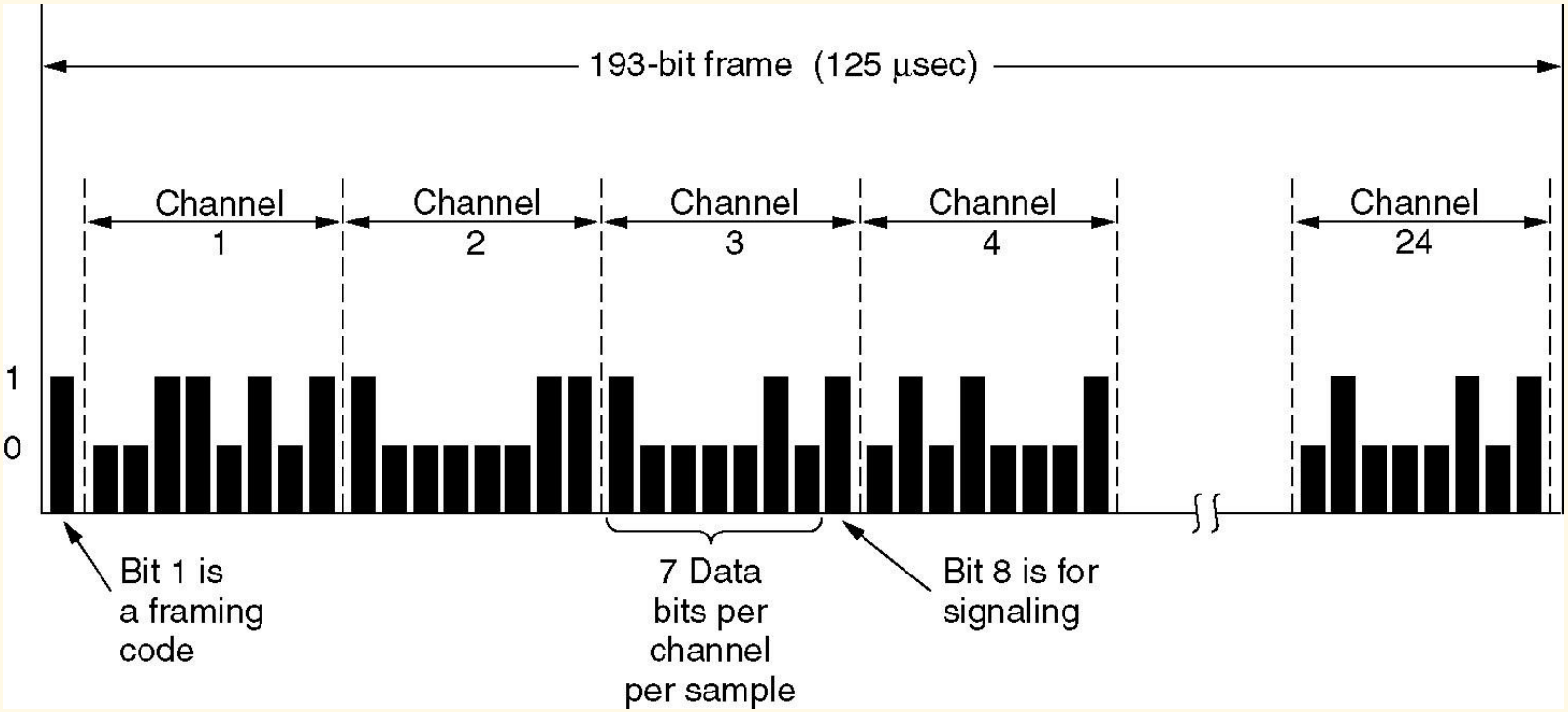

Figure 2-33.T1 Carrier (1.544Mbps)

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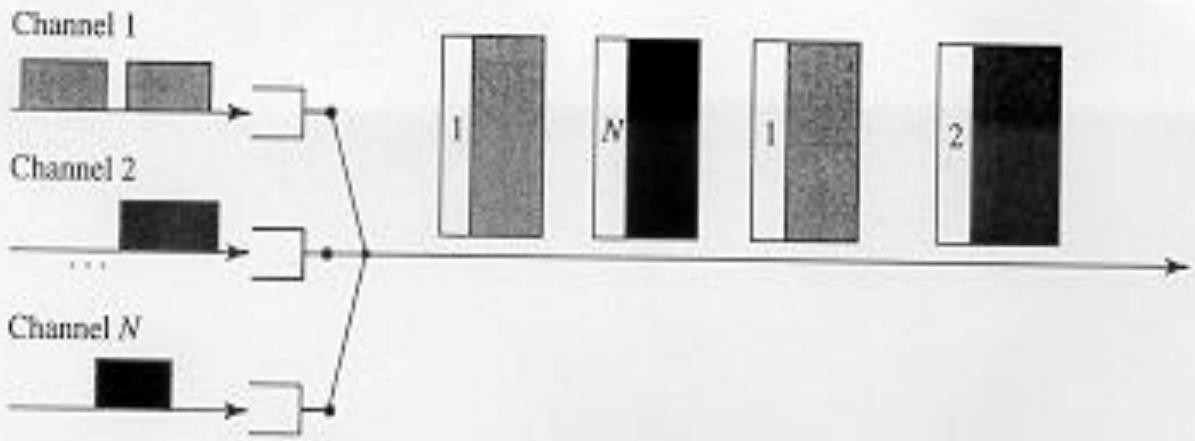
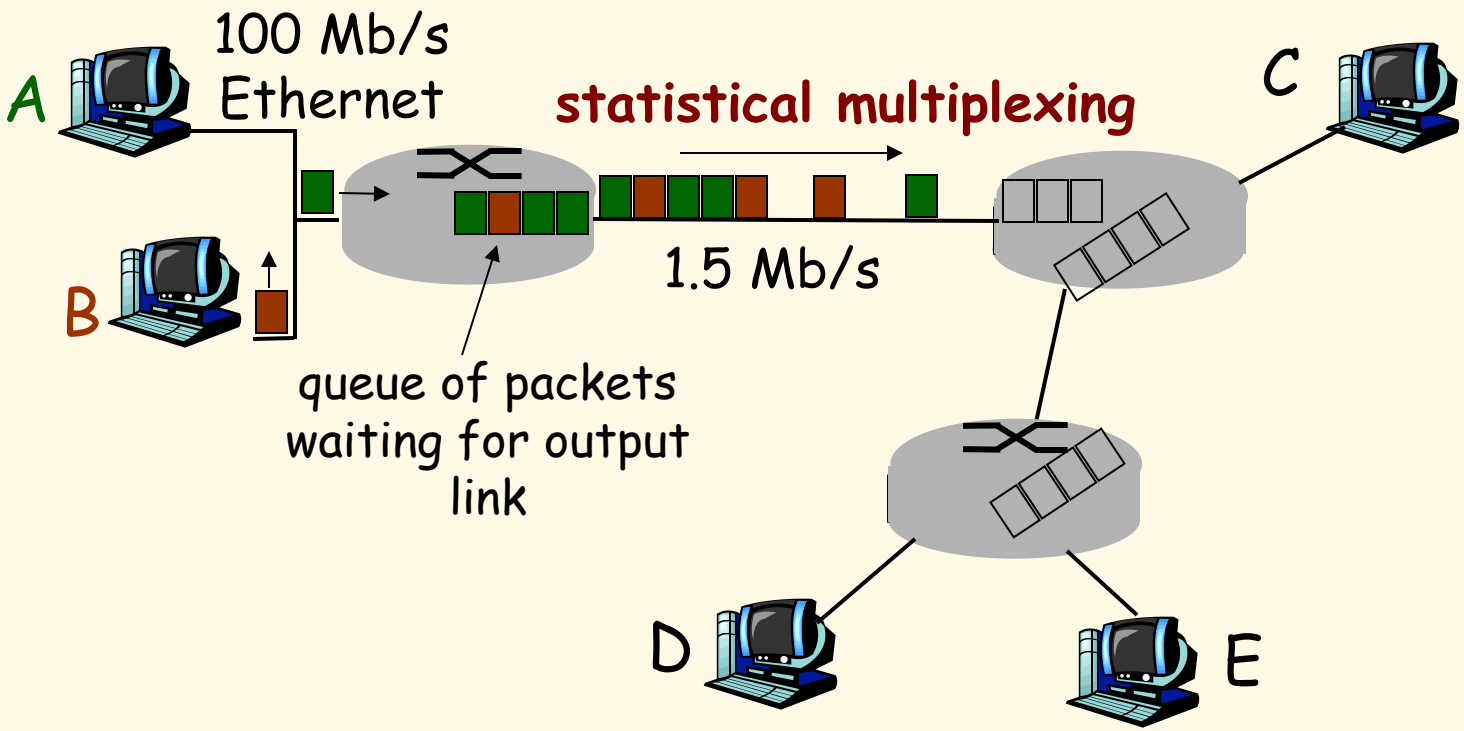
Concentrator [Statistical Multiplexing]



2.10 FIGURE

In statistical multiplexing, the multiplexer visits the incoming channel buffers in some order. The multiplexer empties a buffer before moving to the next one. The buffer contents are tagged to indicate their incoming channel. An idle channel does not waste transmission time.

