Recent Advances in Computer Networking including ATM, Multimedia, Wireless, and Residential Broadband

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- Networking Trends
- ATM Networks
  - Overview
  - Legacy Traffic Over ATM
  - Issues and Challenges
- Multimedia Networking
- Wireless Networks
- Residential Broadband

Schedule: Tentative

9:00-9:15	Course Introduction
9:15-10:15	Trends
10:15-10:30	*Coffee Break*
10:30-11:15	ATM Networks: Overview
11:15-12:00	Legacy Protocols Over ATM
12:00-1:00	*Lunch Break*
1:00-1:15	ATM Issues and Challenges
1:15-2:00	Multimedia
2:00-2:15	*Stretch Break*
2:15-3:30	Wireless
3:30-3:45	*Coffee Break*
3:45-5:00	Residential broadband

References

- A detailed list of references is provided at the end
- You can get to all on-line references via:
  http://www.cis.ohio-state.edu/~jain/refs/au97_ref.htm
- A list of abbreviations is also included at the end

Pre-Test

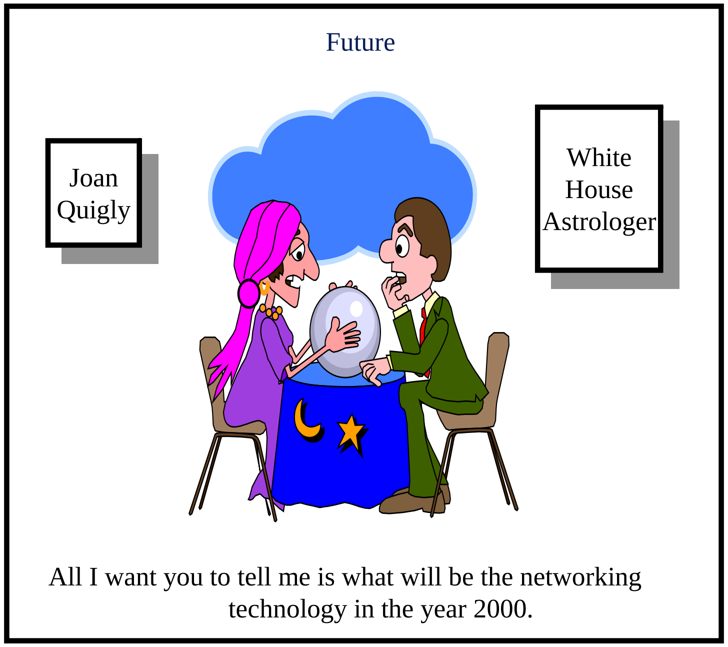
Check if you know the difference between:

- ❑ AAL1 and AAL5
- ❑ LAN emulation and Classical IP over ATM
- ❑ ARP and NHRP
- ❑ JPEG and MPEG?
- ❑ RSVP and ATM reservation styles
- ❑ Spread-spectrum and narrow band
- ❑ Speeds of IEEE 802.3 and IEEE 802.11 networks
- ❑ Home agents and foreign agents in mobile IP
- ❑ HDSL and VDSL
- ❑ HFC and FTTH

Number of items checked ______

- If you checked more than 5 items, you may not gain much from this course.
- If you checked only a few or none, don't worry. This course will cover all this and much more.

Networking Trends



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- General Trends
- Life Cycle of Technologies
- Trends in Applications
- Trends in Topology
- Electro-optical Bottleneck

Trend: Telecommunication and Networking

- From computerization of telephone traffic switching to telephonization of computer traffic switching.

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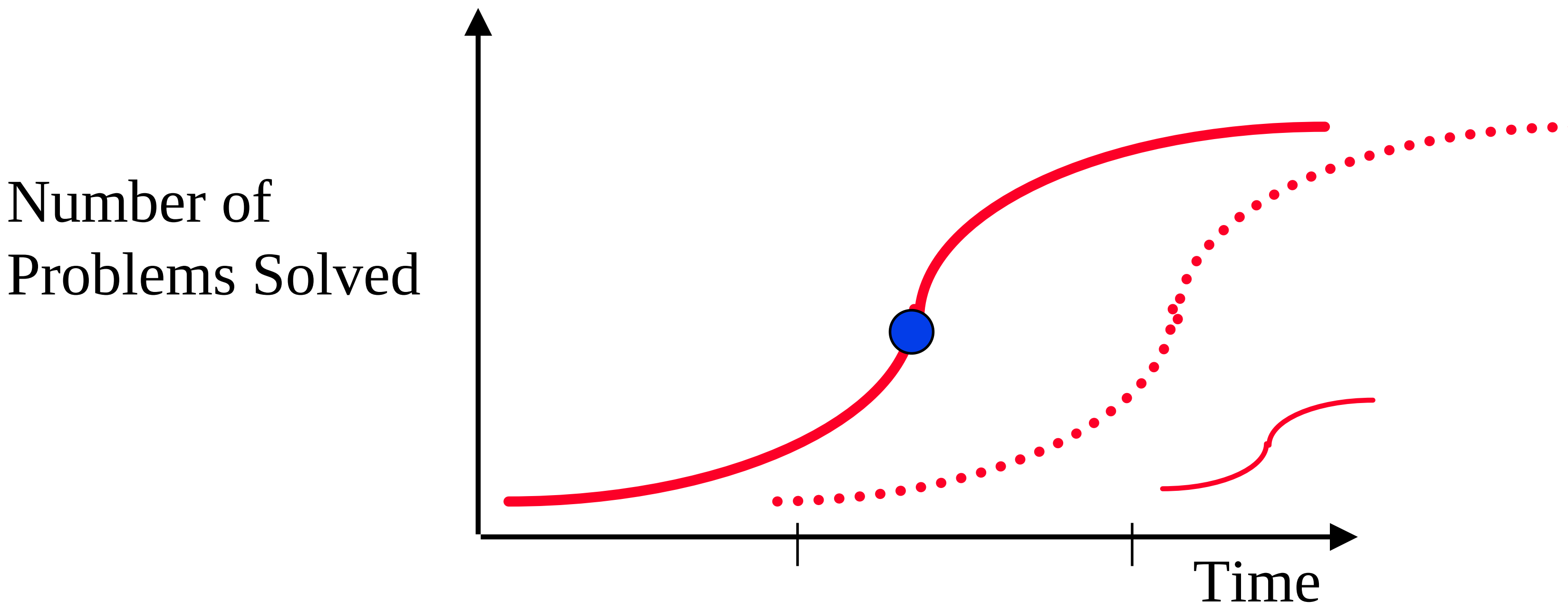
Trend: Networking is Critical

- Communication more critical than computing
  ⇒ Bus performance vs ALU speed
  ⇒ I/O performance vs SPECMarks
- User Location:
  - 1960: Computer room — 1970: Terminal room
  - 1980: Desktop — 1990: Mobile
- System Extent:
  - 1980: 1 Node within 10 m
  - 1990: 100 nodes within 10 km

