Residential Broadband Technologies for High-Speed Access To Homes

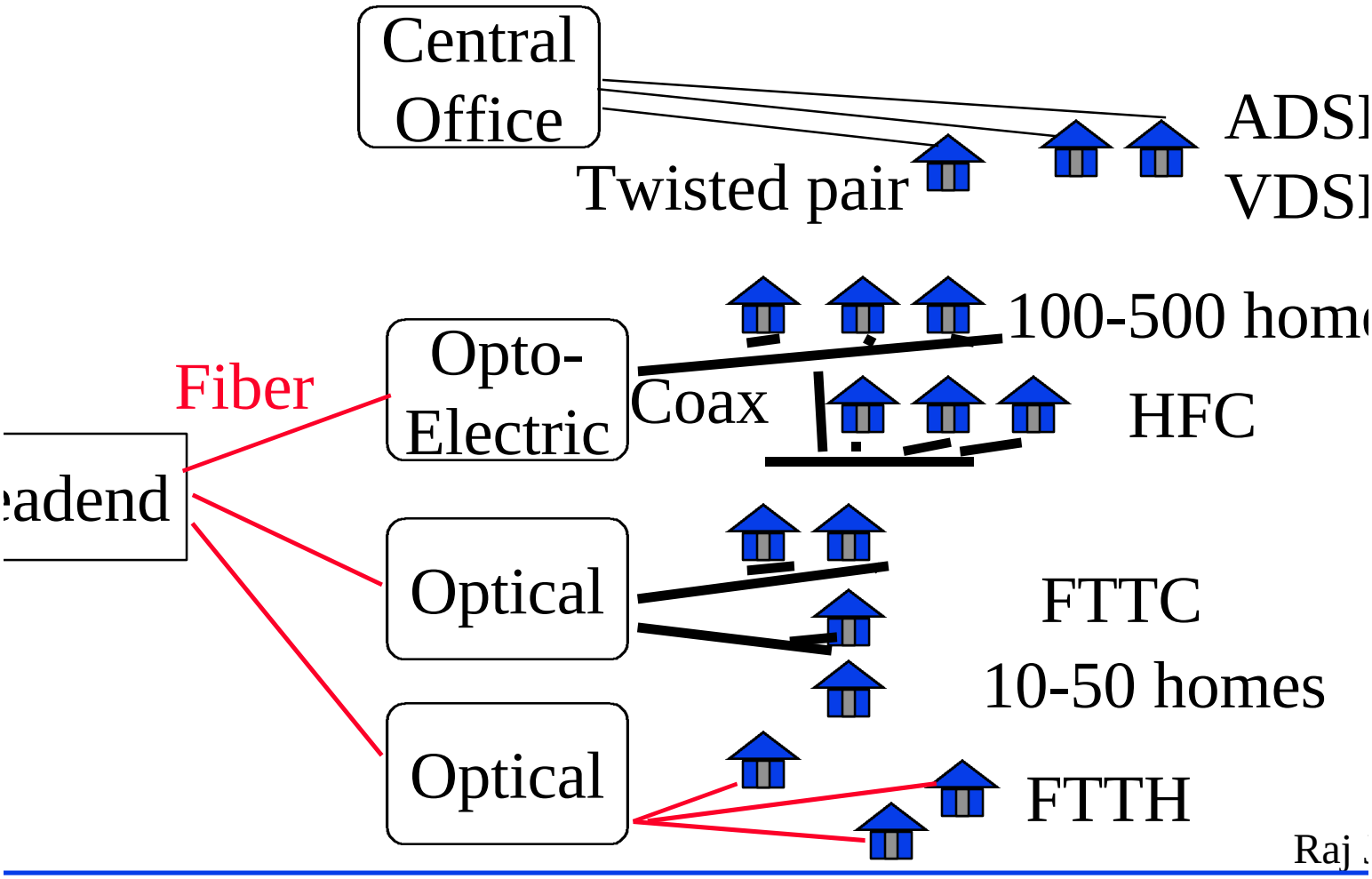
Raj Jain
The Ohio State University
Columbus, OH 43210-1277
http://www.cis.ohio-state.edu/~jain/

- 56 kbps Modems, ISDN
- ADSL, VDSL
- HFC, FTTC, FTTH
- Cable Modems
- Cable Modem Standars: DOCSIS, 802.14, ...

Potential Applications

- Video on demand (VOD)
- Near video on demand (NVOD)
  - staggered starts
- Distance learning, Teleconferencing, Home shoppin
- Telecommuting
- Meter reading
- Security
- Existing cable TV has the media but no switching
- Existing phone service has switching but not enough bandwidth

Residential Access Networks (RANs)



RANs (Cont)

DSL: Digital Subscriber Line (ISDN)

ADSL: Asymmetric DSL

VDSL: Very high data rate DSL

HFC: Hybrid Fiber Coax

FTTC: Fiber to the curb

FTTH: Fiber to the home

Why Modems are Low Speed?