Packet Switching: Statistical Multiplexing



Sequence of A & B packets does NOT have fixed pattern, bandwidth shared on demand ➔ statistical multiplexing.

Wavelength Division Multiplexing

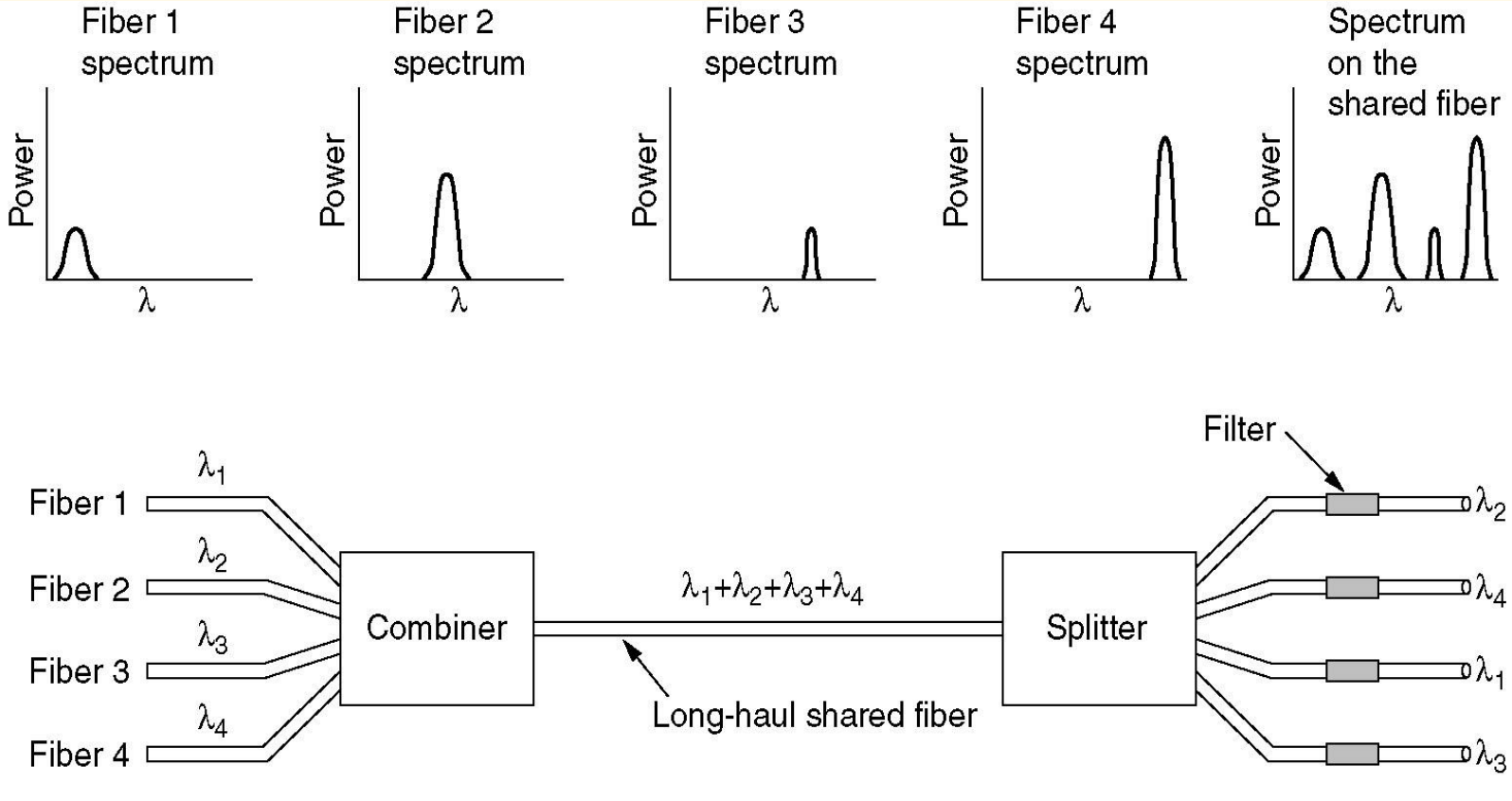


Figure 2-32.

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Physical Media: Twisted Pair

- **Bit:** propagates between transmitter/receiver pairs.
- **physical link:** what lies between transmitter & receiver.
- **guided media:**
  - signals propagate in solid media: copper, fiber, coax.
- **unguided media:**
  - signals propagate freely, e.g., radio.

Unshielded Twisted Pair (UTP)

- two insulated copper wires
  - Category 3: traditional phone wires, 10 Mbps Ethernet
  - Category 5 : 100Mbps Ethernet

Category 5e is now standard!!

EIA/TIA 568 and ISO/IEC 11801 Wiring Grades

Grade 1 - Unshielded Untwisted wiring.
Commonly called inside wire by the Telco community.

Grade 2 - Unshielded twisted pair (UTP) derived from IBM Type 3 spec.

Category 3 - Unshielded twisted pair with 100 ohm impedance and electrical characteristics supporting transmission at frequencies up to 16 MHz. May be used with 10Base-T, 100Base-T4, and 100Base-T2 Ethernet. (Obsolete)

Category 4 - Unshielded twisted pair with 100 ohm impedance and electrical characteristics supporting transmission at frequencies up to 20 MHz. May be used with 10Base-T, 100Base-T4, and 100Base-T2 Ethernet. (Obsolete)

Category 5 - Unshielded twisted pair with 100 ohm impedance and electrical characteristics supporting transmission at frequencies up to 100 MHz. May be used with 10Base-T, 100Base-T4, 100Base-T2, and 100Base-TX Ethernet. May support 1000Base-T, but cable should be tested. (Superceded by Cat5e)

"Modern" Twisted Pair

Table 4.2 Twisted Pair Categories and Classes

	Category 5e Class D	Category 6 Class E	Category 6A Class E_A	Category 7 Class F	Category 7_A Class F_A
Bandwidth	100 MHz	250 MHz	500 MHz	600 MHz	1,000 MHz
Cable Type	UTP	UTP/FTP	UTP/FTP	S/FTP	S/FTP
Insertion loss (dB)	24	21.3	20.9	20.8	20.3
NEXT loss (dB)	30.1	39.9	39.9	62.9	65
ACR (dB)	6.1	18.6	19	42.1	44.1

UTP = Unshielded twisted pair
FTP = Foil twisted pair
S/FTP = Shielded/foil twisted pair

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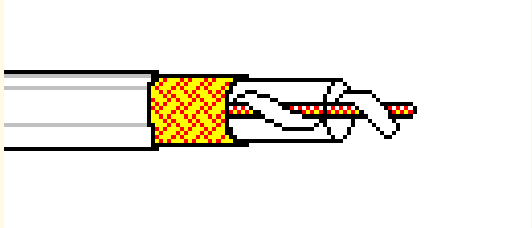
Physical Media: Coaxial Cable and Optical Fiber

Coaxial cable:

- two concentric copper conductors
- bidirectional
- baseband:
  - single channel on cable
  - legacy Ethernet
- broadband:
  - multiple channels on cable
  - HFC



Fiber optic cable:

- glass fiber carrying light pulses, each pulse a bit
- high-speed operation:
  - point-to-point transmission (e.g., 10's-100's Gps)
- low error rate: repeaters spaced far apart ; immune to electromagnetic noise.

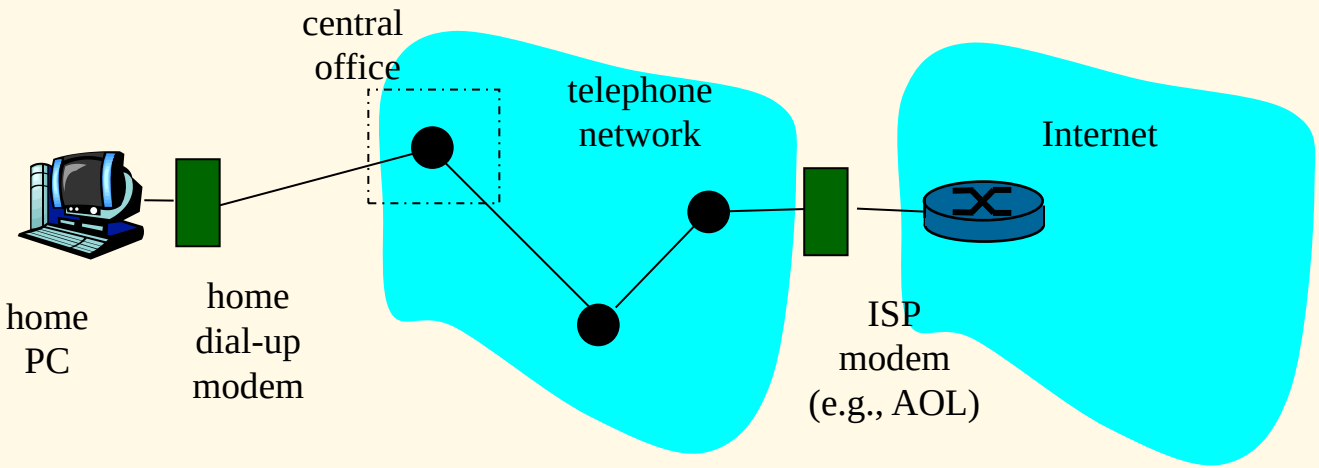
Physical Media: Radio Signals

- signal carried in electromagnetic spectrum.
- no physical "wire"
- bidirectional
- propagation environment effects:
  - reflection
  - obstruction by objects
  - interference