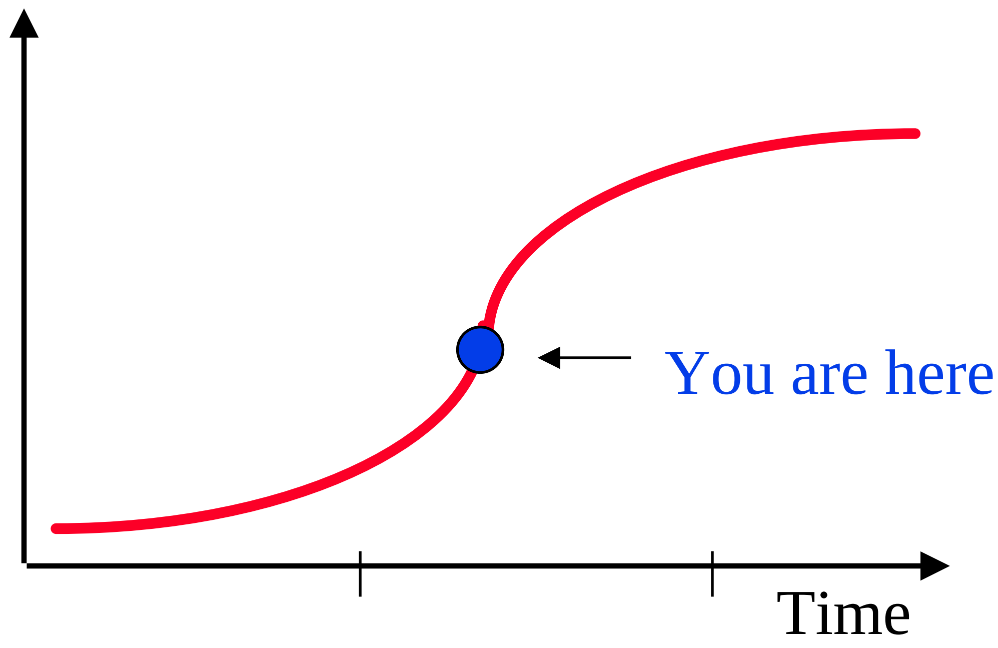
- Last 10 years: Individual computing
  Next 10 years: Cooperative computing
- Past: Corporate networks
  Future:
  - Intercorporate networks
  - National Info Infrastructures
  - International Info Infrastructures

Life Cycles of Technologies



Life Cycles of Networking Technology

Number of Hosts
Bytes per Hosts
Number of Networks
MIPS
Memory Size
Storage



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Networking in Social Fabric

- USENET: Ten million news articles/month
- 18 on-line coffee houses in San Francisco
- National Public Radio Program
- Supreme court decision within one day
- Real estate, on-line catalog
- 137 countries reachable via Email

Trend: Standardization

- Distinction in service, implementation, performance, size, cost
- Religion must be forgotten
  ⇒ Improve on other's ideas as naturally as yours
- Can't succeed alone
  ⇒ Innovation + Technology partnerships
- Vertical vs horizontal specialization
  ⇒ Switch, router, host, applications

Processors
Networking

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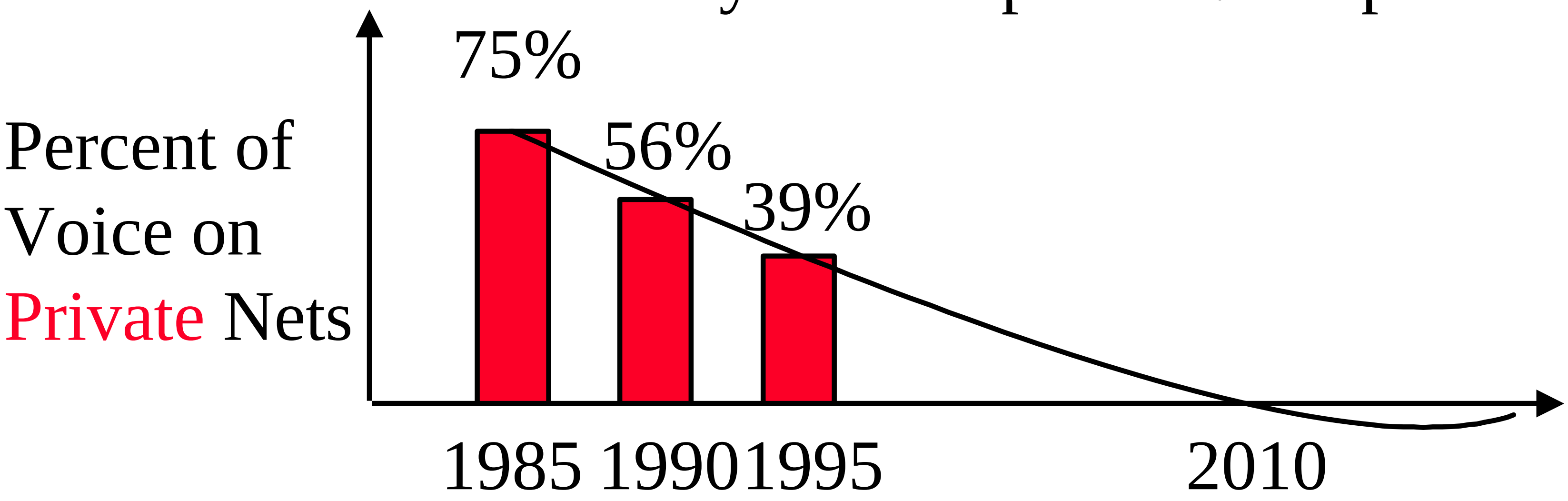
Trends in Applications

- Little Voice
- AT&T: 125 to 130 M calls/day @ 5 min/call
  64 kbps/call ⇒ 28.8 Gbps = 1/1000 of one fiber
- 200 Million X 24 hr/day X 64 kbps = 12.8 Tbps

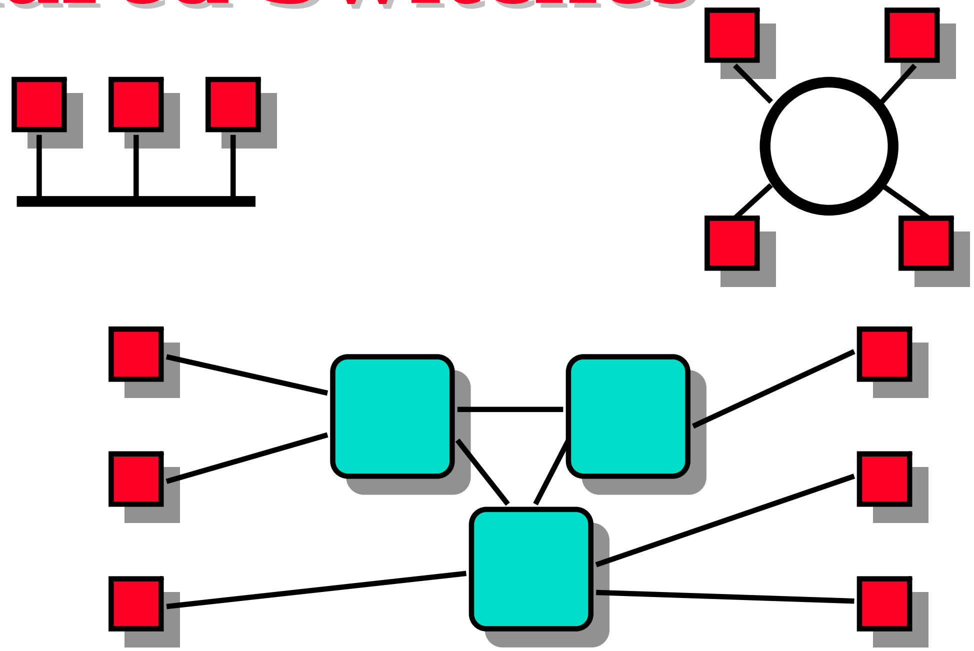


- Ref: IEEE Spectrum, August 1992, p 19.

