Residential Broadband: Technologies for High-Speed Access To Homes

Raj Jain

Raj Jain is now at
Washington University in Saint Louis
Jain@cse.wustl.edu
http://www.cse.wustl.edu/~jain/

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

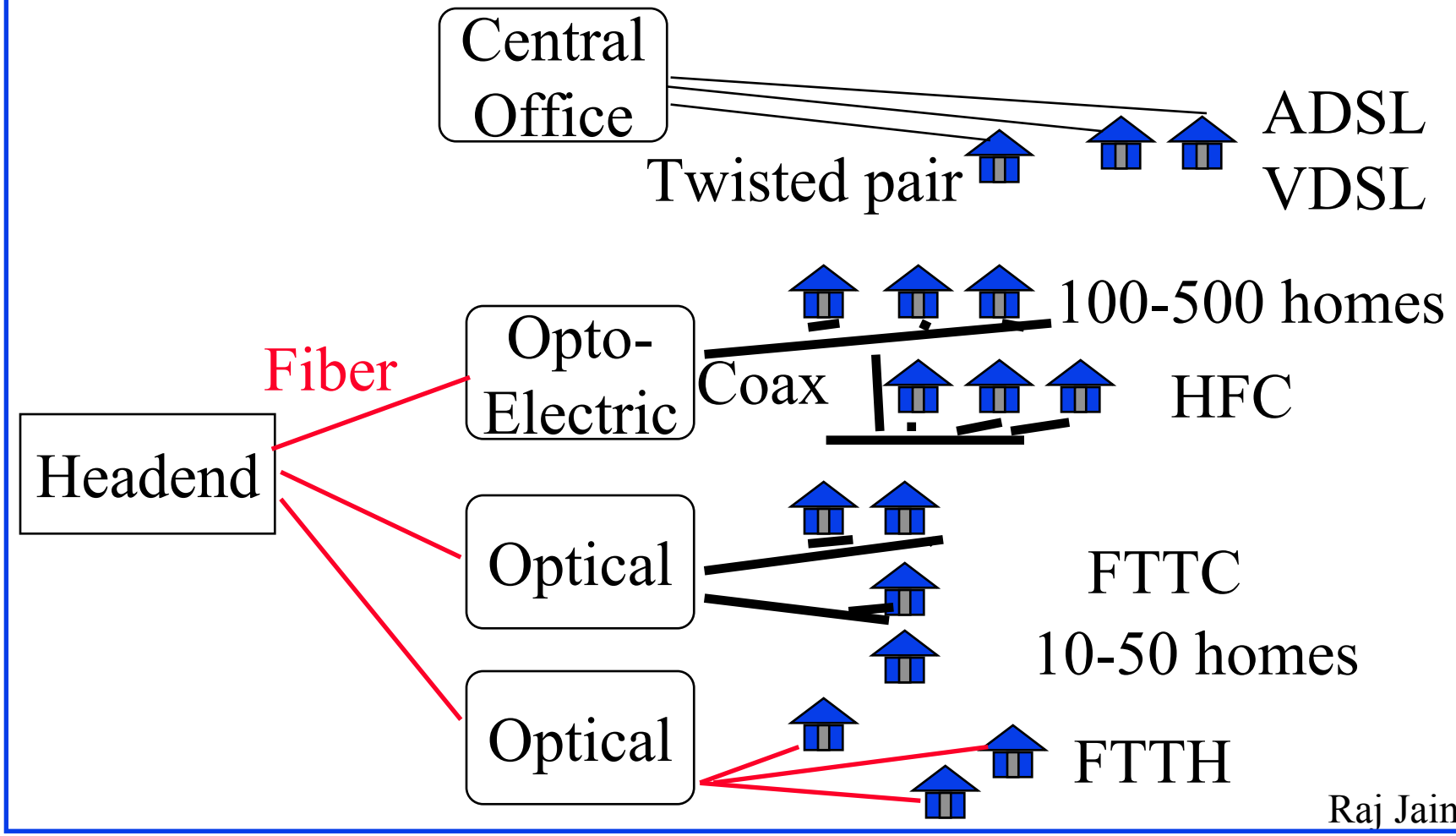
Potential Applications

- Video on demand (VOD)
- Near video on demand (NVOD)
  - staggered starts
- Distance learning, Teleconferencing, Home shopping
- 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)