Radio link types:

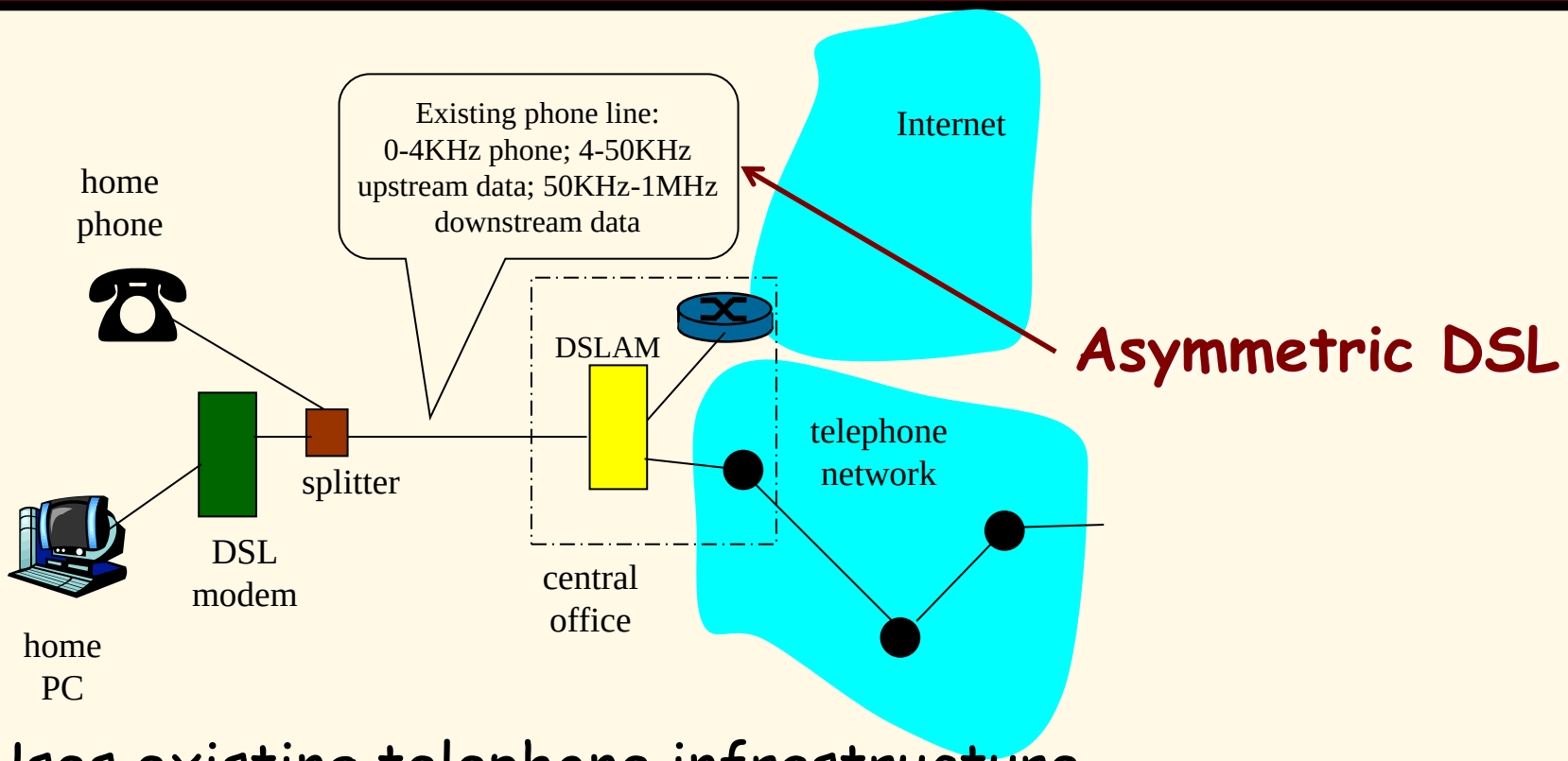
- terrestrial microwave
  - e.g. up to 45 Mbps channels
- LAN (e.g., Wifi)
  - 11Mbps, 54 Mbps, 200Mbps
- wide-area (e.g., cellular)
  - 4G cellular: ~ 100 Mbps
- satellite
  - Kbps to 45Mbps channel (or multiple smaller channels)
  - 270 msec end-end delay
  - geosynchronous versus low altitude

Dial-up Modem



- Uses existing telephony infrastructure.
- Home is connected to central office (analog signals).
- up to 56Kbps direct access to router (often less)
- Can't surf and phone at same time: not "always on".

Digital Subscriber Line (ADSL)



- Uses existing telephone infrastructure.
- up to 1 Mbps upstream (today typically < 256 kbps)
- up to 8 Mbps downstream (today typically < 1 Mbps)
- dedicated physical line to telephone central office

Comparison of xDSL Alternatives

	ADSL	HDSL	SDSL	VDSL
Data rate	1.5 to 9 Mbps downstream 16 to 640 kbps upstream	1.544 or 2.048 Mbps	1.544 or 2.048 Mbps	13 to 52 Mbps downstream 1.5 to 2.3 Mbps upstream
Mode	Asymmetric	Symmetric	Symmetric	Asymmetric
Copper pairs	1	2	1	1
Range (24-gauge UTP)	3.7 to 5.5 km	3.7 km	3.0 km	1.4 km
Signaling	Analog	Digital	Digital	Analog
Line code	CAP/DMT	2B1Q	2B1Q	DMT
Frequency	1 to 5 MHz	196 kHz	196 kHz	≥ 10 MHz
Bits/cycle	Varies	4	4	Varies

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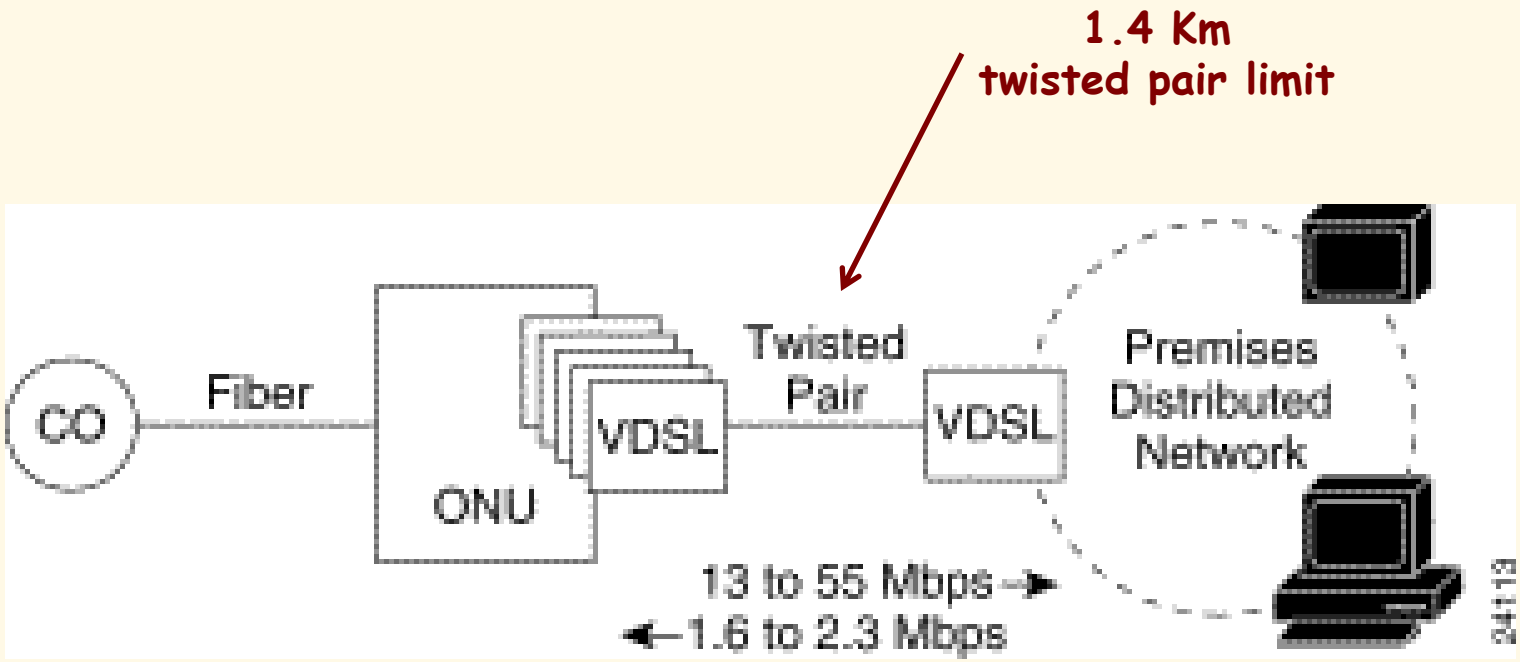
VDSL


1.4 Km
twisted pair limit
CO
Fiber
ONU
VDSL
Twisted
Pair
VDSL
Premises
Distributed
Network
13 to 55 Mbps
1.6 to 2.3 Mbps
24113

Residential Access: Cable Modems

- Does not use telephone infrastructure
  - Instead uses cable TV infrastructure.
- HFC: hybrid fiber coax
  - asymmetric: up to 40Mbps downstream, 6 Mbps upstream
- network of cable and fiber attaches homes to ISP router:
  - homes share access to router
  - unlike DSL, which has dedicated access.