Telephone line bandwidth = 3.3 kHz

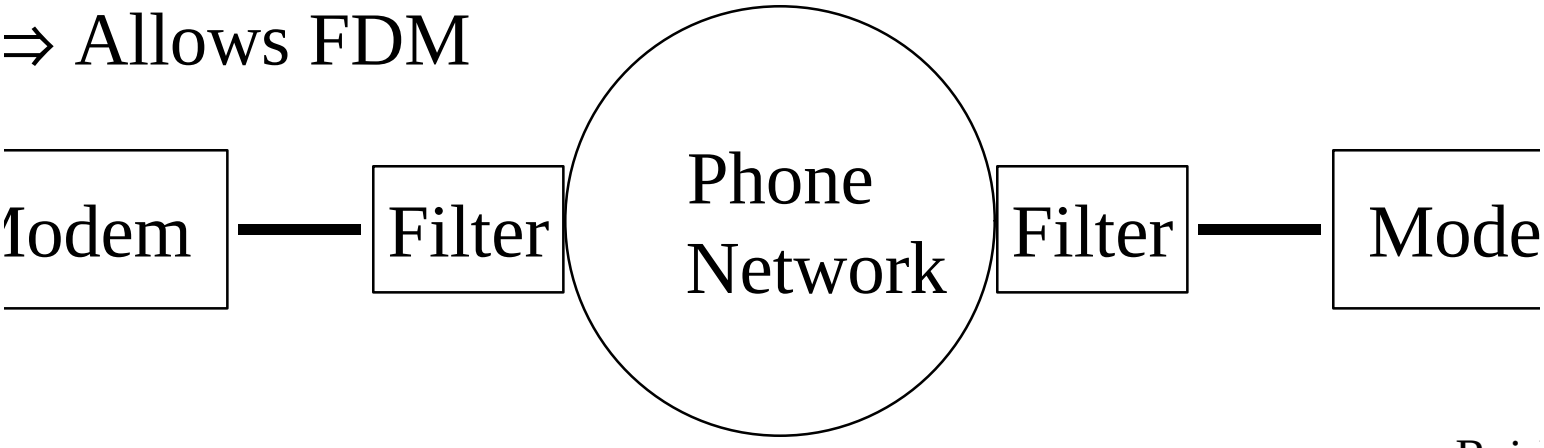
V.34 Modem = 28.8 kbps ⇒ 10 bits/Hz

Better coding techniques. DSP techniques.

Cat 3 UTP can carry higher bandwidth

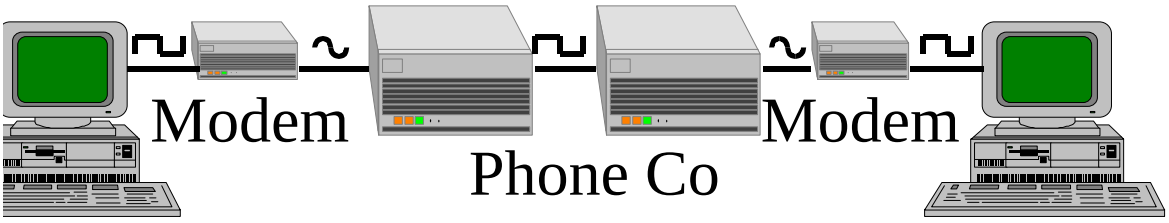
Phone companies put 3.3 kHz filters at central office

⇒ Allows FDM

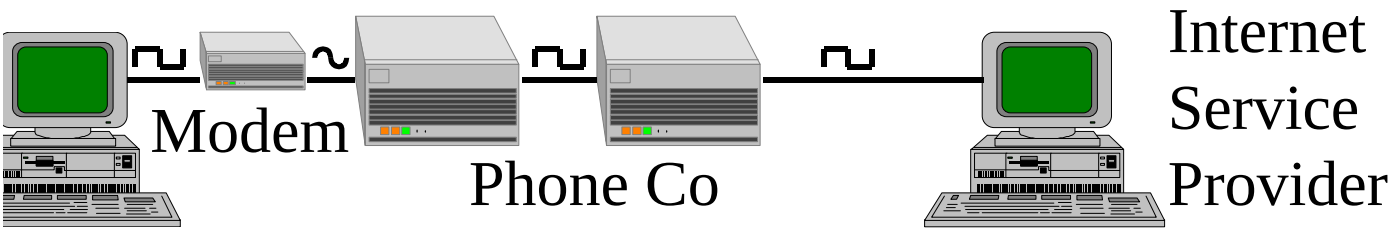


56 kbps Modems

Past:



Current:



ISP's have direct digital link (T1 or T3)