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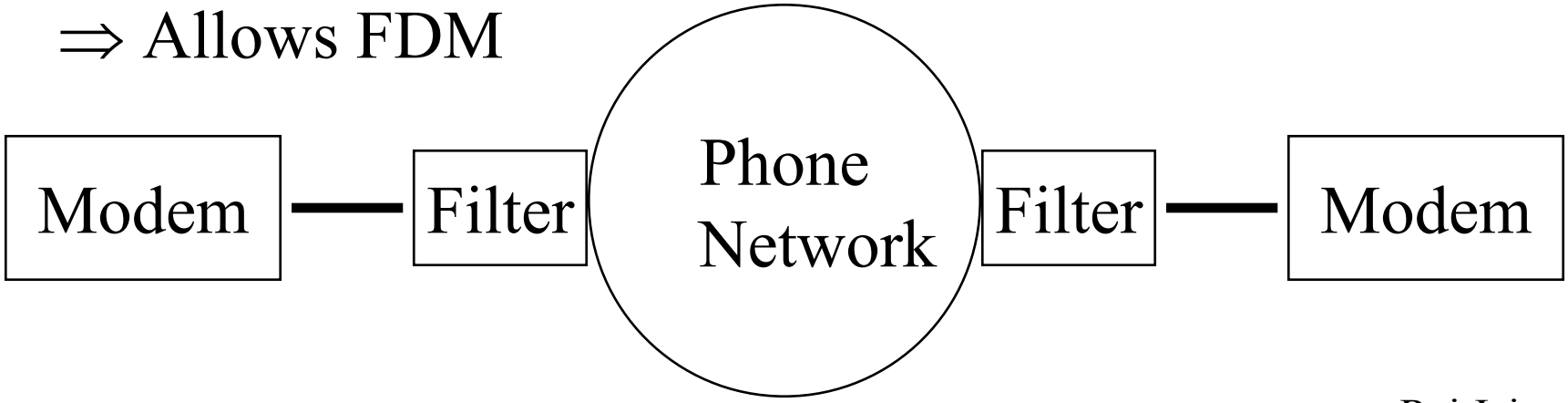
RANs (Cont)

- 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

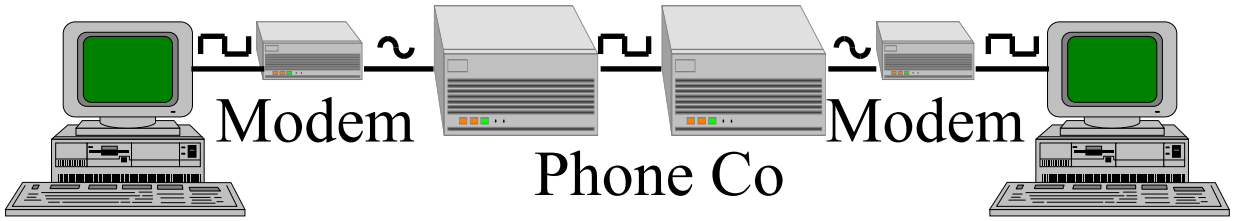
Why Modems are Low Speed?

- 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

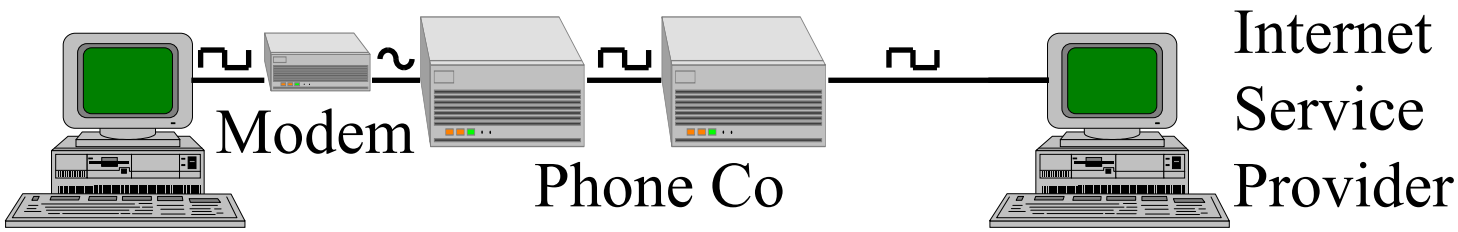


56 kbps Modems

- Past:



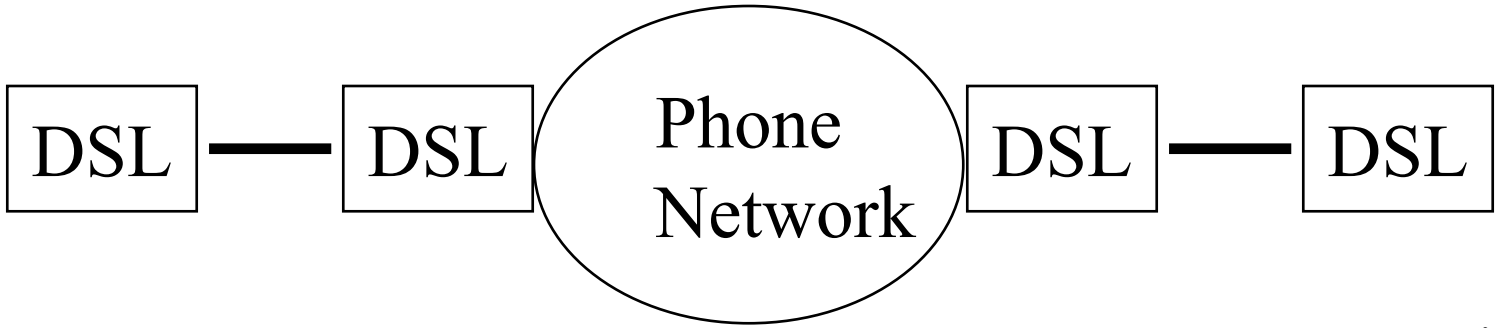
- Current:



- ISP's have direct digital link (T1 or T3)
- Only one D/A/D conversion ⇒ Higher speed possible

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

- Initially T1/E1 over copper used AMI coding ⇒ Repeaters every 3000 - 6000 ft
- Uses 1.5 MHz for 1.5 Mbps ⇒ Wasteful of bandwidth ⇒ Interference ⇒ Can't put more than 1 circuit in a 50 pair cable
- HDSL transmits T1/E1 over two pairs using 80 to 240 kHz ⇒ repeaters at 12,000 ft
- Used 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 $\Rightarrow$ Crosstalk
- Downstream signals are all same amplitude $\Rightarrow$ Not affected
- Upstream signals start at different distances $\Rightarrow$ Different amplitudes $\Rightarrow$ Weak signals are highly affected
- Solutions:
  1. Use asymmetric rates
  2. Use lower frequencies for upstream (Cross talk increases with frequencies)