Electro-optic Bottleneck

- Bandwidth of fiber = 25 THz/window
- Bandwidth of electronics = 1-10 Gbps
- Switching bottleneck ⇒ Optical switching ⇒ All-optical networks
- Switches more expensive than media:
  Less switches and more links
- Higher connectivity, less hops
- Distributed-media shared-switching (like WANs) and not
  distributed-switching shared-media (like LANs)

Shared Media Access vs Shared Switches



- Variable bandwidth/station
- Cost $\propto$ bandwidth
- Incremental upgradability
- Natural spatial reuse

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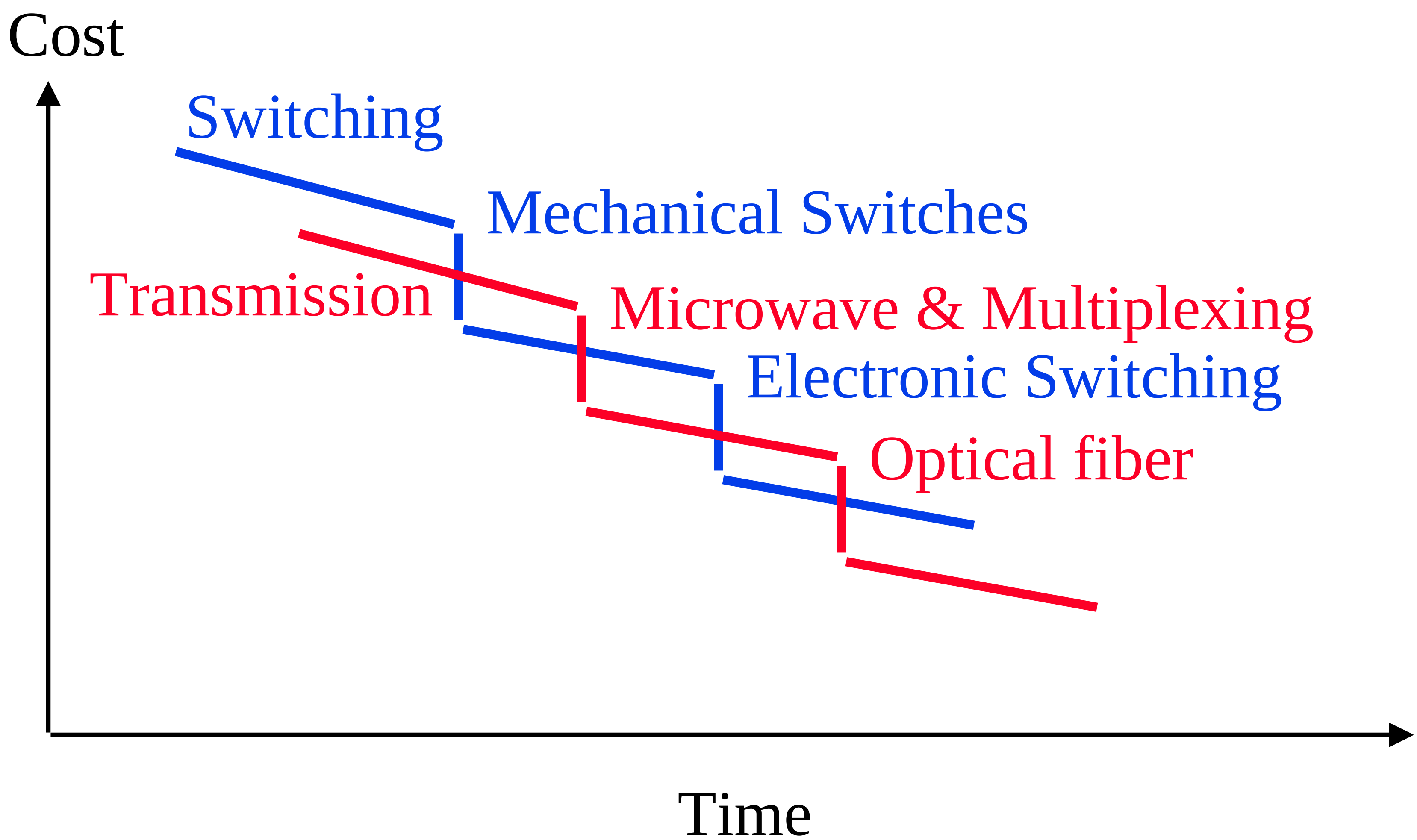
Switching vs Transmission



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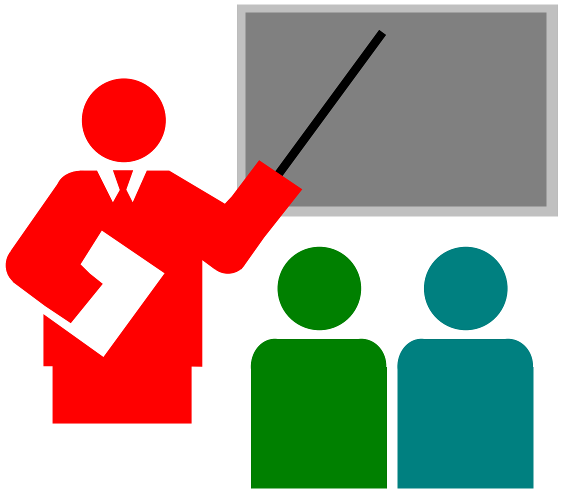
Summary



- Networking is critical and growing exponentially.
- Computer and Telecommunications industry merging
- Standardization
- Shared switching rather than shared media

ATM Networks

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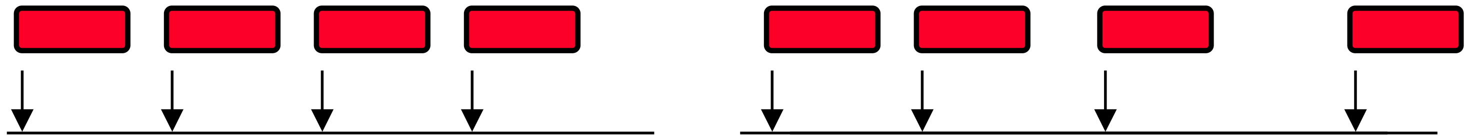
- ATM: Overview
- ATM Protocol Layers
- Network Interfaces
- Adaptation Layers
- Physical Layers

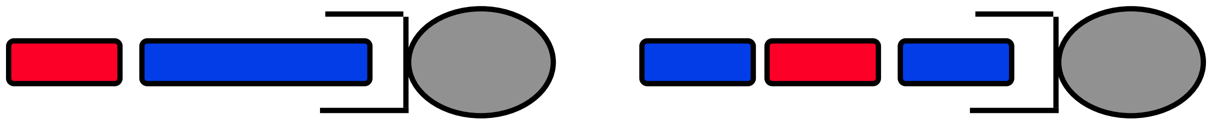
ATM Networks: Overview

- STM = Synchronous Transfer Mode,
  ATM = Asynchronous Transfer Mode

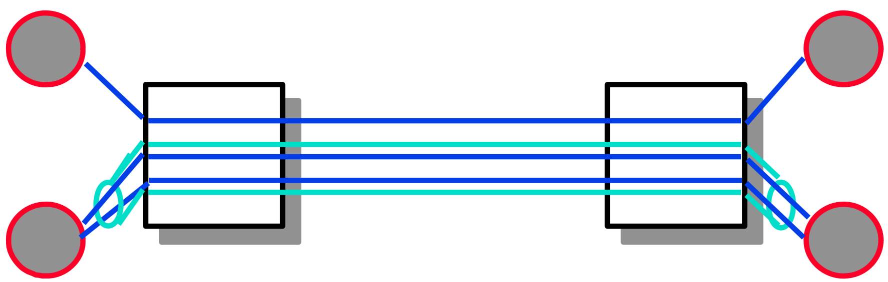


Allows any-speed and even variable rate connection

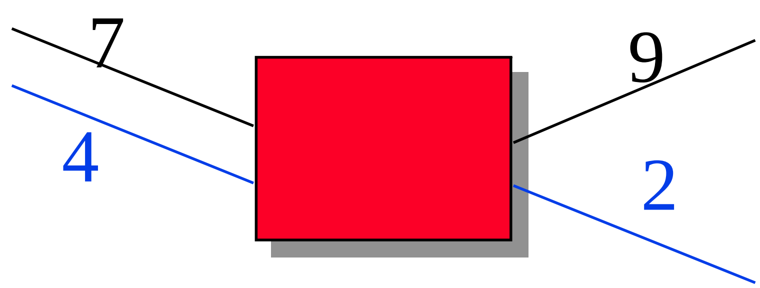
- ATM = Short fixed size 53-byte cells



- Connection oriented ⇒ Virtual Channels (VC)