Only one D/A/D conversion ⇒ Higher speed possib

DSL

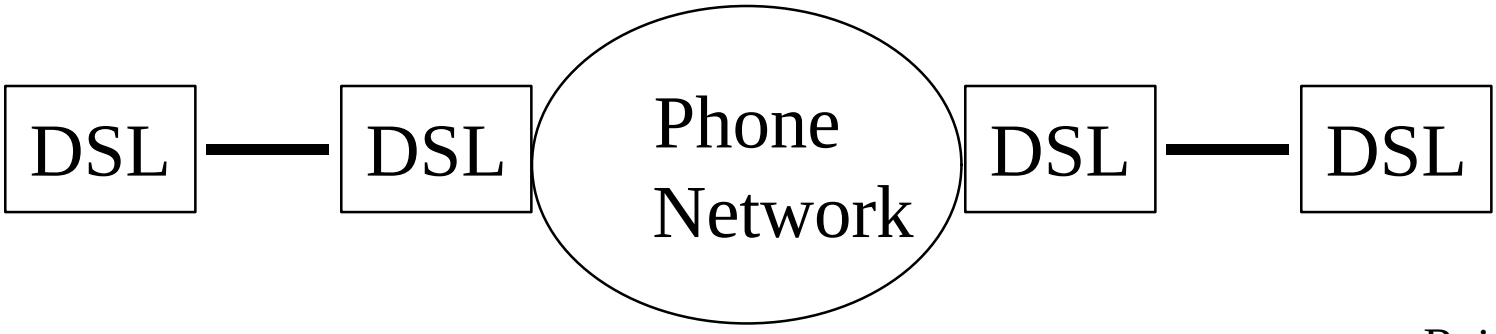
Digital Subscriber Line = ISDN

64×2 + 16 + overhead
= 160 kbps up to 18,000 ft

DSL requires two modems (both ends of line)

Symmetric rates ⇒ transmission and reception on same wire ⇒ Echo cancellation

Use 0 to 80 kHz ⇒ Can't use POTS simultaneously



DSL Technologies

DSL: Digital Subscriber Line (ISDN)

HDSL: High data rate DSL (T1/E1 on 2 pairs)

SDSL: Single line DSL (T1/E1)

ADSL: Asymmetric DSL

RADSL: Rate-adaptive ADSL

VDSL: Very high data rate DSL

VADSL: Very high data rate Asymmetric DSL = VDSL

BDSL: Another name for VDSL

VDSLe: European version of VDSL

HDSL

nitially T1/E1 over copper used AMI
:oding ⇒ Repeaters every 3000 - 6000 ft

Jses 1.5 MHz for 1.5 Mbps ⇒ Wasteful of bandwic
⇒ Interference ⇒ Can't put more than 1 circuit in a
50 pair cable

HDSL transmits T1/E1 over two pairs using 80 to 24
kHz ⇒ repeaters at 12,000 ft

Jsed in PBX interconnection, cellular antenna
stations, interexchange POPs

SDSL = Single pair version of HDSL. T1/E1
simultaneously. Up to 10000 ft.

ADSL

Asymmetric Digital Subscriber Line

Asymmetric ⇒ upstream << Downstream

Symmetric ⇒ Significant decrease in rate

6 Mbps downstream, 640 kbps upstream

Using existing twisted pair lines

No interference with phone service (0-3 kHz)
⇒ Your phone isn't busy while netsurfing

Up to 7500 m

ANSI T1.413 Standard

Quickest alternative for Telcos

Why Asymmetric?

Unshielded twisted pair ⇒ Crosstalk

Downstream signals are all same amplitude ⇒ Not affected

Upstream signals start at different distances ⇒ Different amplitudes ⇒ Weak signals are highly affected

Solutions:

1. Use asymmetric rates
2. Use lower frequencies for upstream (Cross talk increases with frequencies)

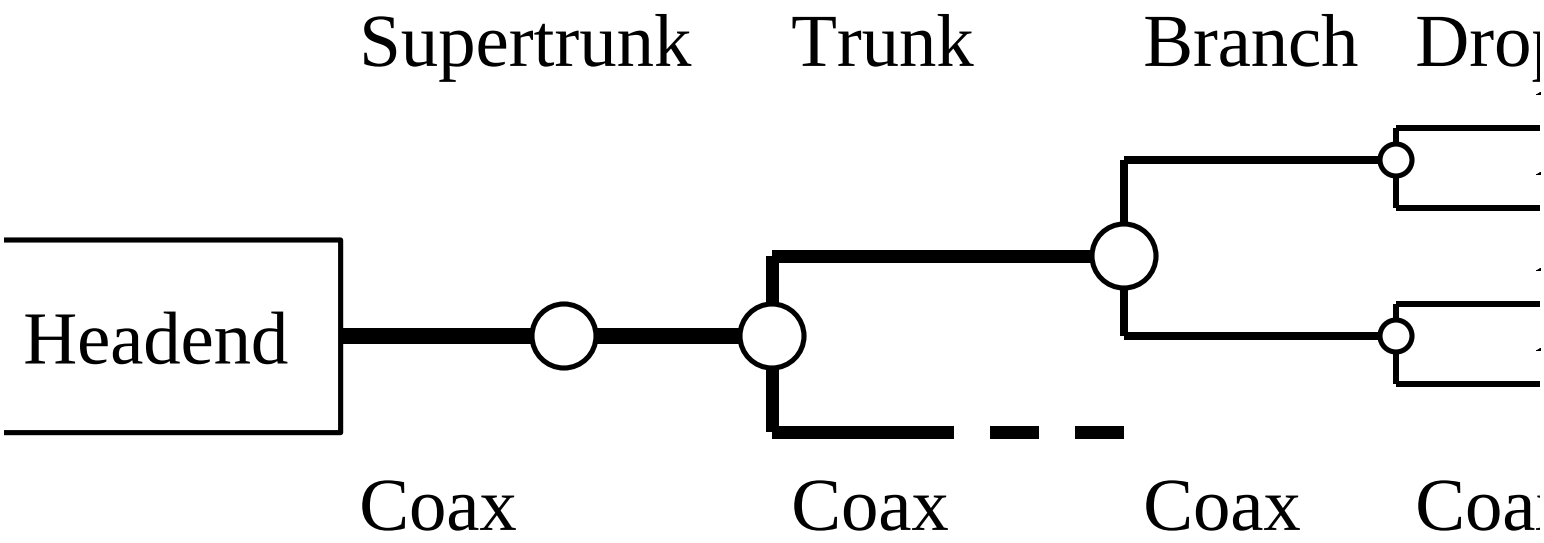
VDSL

- Very High-Speed Digital Subscriber Lines
- Also called VADSL, BDSL, VHDSL
- ANSI T1E1.4 standardized the name VDSL and ETS also adopted it
- VDSLe to denote European version
- For use in FTTC systems
- Downstream Rates: 51.84 -55.2 Mbps (300 m), 25.9 27.6 Mbps (1000 m), 12.96 - 13.8 Mbps (1500 m)

VDSL (Cont)

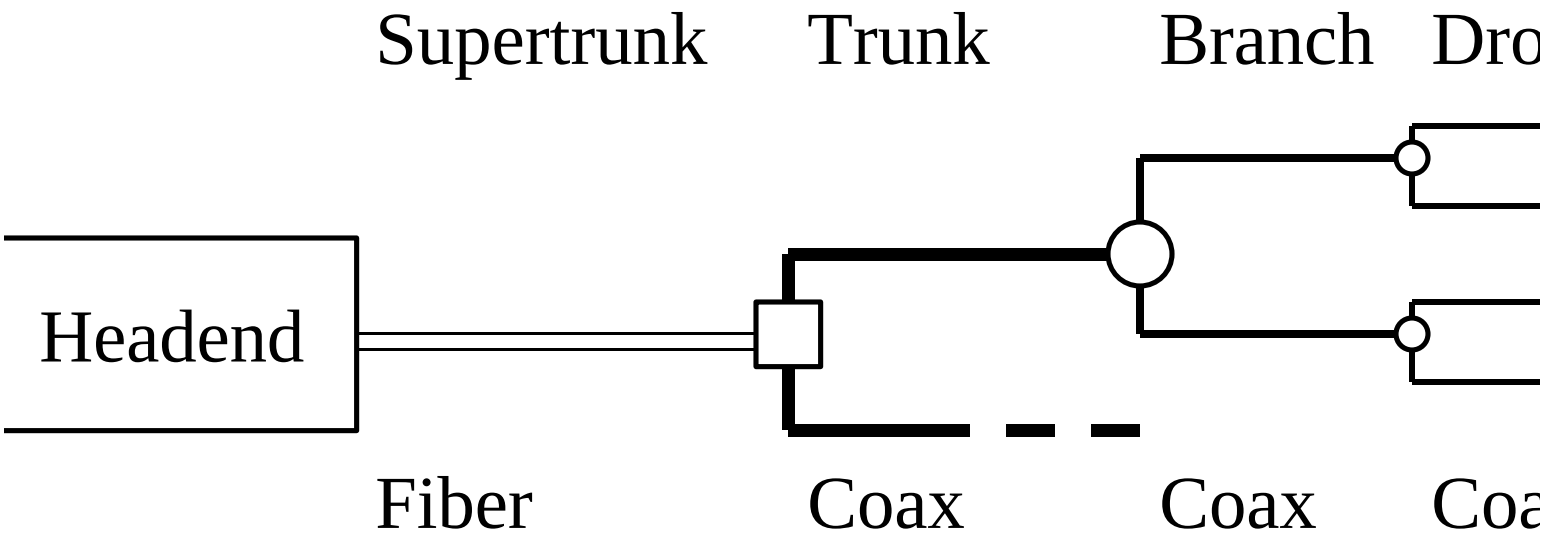
- Upstream Rates: 1.6-2.3 Mbps,
  Downstream: 9.2 Mbps, Same as downstream
- Admits passive network termination
  ⇒ Can connect multiple VDSL modems like extension phones
  (ADSL requires active termination)
- Unlike ADSL, VDSL uses ATM to avoid packet handling and channelization
- Orkit Communications (Israel) demoed VDSL modems at Supercomm'96