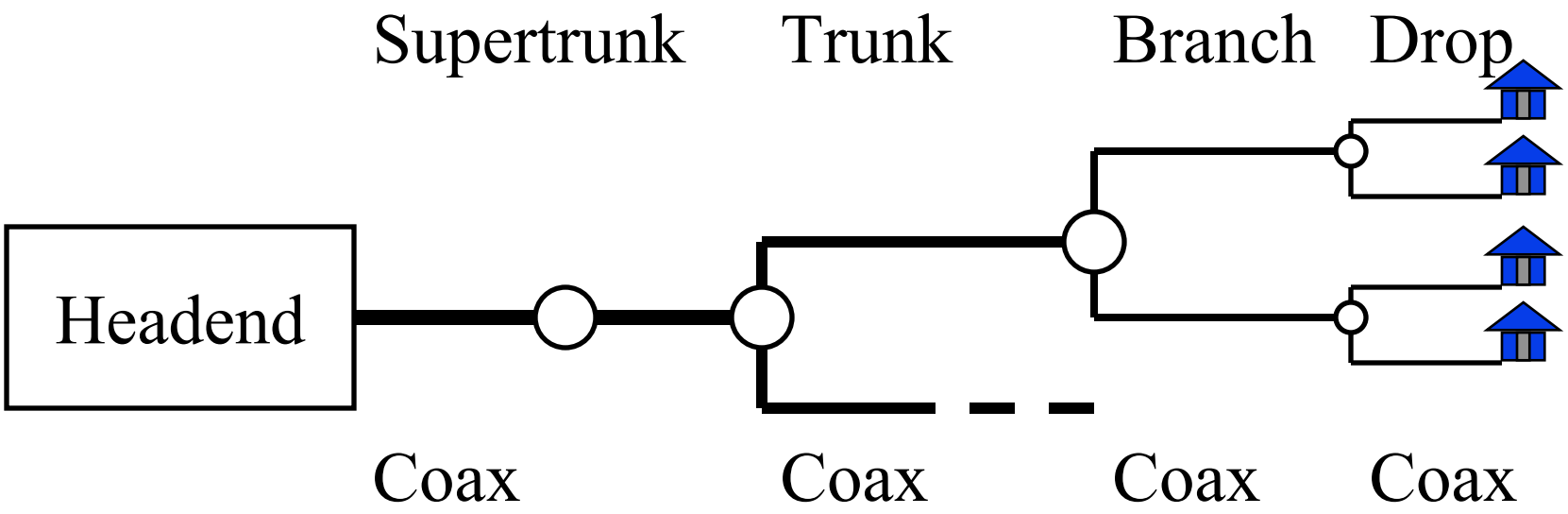
VDSL

- Very High-Speed Digital Subscriber Lines
- Also called VADSL, BDSL, VHDSL
- ANSI T1E1.4 standardized the name VDSL and ETSI also adopted it
- VDSLe to denote European version
- For use in FTTC systems
- Downstream Rates: 51.84 -55.2 Mbps (300 m), 25.92-27.6 Mbps (1000 m), 12.96 - 13.8 Mbps (1500 m)

VDSL (Cont)

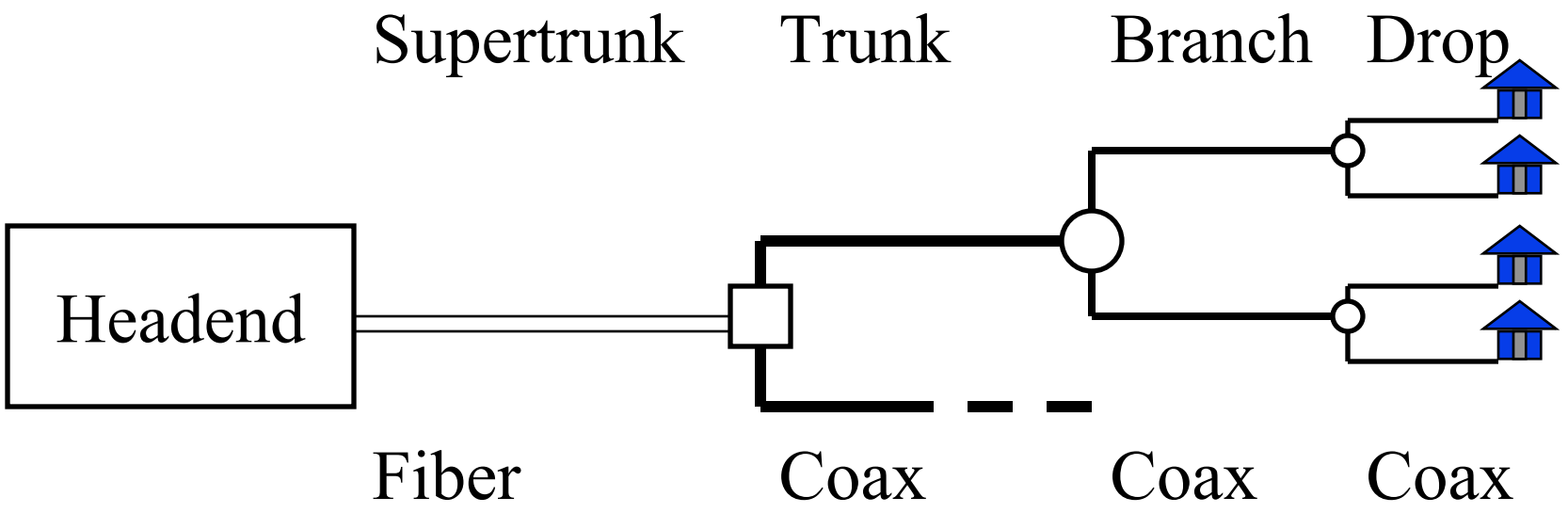
- Upstream Rates: 1.6-2.3 Mbps,
  19.2 Mbps, Same as downstream
- Admits passive network termination
  $\Rightarrow$ Can connect multiple VDSL modems like extension phones
  (ADSL requires active termination)
- Unlike ADSL, VDSL uses ATM to avoid packet handling and channelization
- Orkit Communications (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