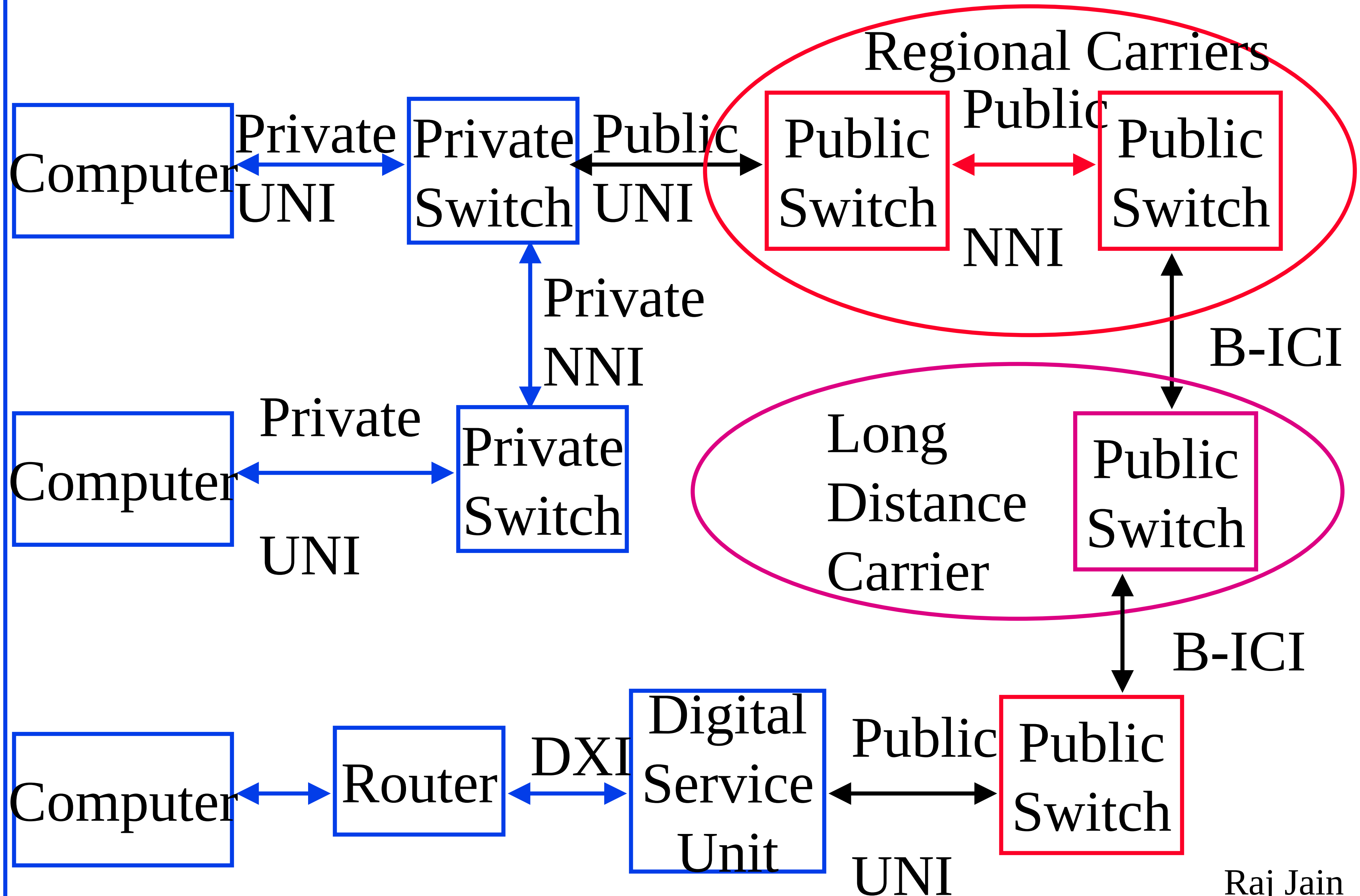


- Labels vs addresses
  ⇒ Better scalability in number of nodes



- Switches vs routers
  ⇒ Faster due to fixed size, short address, simplicity
- Seamless ⇒ Same technology for LAN, WAN,
- Data, voice, video integration
- Everyone else is doing it

ATM Network Interfaces



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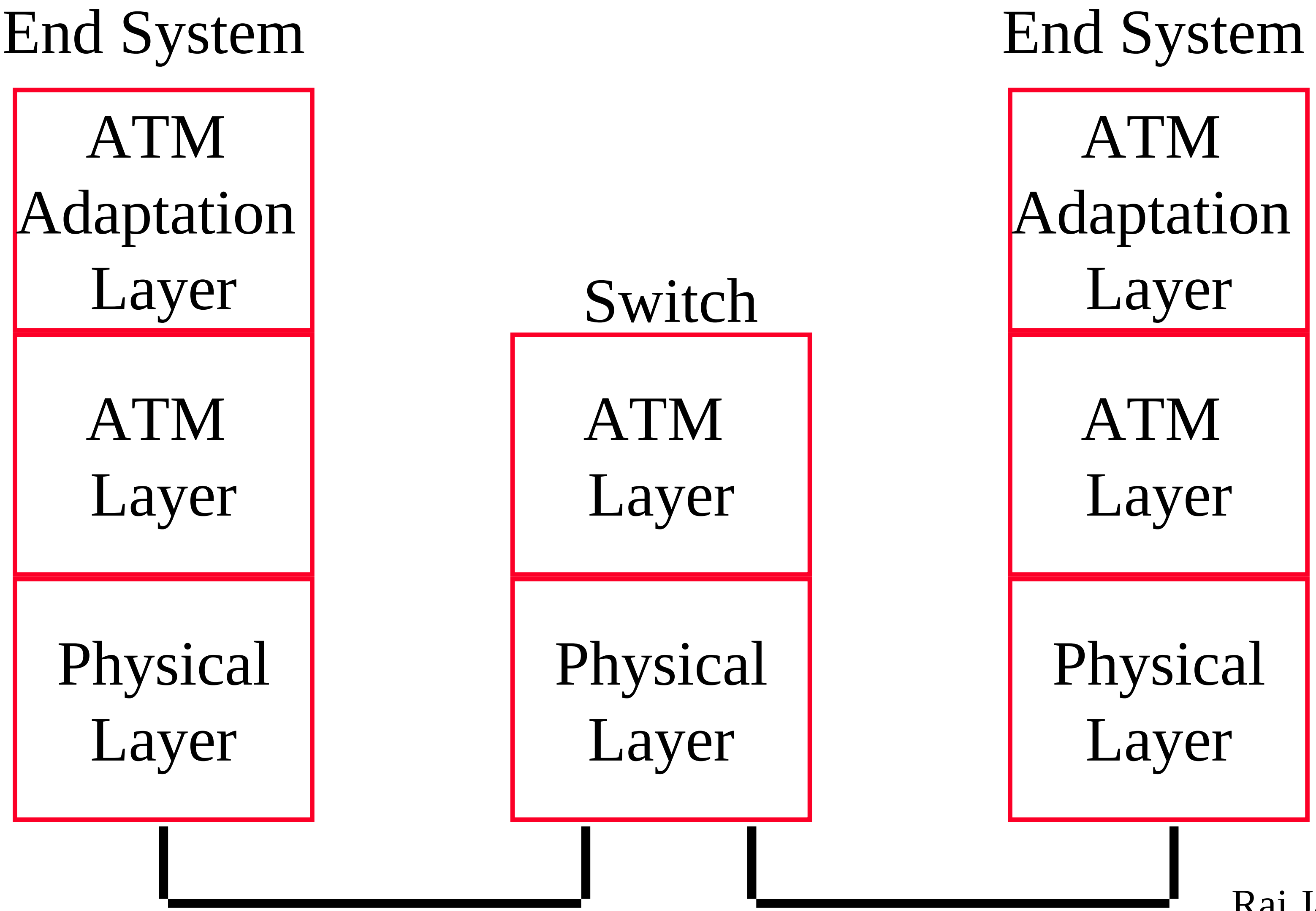
ATM Network Interfaces