Residential Access: Cable Modems

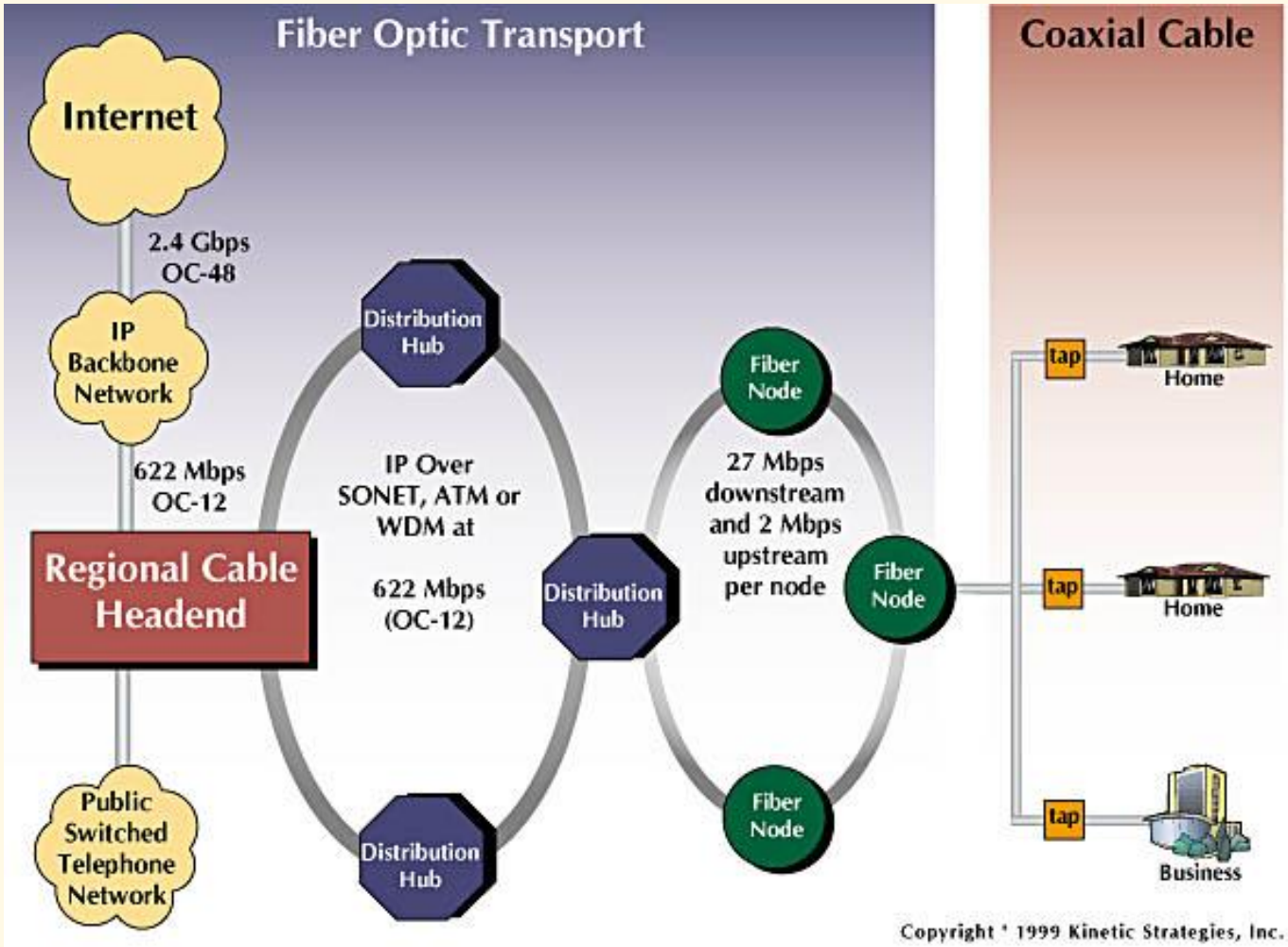
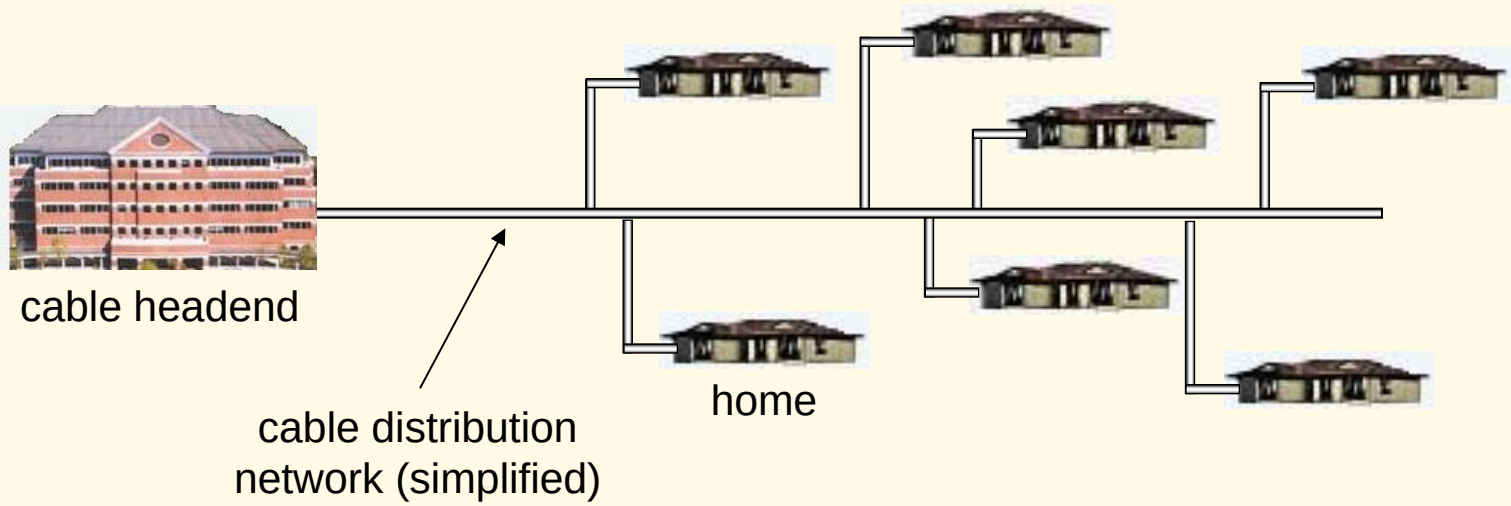


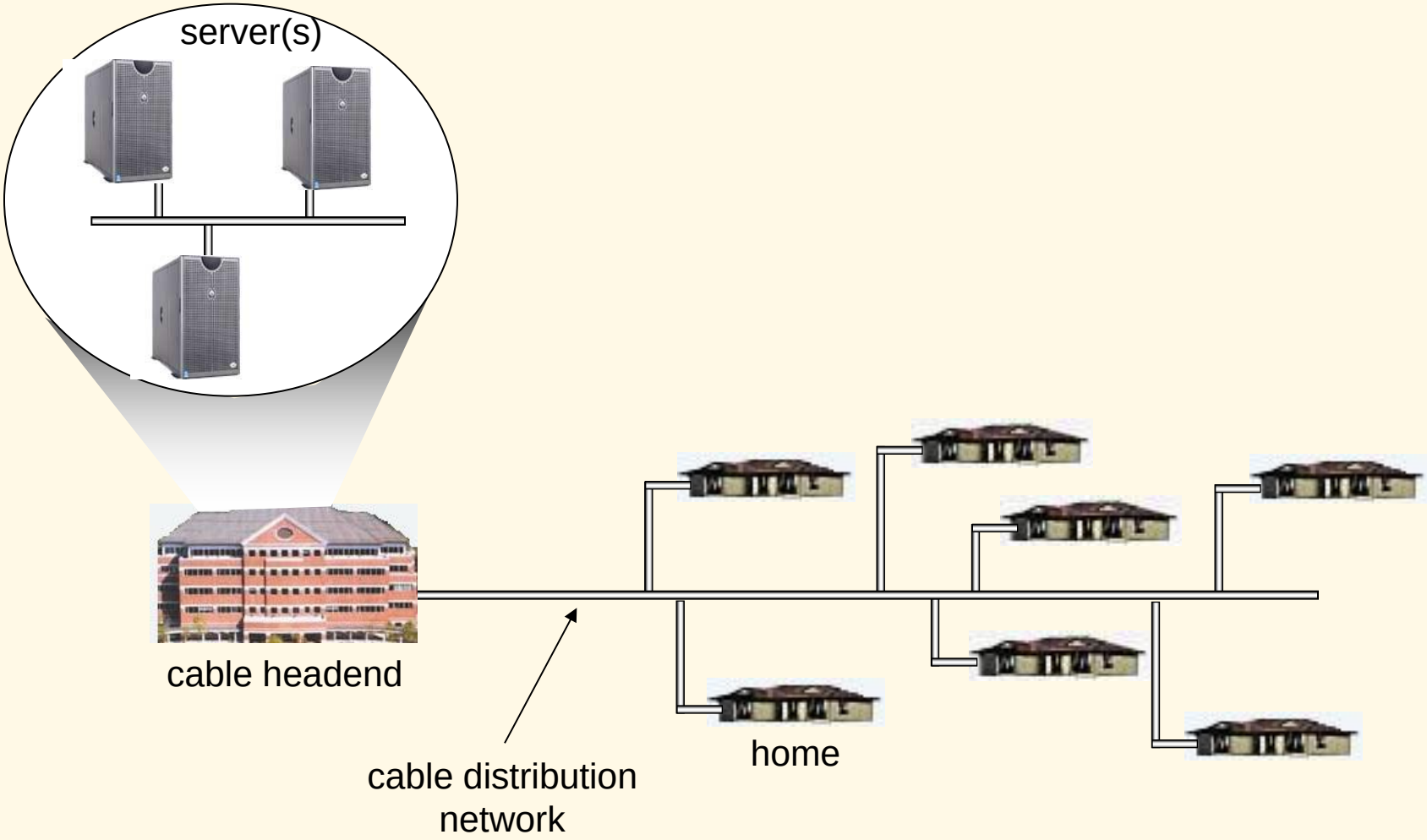
Diagram: http://www.cabledatacomnews.com/cmic/diagram.html