CATV Distribution Systems



Amplifiers at extension and branch points
These amplifiers require periodic retuning
Some of these amplifiers are one-way

Hybrid Fiber-Coax



- Replace supertrunk with fiber
- Electro-optical conversion at headend
- Opto-electrical conversion at fiber node
- Amplifiers are removed.
- Allows two-way, More bandwidth, less noise

Cable Modems

- Modulate RF frequencies into cable.
- Cost $395 to $995
- If cable is still one-way, upstream path through POT
- $30 to $40 per month flat service charge
- 5 Mbps downstream, 1.5 Mbps upstream
- MAC protocol required to share upstream bandwidth
- haring ⇒ Security issues
- ervers at headend to avoid Internet bottleneck
- @home Plans to create high-speed backbone across t

DOCSIS

- Data over Cable Service Interface Specification
- Developed by Multimedia Cable Network System Partners (MCNS): TCI, Time Warner, …
- Cablelabs helped manage changes
- Rapidly develop standards (Faster than IEEE)
- Intellectual Property Agreement among partners
- V1.0 initial release in December 1996, Final draft in July 1998. Many deployments.
- V1.1 in March 1999 added QoS (802.1p), multicast, fragmentation. Required for packet voice.
- V1.2 will add higher speed upstream

DOCSIS: Key Features

Switched Ethernet service ⇒ One large LAN

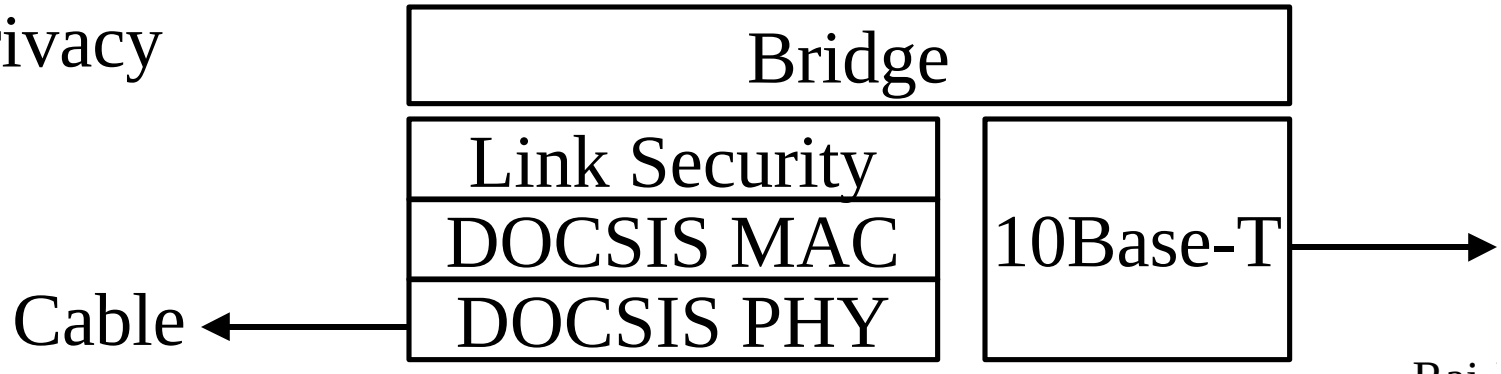
Downstream packets use 188-byte MEPG2 transport stream frames

⇒ Compatible with digital video standards

⇒ Allows mixing data and video in the same channe

Upstream is slotted. Head-end allocates minislots.