- User to Network Interface (UNI):
  Public UNI, Private UNI
- Network to Node Interface (NNI):
  - Private NNI (P-NNI)
  - Public NNI =Inter-Switching System Interface (ISSI)
    Intra-LATA ISSI (Regional Bell Operating Co)
  - Inter-LATA ISSI (Inter-exchange Carriers)
    $\Rightarrow$ Broadband Inter-Carrier Interface (B-ICI)
- Data Exchange Interface (DXI)
  Between routers and ATM Digital Service Units (DSU)

Protocol Layers



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Protocol Layers

- The ATM Adaptation Layer
  - How to break application messages to cells
- The ATM Layer
  - Transmission/Switching/Reception
  - Congestion Control/Buffer management
  - Cell header generation/removal at source/destination
  - Cell address translation
  - Sequential delivery

ATM Cell Header Format

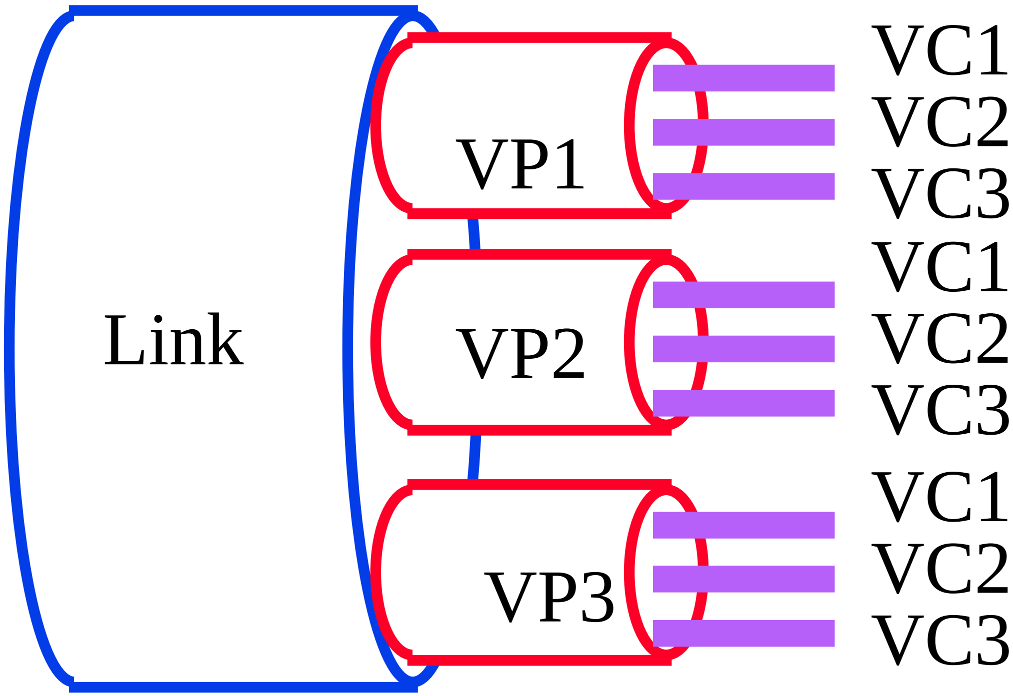
- GFC = Generic Flow Control
  - (Was used in UNI but not in NNI)
- VPI/VCI = 0/0 $\Rightarrow$ Idle cell; 0/n $\Rightarrow$ Signaling
- HEC: $1 + x + x^2 + x^8$

<table>
<tr><td>GFC/VPI</td><td colspan="2">VPI</td></tr>
<tr><td>VPI</td><td colspan="2">VCI</td></tr>
<tr><td colspan="3">VCI</td></tr>
<tr><td>VCI</td><td>PTI</td><td>CLP</td></tr>
<tr><td colspan="3">Header Error Check (HEC)</td></tr>
</table>

Payload

Connection Identifiers

- Each cell contains a 24/28-bit connection identifier
  First 8/12 bits: Virtual Path,
  Last 16 bits: Virtual Circuit
- VP service allows new VC's w/o orders to carriers



Original Classes of Traffic

	Class A	Class B	Class C	Class D
Time Synch	Required		Not Required	
Bit Rate	Constant	Variable		
Connection Mode	Connection oriented			Connectionless
AAL	AAL 1	AAL 2	AAL 3	AAL 4
Examples	Circuit emulation	Compressed Video	Frame Relay	SMDS

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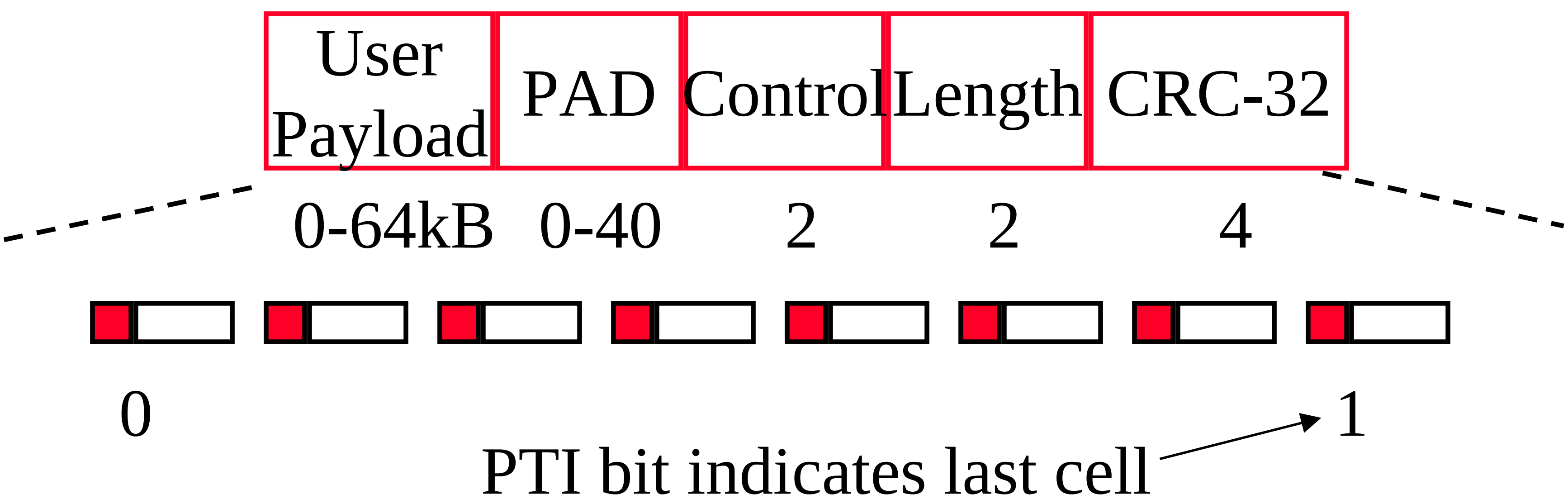
AAL 5