Cable Network Architecture: Overview

Typically 500 to 5,000 homes



Cable Network Architecture: Overview



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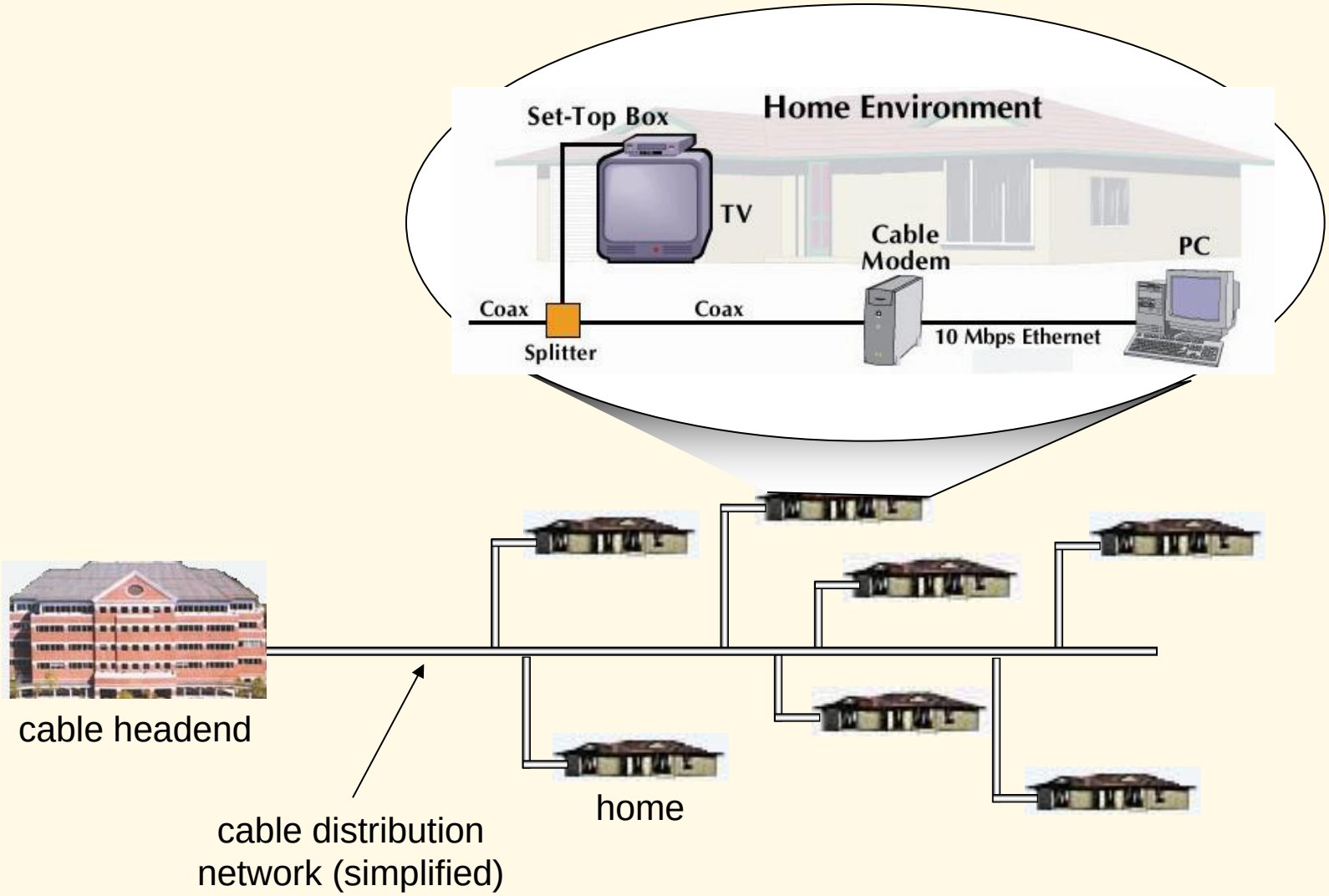
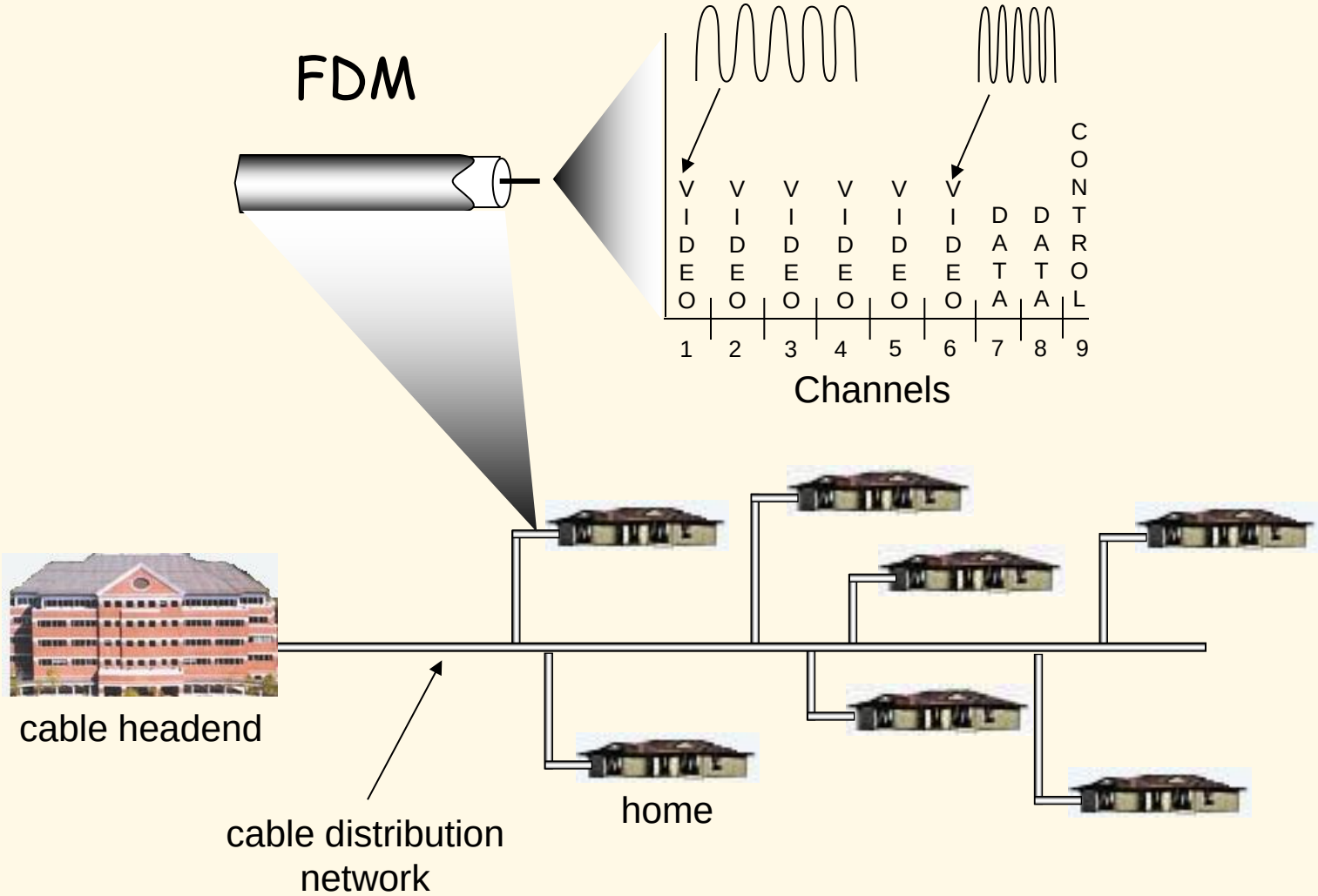