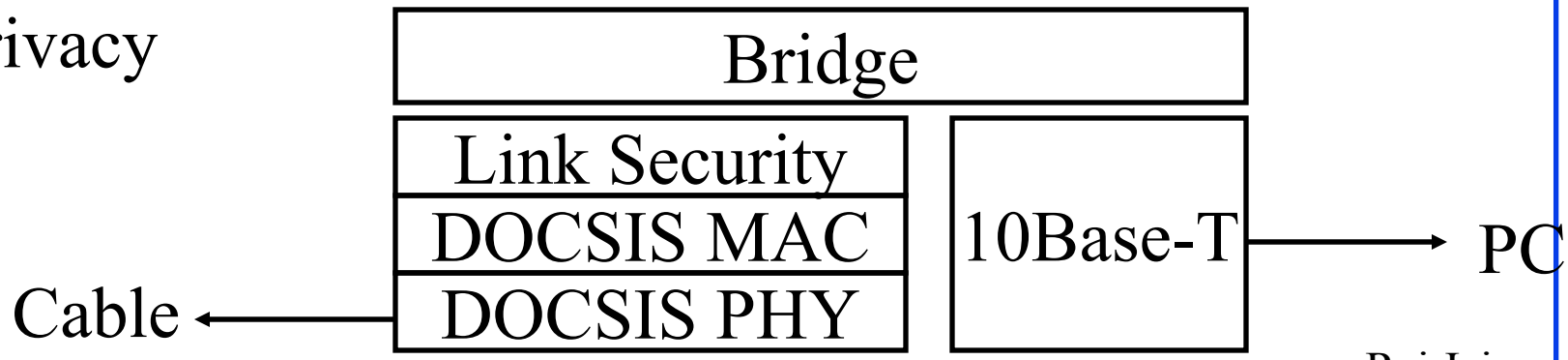
- Modulate RF frequencies into cable.
- Cost $395 to $995
- If cable is still one-way, upstream path through POTS
- $30 to $40 per month flat service charge
- 45 Mbps downstream, 1.5 Mbps upstream
- MAC protocol required to share upstream bandwidth
- Sharing ⇒ Security issues
- Servers at headend to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

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

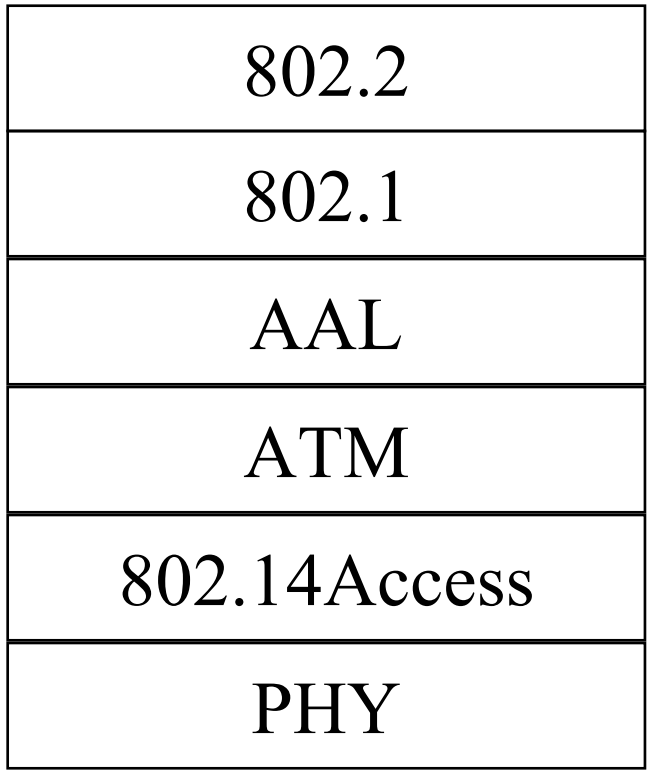
- Switched Ethernet service ⇒ One large LAN
- Downstream packets use 188-byte MEPG2 transport stream frames
  ⇒ Compatible with digital video standards
  ⇒ Allows mixing data and video in the same channel
- Upstream is slotted. Head-end allocates minislots.
- Packets can be optionally encrypted using DES for privacy