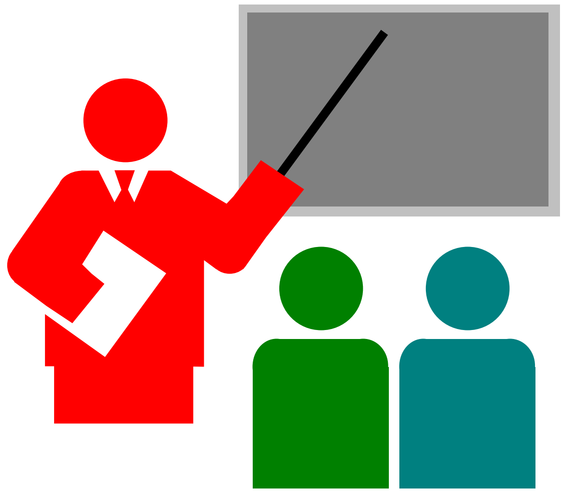
- Designed for data traffic
- Less overhead bits than AAL 3/4
  ⇒ Simple and Efficient AAL (SEAL)
- No per cell length field, No per cell CRC



Physical Media Dependent Layers (PMDs)

- Multimode Fiber: 100 Mbps using 4b/5b (TAXI), 155 Mbps SONET STS-3c, 155 Mbps 8b/10b
- Single-mode Fiber: 155 Mbps STS-3c, 622 Mbps
- Shielded Twisted Pair (STP): 155 Mbps 8b/10b
- Coax: 45 Mbps, DS3, 155 Mbps
- Unshielded Twisted Pair (UTP)
  - UTP-3 (phone wire) at 25.6 Mbps, 51.84 Mbps
  - UTP-5 (Data grade UTP) at 155 Mbps
- DS1, DS3, STS-3c, STM-1, E1, E3, J2, n × T1

Summary



- ATM Overview: History, Why and What
- Protocol Layers: AAL, ATM, Physical layers, Cell format
- Interfaces: PNNI, NNI, B-ICI, DXI

ATM : Key References

- H. Dutton and Peter Lenhard, “Asynchronous Transfer Mode (ATM) Technical Overview,” 2nd Ed., Prentice Hall, 1995.
- S. Siu and R. Jain, "A brief overview of ATM: Protocol Layers, LAN Emulation and Traffic Management" Computer Communications Review (ACM SIGCOMM), April 1995. Available at http://www.cis.ohio-state.edu/~jain/
- http://www.atmfourm.com
  ftp://ftp.atmforum.com/pub/approved-specs/
- http://www.cis.ohio-state.edu/~jain/refs/hot_refs.htm

Legacy Protocols Over ATM

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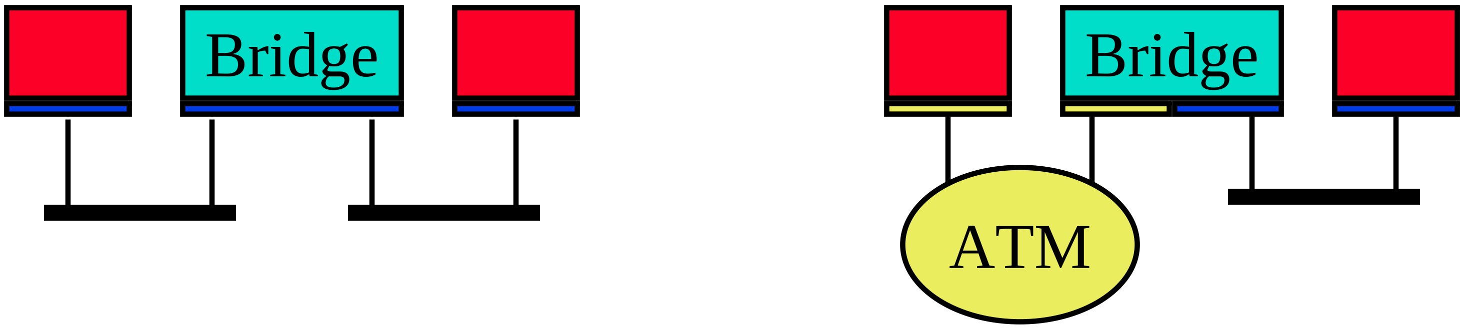
- LAN Emulation
- IP Over ATM
- Next-Hop Resolution Protocol (NHRP)

LAN Emulation



- Problem: Need new networking s/w for ATM
- Solution: Let ATM network appear as a virtual LAN
- LAN emulation implemented as a device driver below the network layer

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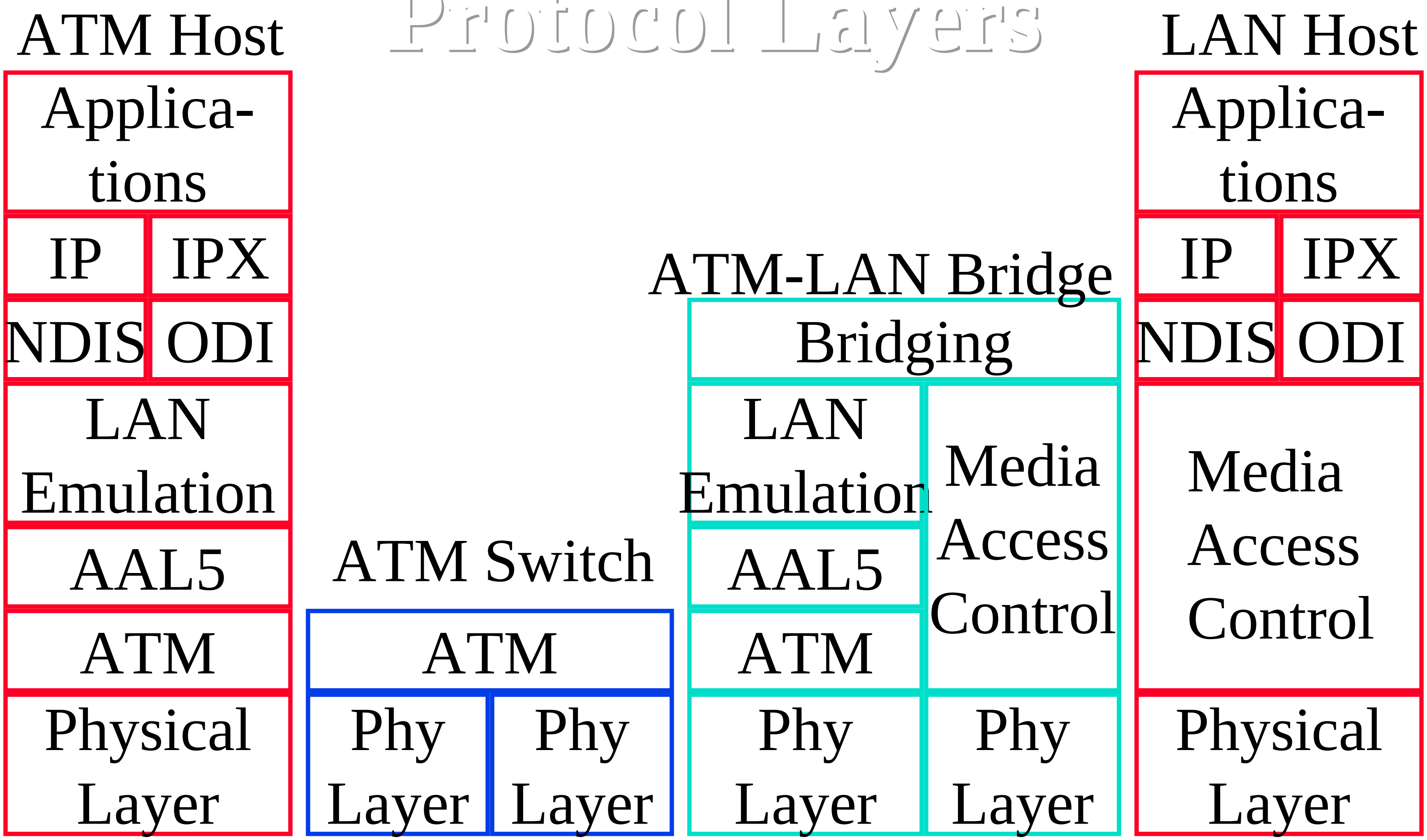
Features