Cable Network Architecture: Overview



DOCSIS (Data-Over-Cable Service Interface Specification)

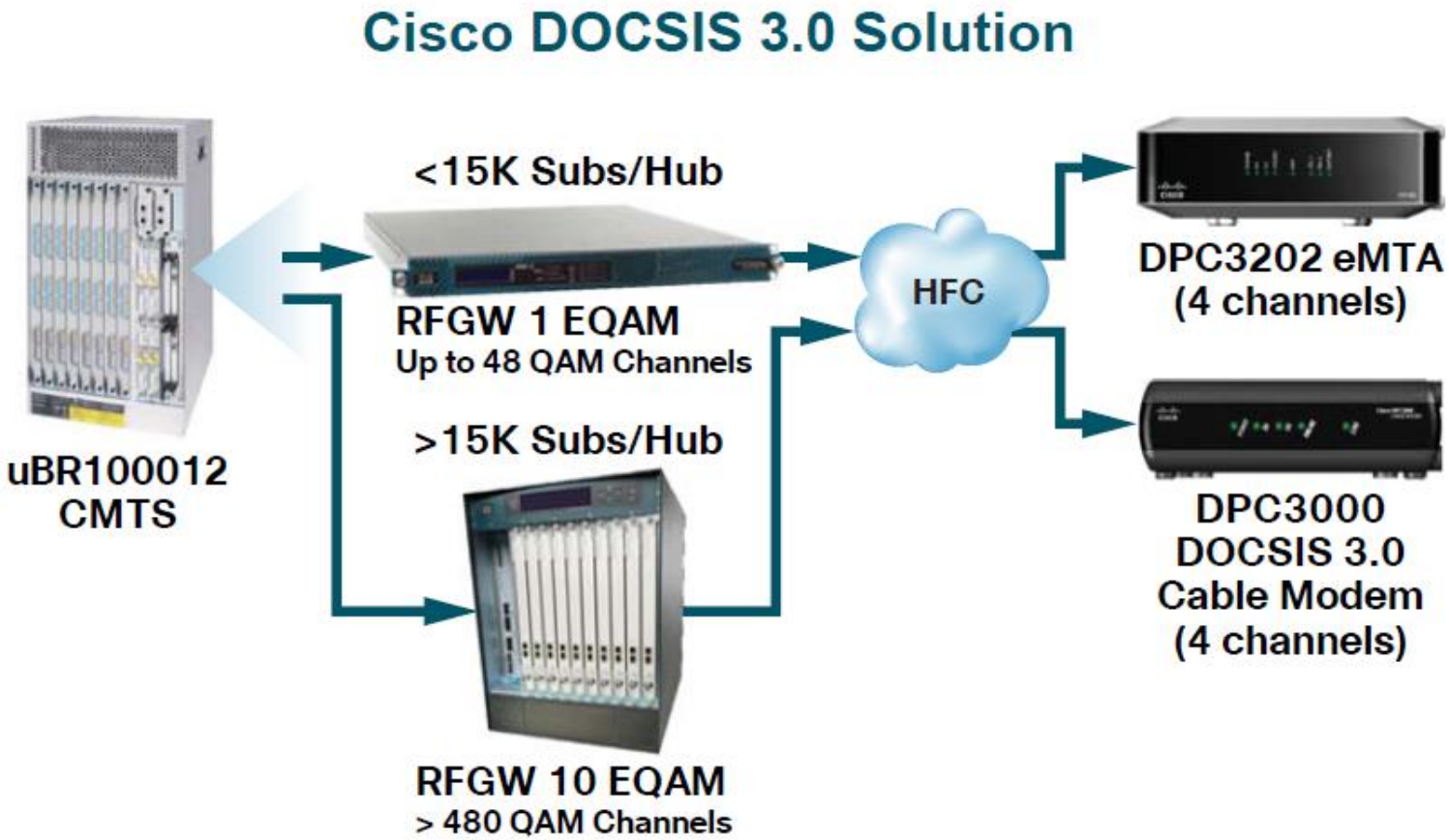
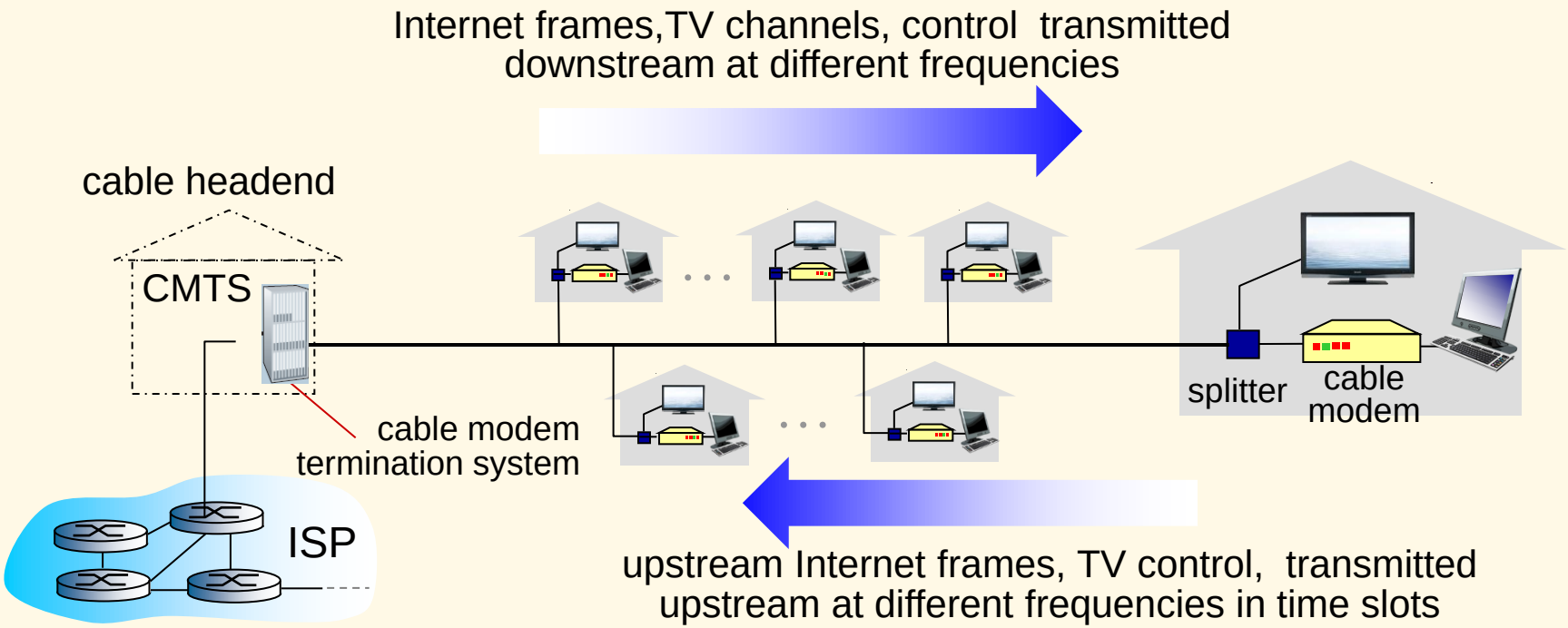


Figure 4. M-CMTS and DOCSIS 3.0 Downstream Channel Bonding

Cable Access Networks



- FDM over upstream, downstream frequency channels
- multiple 40Mbps downstream (broadcast) channels (6MHz)
  - single CMTS transmits into channels and received by all modem receivers.