Packets can be optionally encrypted using DES for privacy

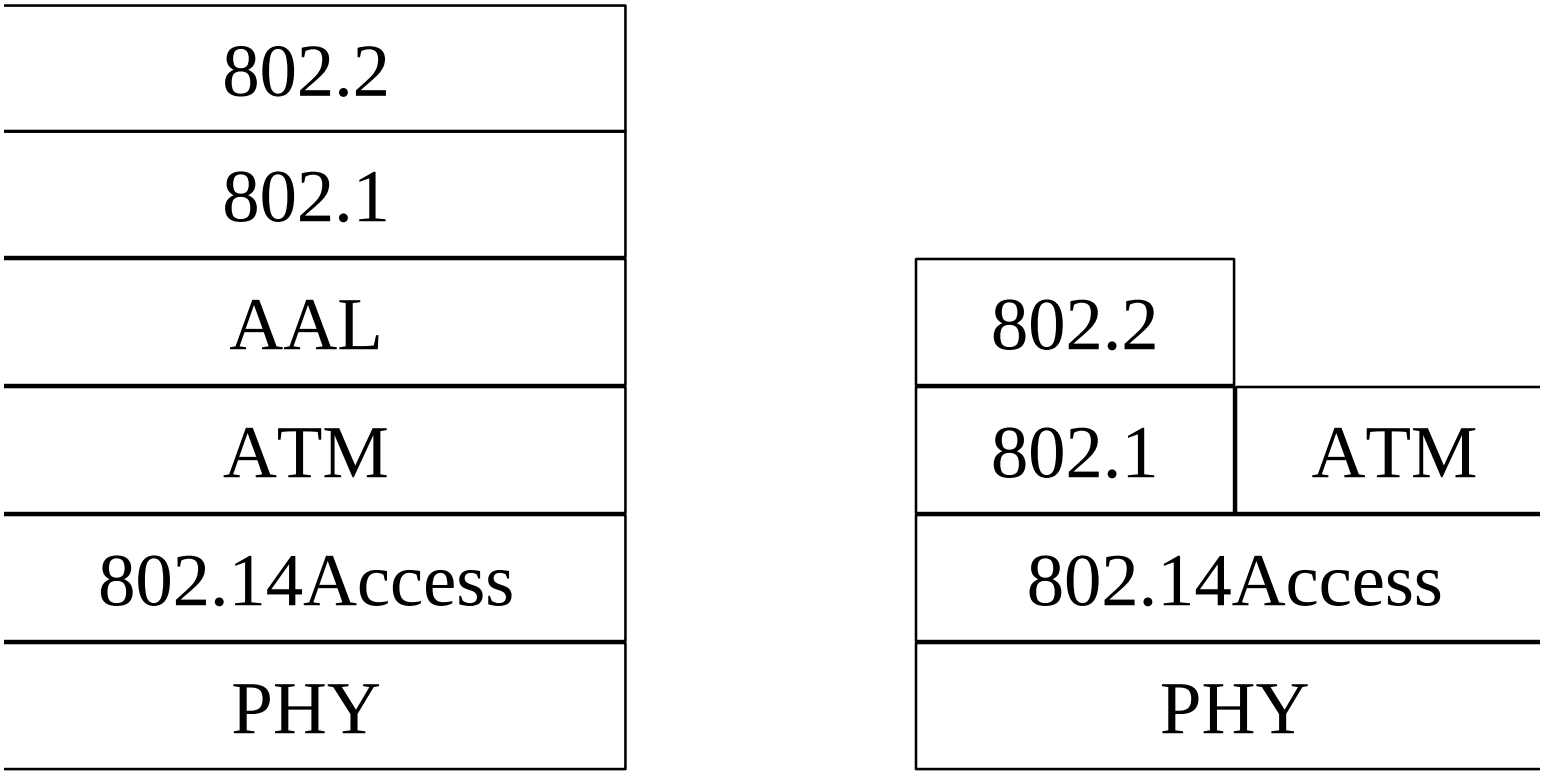


Raj

IEEE 802.14

- Started November 1994. Still continuing.
- ATM and Ethernet interfaces
- Different MAC and PHY than DOCSIS
- Addresses: Permanent (48-bit) and
  14-bit local id

IEEE 802.14 Protocol Stack



All ATM

√ATM Friendly

Other Standards

OpenCable Project:

- DOCSIS-like effort for set-top boxes
- Initiated by cable industry
- Managed by Cablelabs
- Builds on the DOCSIS for new interactive service
- Ref: www.opencable.com

PacketCable Project:

- DOCSIS-like effort for packet voice
- Initiated by cable industry. Managed by Cablelab
- POTS over HFC
- Ref: www.packetcable.com

Other Standards (Cont)

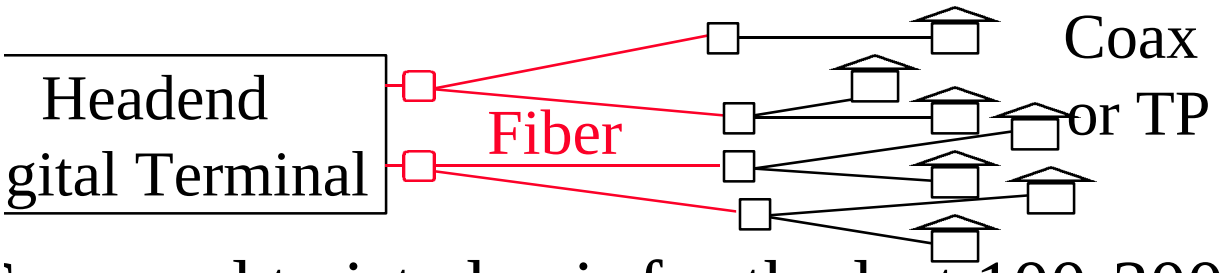
DAVIC/DVB:

- Digital Audio Video Council/Digital Video Broadcasters
- European set-top box designers
- ATM cell based transport
- Ref: www.davic.org

IETF IP over Cable Data Network working group, http://www.ietf.org/html.charters/ipcdn-charter.html

SCTE (Society of Cable Telecommunications Engineers), www.scte.org

Fiber to the Curb (FTTC)



Coax and twisted pair for the last 100-300 m

Coax is used for analog video, TP is used for POTS

Baseband ⇒ No frequency multiplexing

Passive optical network ⇒ signal is optically broadca
to several curbs ⇒ Time division multiplexing

Up to 50 Mbps downstream, Up to 20 Mbps upstrean

Co-exist with POTS or ISDN on the same cable pair

Twisted pair ⇒ EMI ⇒ withstand legal 400W radio
transmissions at 10 m

Fiber to the Home (FTTH)

- Fully optical ⇒ No EMI
- Initially passive optical network ⇒ Time division multiplexing
- Upstream shared using a MAC
- 155 Mbps bi-directional
- Need new fiber installation

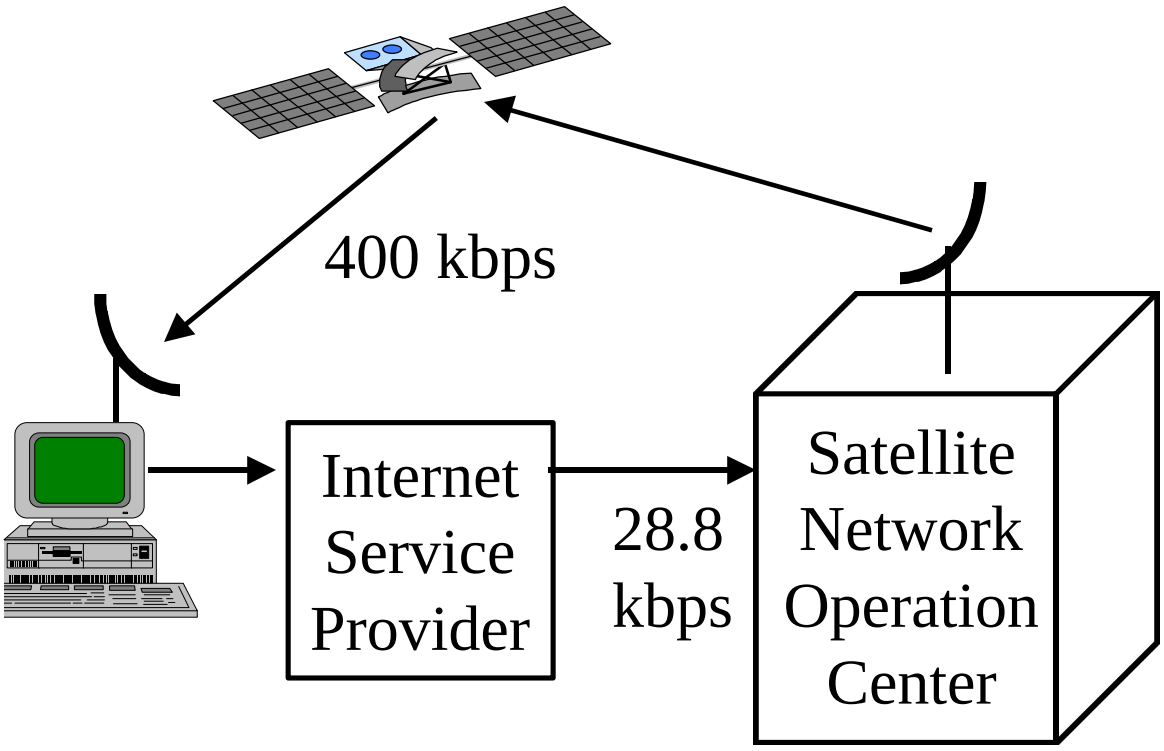
Comparison of RANs

ch-logy	Typical Downstream Rate	Typical Upstream Rate	Max Distance	Homes Per Opt. Unit
FC	45 Mbps Shared	1.5 Mbps Shared	N/A	500
TC	25-50 Mbps	25-50 Mbps	100 m	10-50
TH	155 Mbps	155 Mbps	N/A	10-200
DSL	6 Mbps	640 kbps	4,000 m	1,000
DSL	13-50 Mbps	1.6-5 Mbps	2,000 m	100