- One ATM LAN can be multiple virtual LANs
- Logical subnets interconnected via routers
- Need drivers in hosts to support each LAN
- Only IEEE 802.3 and IEEE 802.5 frame formats supported
- Doesn't allow passive monitoring
- No token management (SMT), collisions, beacon frames

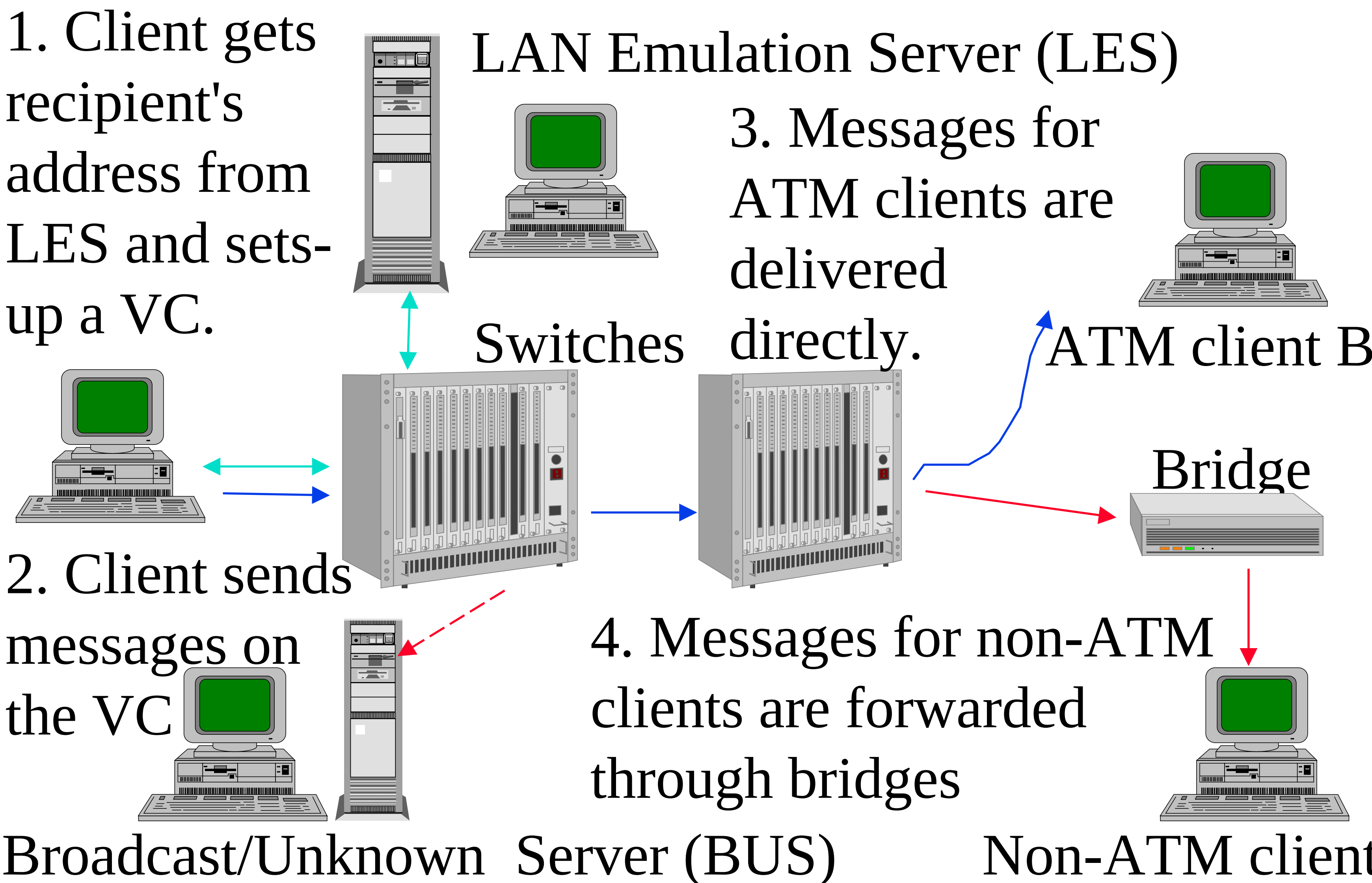
LE Header (2 Bytes)	IEEE 802.3 or 802.5 Frame

Protocol Layers



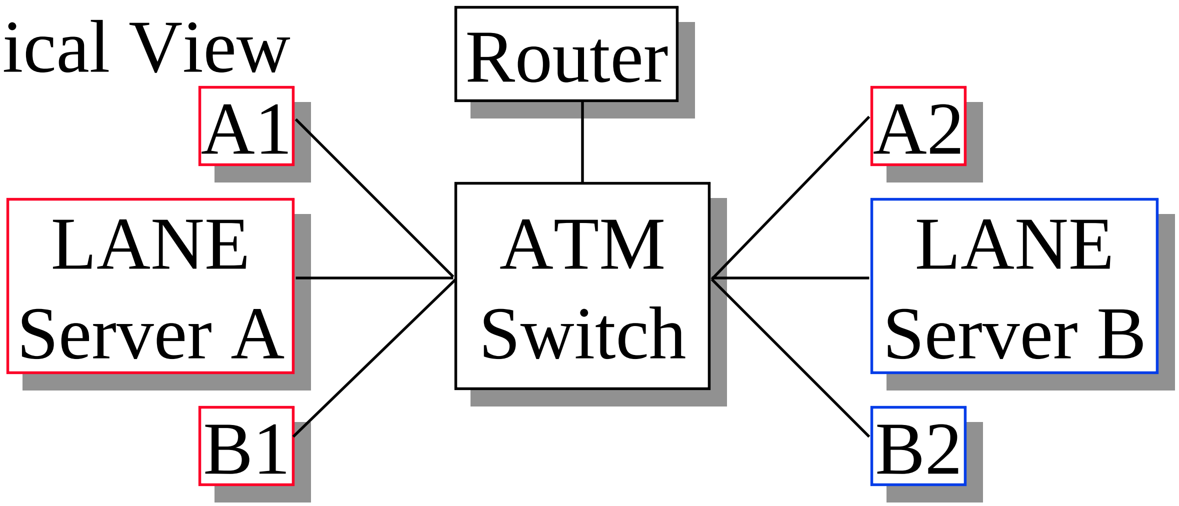
- NDIS = Network Driver Interface Specification
- ODI = Open Datalink Interface