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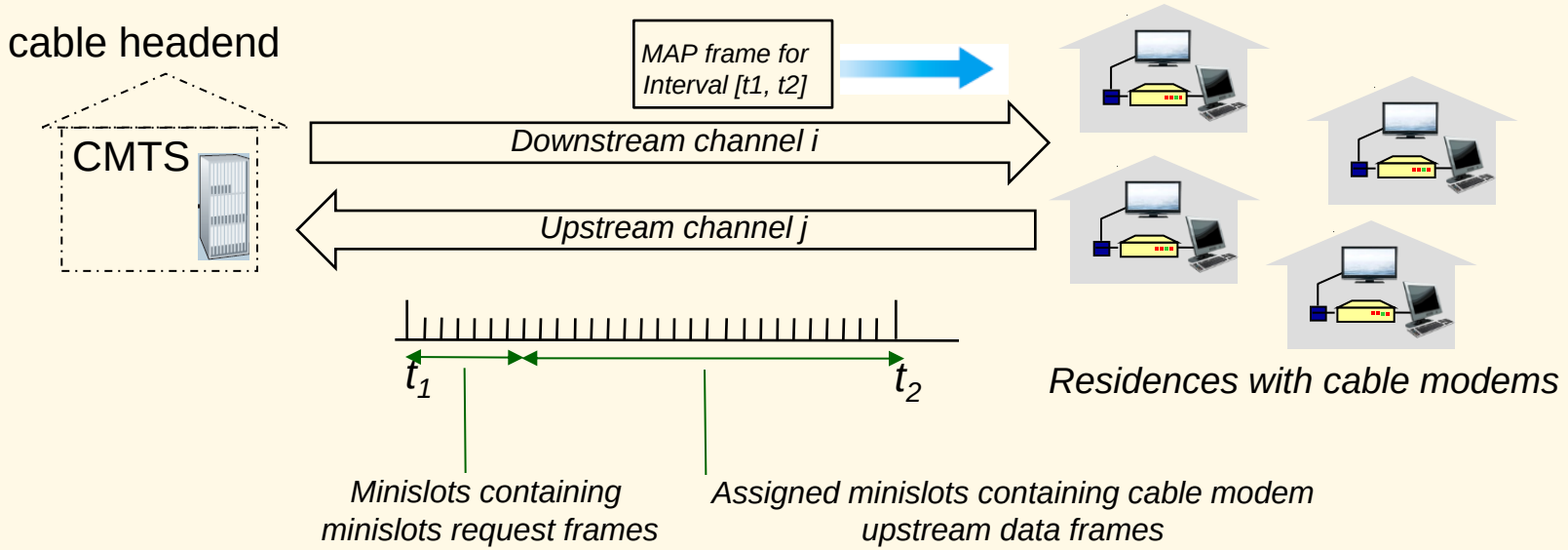
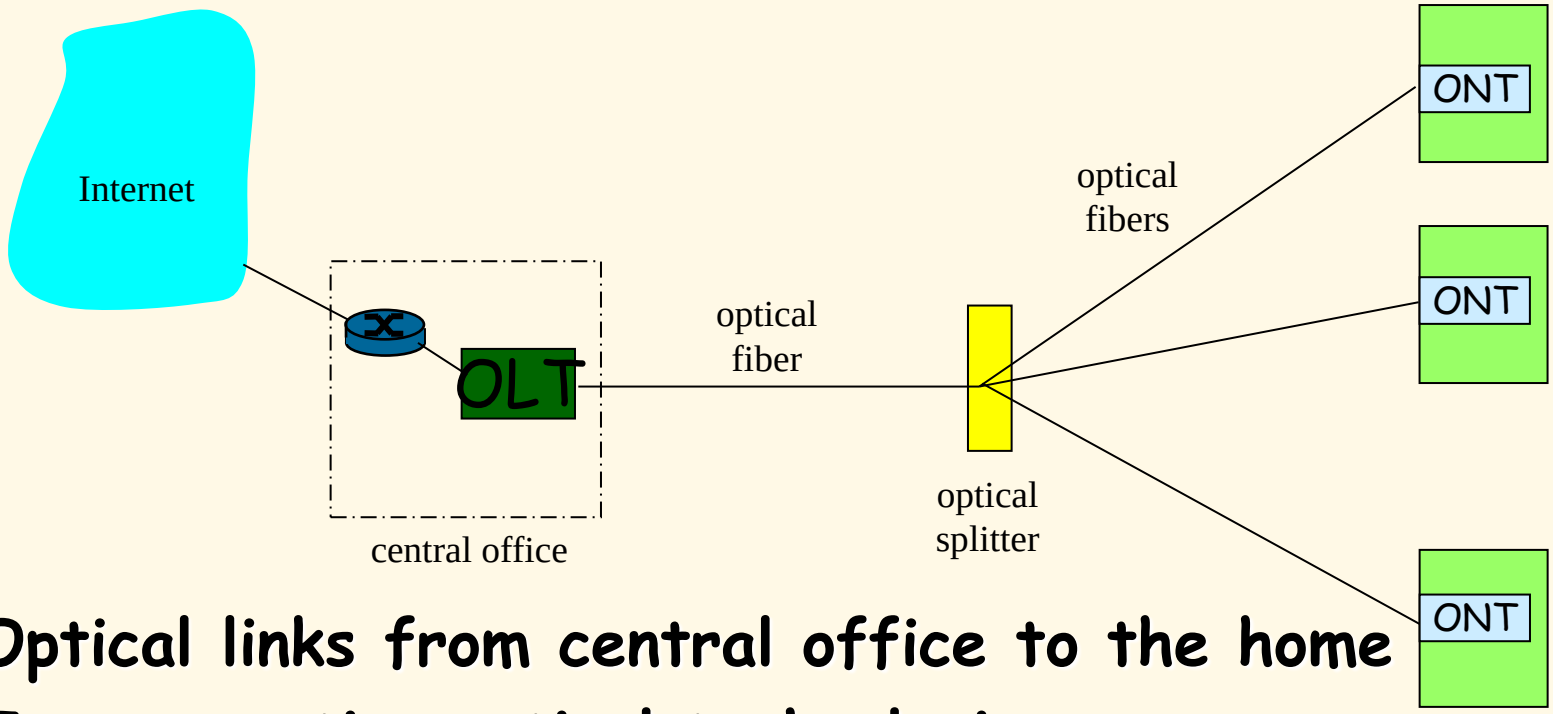
DOCSIS Cable Access Networks



- multiple 30 Mbps upstream channels (6.4MHz)
- TDM-like upstream mini-slots

K & R

Fiber to the Home



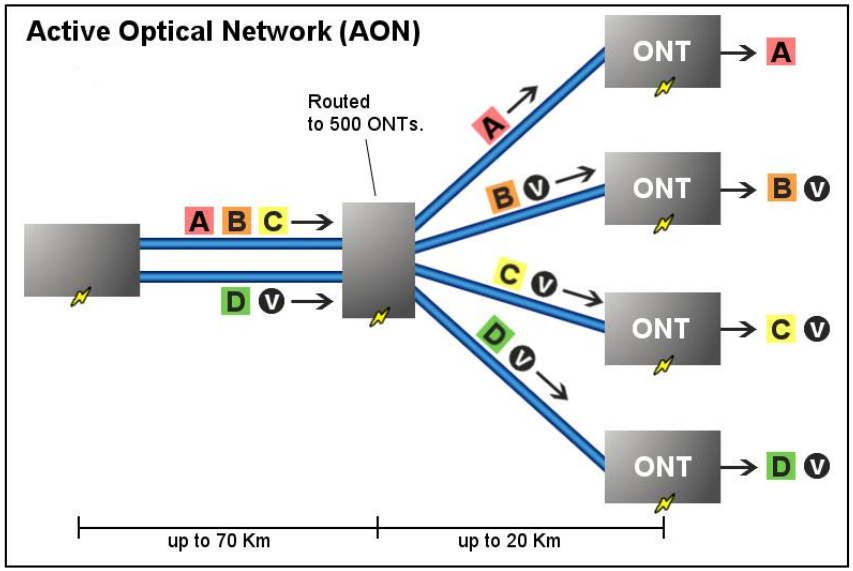
- Optical links from central office to the home
- Two competing optical technologies:
  - Passive Optical network (PON) ← Verizon FIOS
  - Active Optical Network (AON)
- Higher Internet rates. Fiber also carries television and phone services.

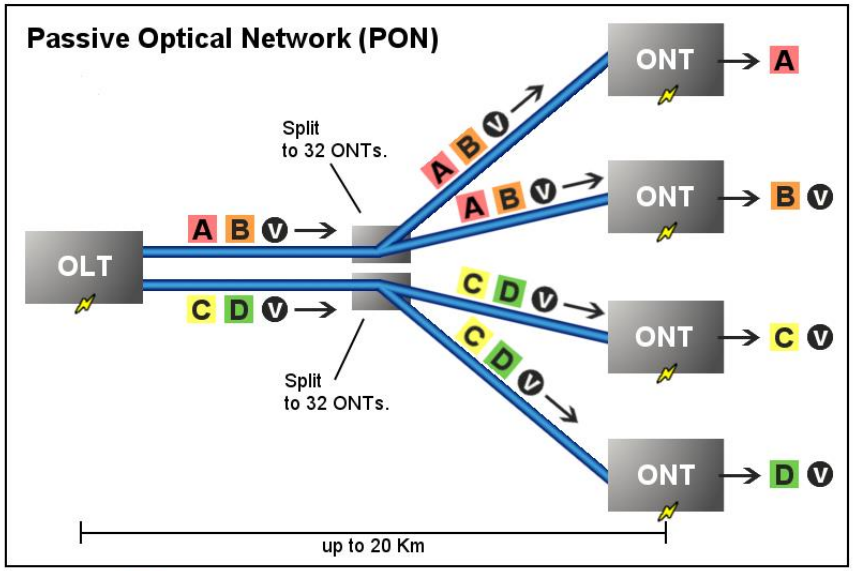
AON Active Optical Network

- Uses electrical powered switches
- More range
- Less reliable

PON Passive Optical Network

- Optical splitters do not need electrical power.
- Hard to isolate failure
- Transmission speed may be slower during peak hours.