ADSL Vs Cable Modems

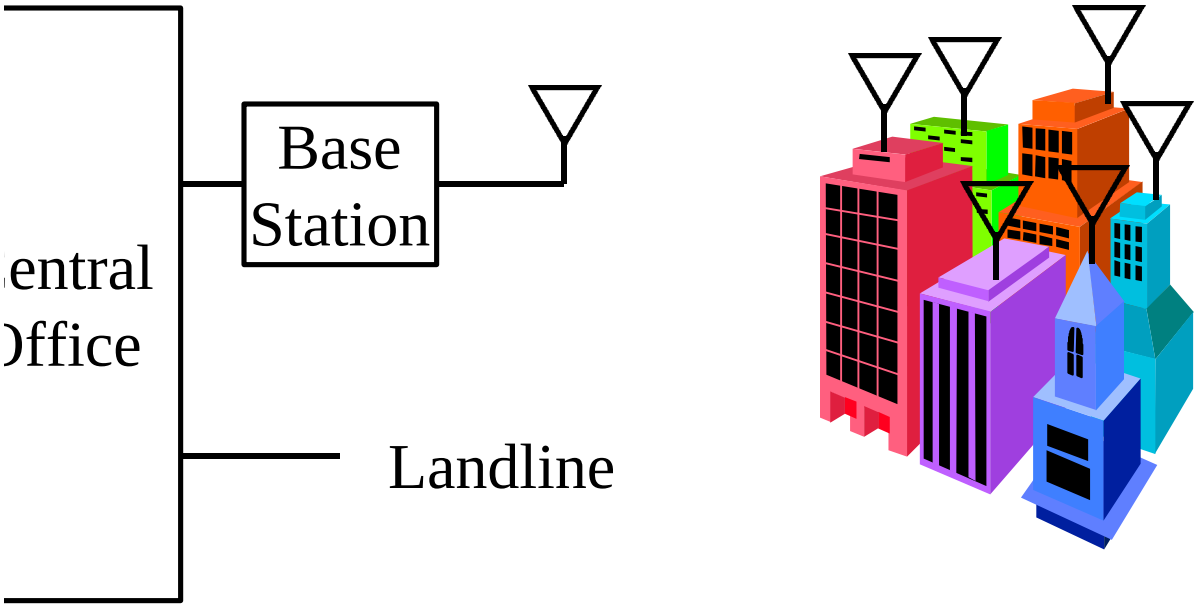
DSL	Cable Modems
ıone company	Cable company
vitching experience ıt low bandwidth ckts	No switching but high bandwidth infrastructure
ɔint-to-point ⇒ Data ivacy	Broadcast. Sharing ⇒ More cost effective
ırrently 1.5 to 8 Mbps	10 to 30 Mbps
ɛrf = fn(location)	Independent of location
ıone everywhere	Cable only in suburbs (not in office parks)
xisting customers ⇒ DN and T1 obsolete	New Revenue

Satellites for Data



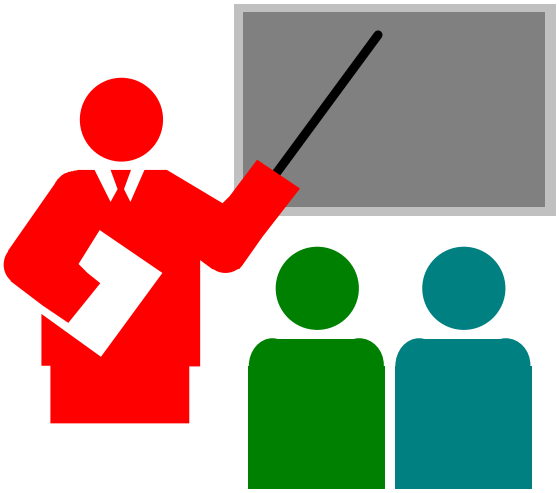
- DirecPC from Hughes
- One-way high-speed connection

Wireless Local Loop



Fixed, high, directional antennas ⇒ Lower loss, no handoff

Summary



- High Speed Access to Home:
  ADSL, VDSL, HFC, FTTC, FTTH
- 6 to 155 Mbps downstream, 1.5 Mbps upstream
- Both cable and telecommunication companies are
  rying to get there with minimal modification to thei
  nfrastructure

RBB: Key References

For a detailed list of references, see http://www.cis.ohio-state.edu/~jain/refs/rbb_refs.htm

Cable Data Networks, http://www.cis.ohio-state.edu/~jain/cis788-97/cable_modems/index.hm

Digital Subscriber Lines and Cable Modems, http://www.cis.ohio-state.edu/~jain/cis788-97/rbb/index.htm

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ANSI T1.413, ADSL Metallic Interface

EEE 802.14 Working group,
ttp://www.walkingdog.com

The ADSL Forum, http://www.adsl.com

Cable Labs, http://www.cablemodem.com

Cable Modem FAQ,
ttp://www.cox.com/modemfaq.html