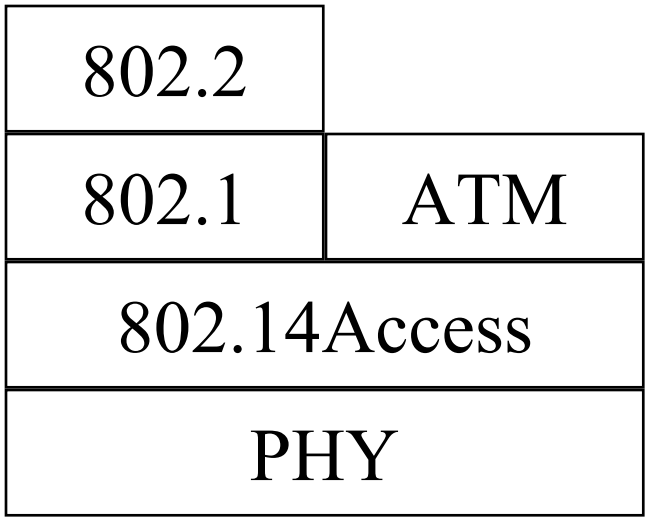
IEEE 802.14

- 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

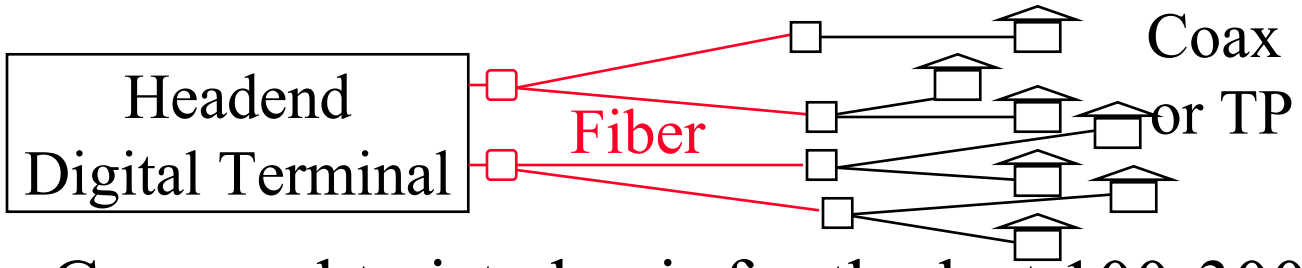
Other Standards

- OpenCable Project:
  - DOCSIS-like effort for set-top boxes
  - Initiated by cable industry
  - Managed by Cablelabs
  - Builds on the DOCSIS for new interactive services
  - Ref: www.opencable.com
- PacketCable Project:
  - DOCSIS-like effort for packet voice
  - Initiated by cable industry. Managed by Cablelabs.
  - 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 broadcast to several curbs ⇒ Time division multiplexing
- Up to 50 Mbps downstream, Up to 20 Mbps upstream
- 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