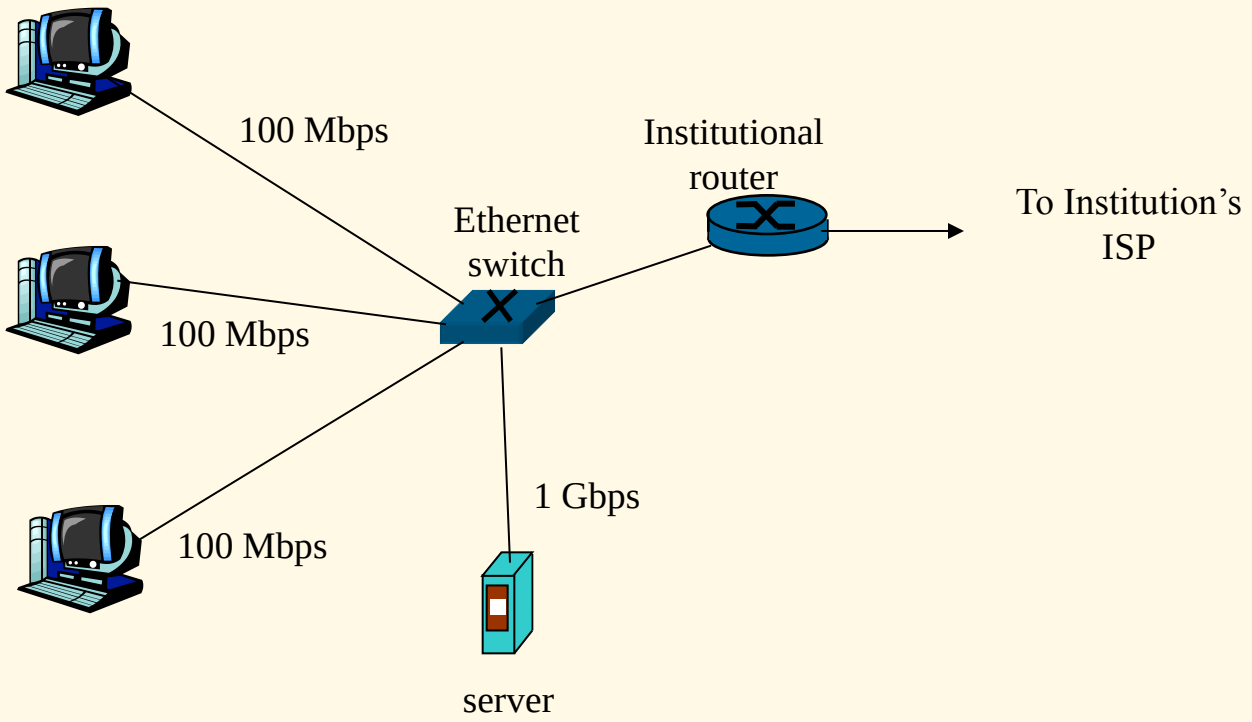




Key: A - Data or voice for a single customer. V - Video for multiple customers.

Wikipedia

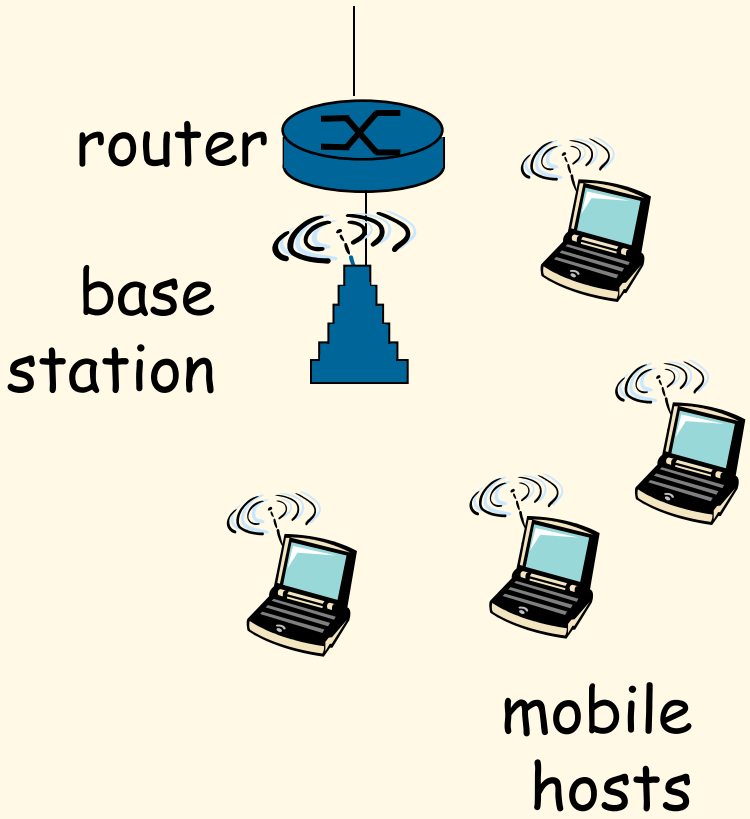
Ethernet Internet Access



- Typically used in companies, universities, etc
- 10 Mbs, 100Mbps, 1Gbps, 10Gbps Ethernet
- Today, end systems typically connect into Ethernet switch.

Wireless Access Networks

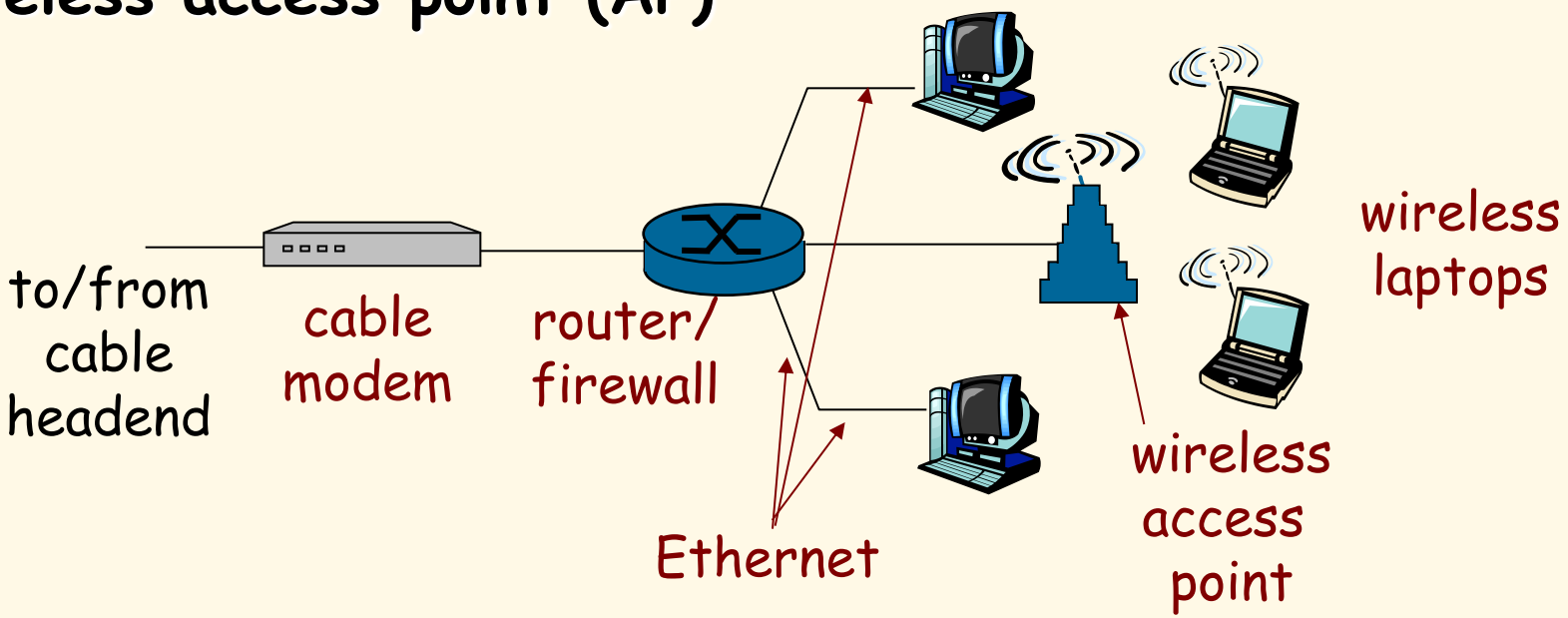
- Shared wireless access network connects end system to router
  - via base station aka "access point".
- Wireless LANs:
  - 802.11b/g/n (WiFi): 11, 54, 200 Mbps
- Wider-area Wireless Access
  - provided by telco operator
  - ~1Mbps over cellular system (EVDO, HSDPA) 3G and 4G LTE
  - next up (?): WiMAX (10's Mbps) over wide area



Residential Networks

Typical Residential Network Components:

- DSL or cable modem
- router/firewall/NAT
- Ethernet
- wireless access point (AP)



Physical Layer Summary

- Definitions (analog versus digital)
- Multiplexing (FDM, TDM, statistical)
- Transmission Media (UTP, Coax, Fiber, Radio, Satellite)
- End System Choices (Dial-Up, ADSL, Cable,Ethernet, Wireless AP, Fiber-to-the Home)
- Residential Configurations