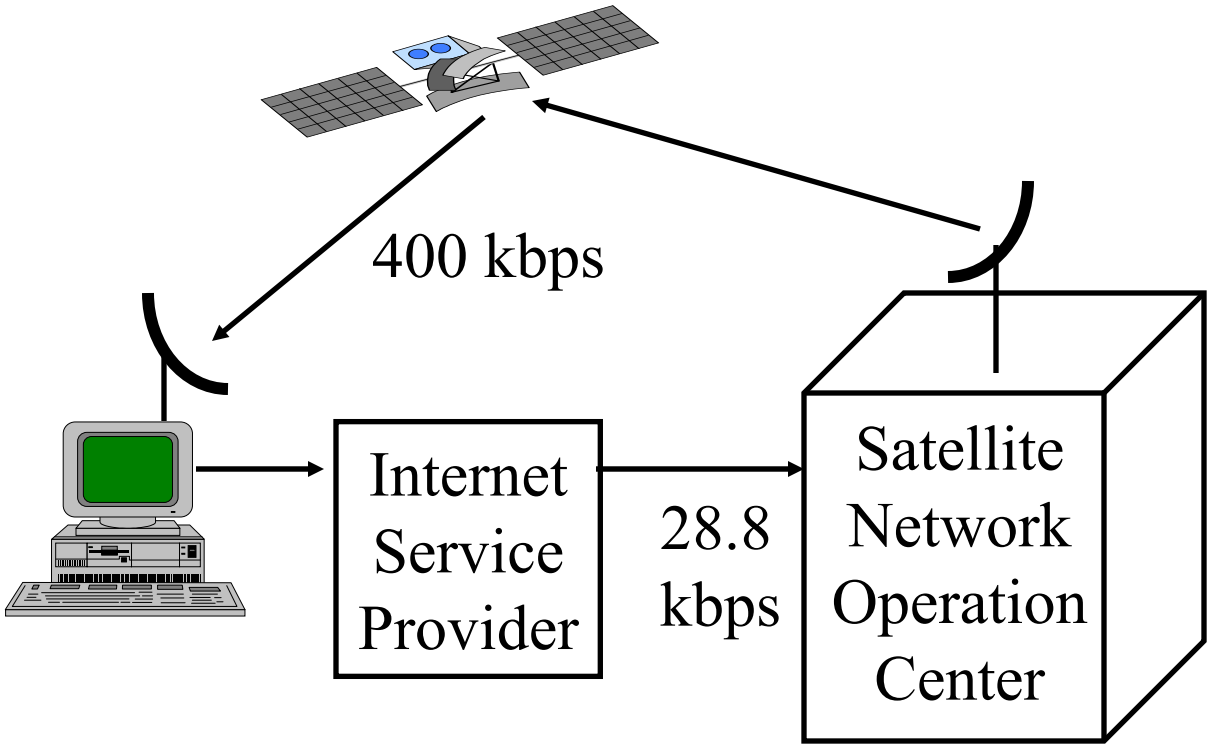
Comparison of RANs

Tech-nology	Typical Downstream Rate	Typical Upstream Rate	Max Distance	Homes Per Opt. Unit
HFC	45 Mbps Shared	1.5 Mbps Shared	N/A	500
FTTC	25-50 Mbps	25-50 Mbps	100 m	10-50
FTTH	155 Mbps	155 Mbps	N/A	10-200
ADSL	6 Mbps	640 kbps	4,000 m	1,000
VDSL	13-50 Mbps	1.6-5 Mbps	2,000 m	100

ADSL Vs Cable Modems

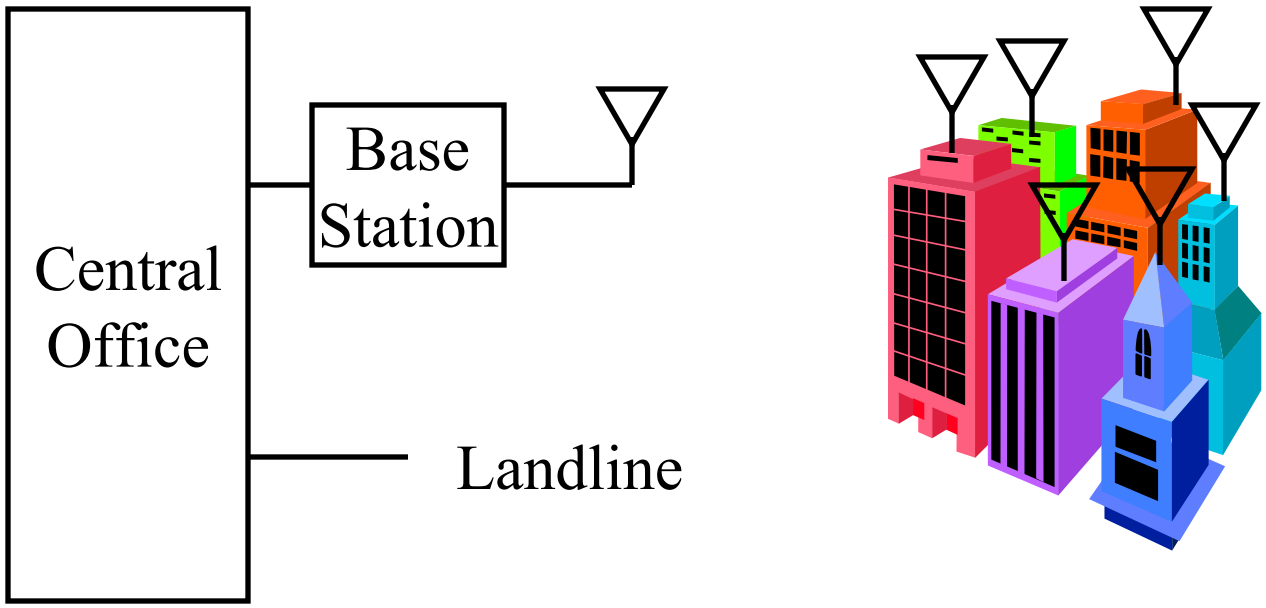
ADSL	Cable Modems
Phone company	Cable company
Switching experience but low bandwidth ckts	No switching but high bandwidth infrastructure
Point-to-point ⇒ Data privacy	Broadcast. Sharing ⇒ More cost effective
Currently 1.5 to 8 Mbps	10 to 30 Mbps
Perf = fn(location)	Independent of location
Phone everywhere	Cable only in suburbs (not in office parks)
Existing customers ⇒ ISDN and T1 obsolete	New Revenue

Satellites for Data



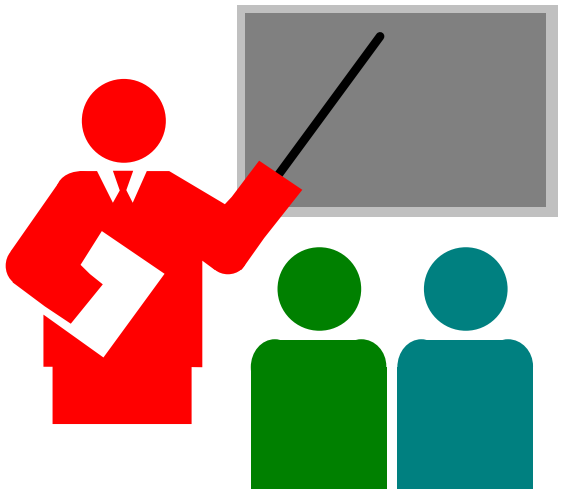
- DirecPC from Hughes
- One-way high-speed connection

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 trying to get there with minimal modification to their infrastructure

RBB: Key References

- For a detailed list of references, see http://www.cse.ohio-state.edu/~jain/refs/rbb_refs.htm
- Cable Data Networks, http://www.cse.ohio-state.edu/~jain/cis788-97/cable_modems/index.hm
- Digital Subscriber Lines and Cable Modems, http://www.cse.ohio-state.edu/~jain/cis788-97/rbb/index.htm

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- "Cable TV access method and physical layer specification," IEEE Project 802.14/a Draft 3 Revision 1, August 1998, http://www.walkingdog.com/catv/ieee_802.14d3r2.pdf
- ANSI T1.413, ADSL Metallic Interface
- IEEE 802.14 Working group, http://www.walkingdog.com
- The ADSL Forum, http://www.adsl.com
- Cable Labs, http://www.cablemodem.com
- Cable Modem FAQ, http://www.cox.com/modemfaq.html