LAN Emulation

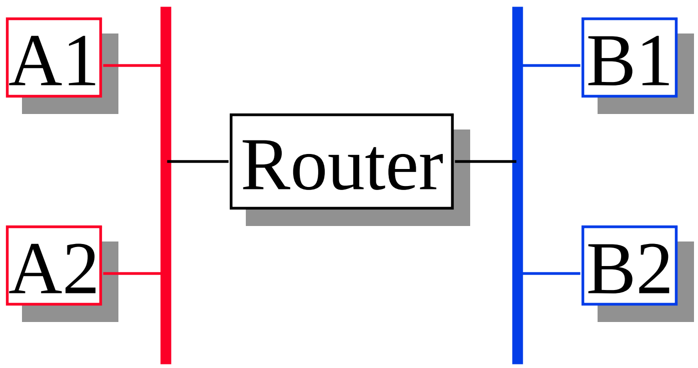


ATM Virtual LANs

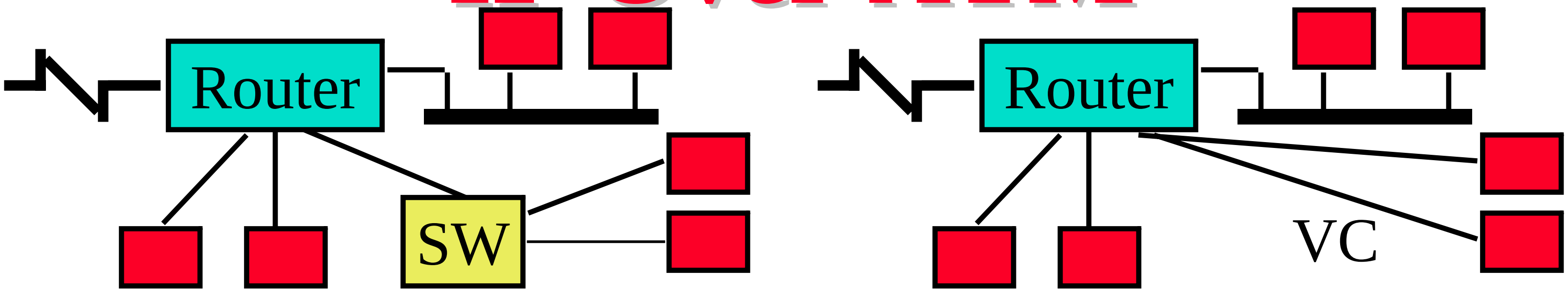
- Physical View



- Logical View

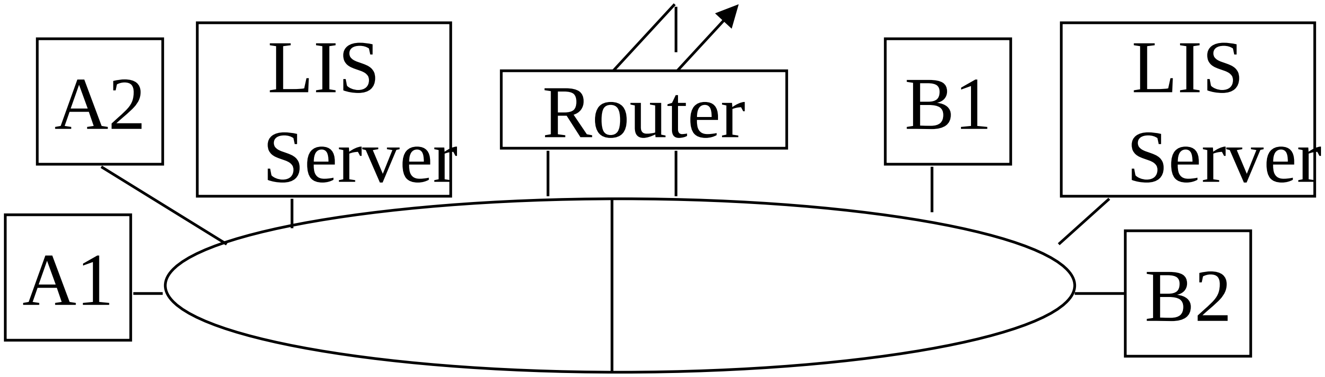


IP Over ATM



- ATM similar to point-to-point WANs. Simpler than LAN emulation
- IP address: 123.145.134.65
  ATM address: ...1-614-999-2345-…
- Issue: IP Address ⇔ ATM Address translation
  - Address Resolution Protocol (ARP)
  - Inverse ATM ARP: VC ⇒ IP Address
- Solution: Logical IP Subnet (LIS) Server

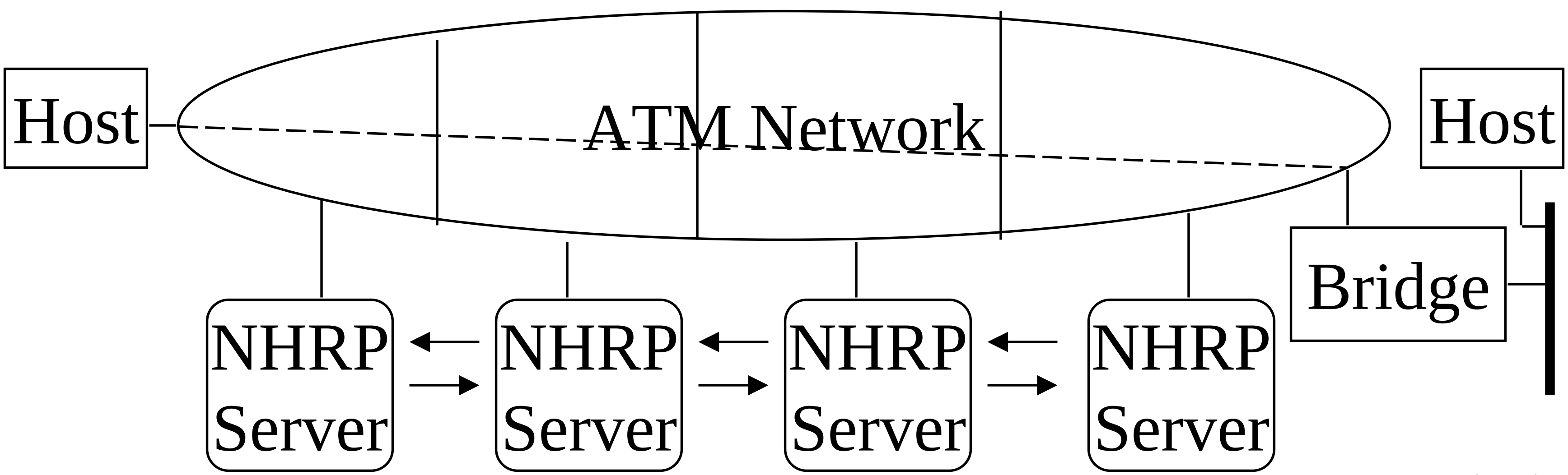
ARP Over ATM (RFC 1577)



- ATM stations are divided in to Logical IP Subnets
- Each LIS has a LIS server for address resolution
- Clients ask LIS server for destination's ATM address
- Clients within the same LIS use direct VCs
- All traffic between LIS passes through a router
- Server does not broadcast unresolved ARP requests

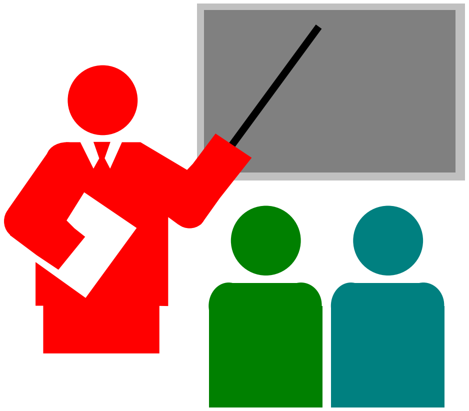
NHRP

- Problem with RFC 1577 Approach: Data needs to go through routers even if on the same ATM net
- Like going to the airport just to go to next block
- Solution: Next Hop Routing Protocol
- Provides the next hop towards the destination.



- Developed by Routing over Large Clouds (ROLC) group
- Hosts are configured with the address of server
- NHRP servers cache the results
- NHRP replies can be non-authoritative or authoritative
- NHRP requests can be non-authoritative or authoritative
- Authoritative requests generally issued after failures.
- While waiting for NHRP shortcut, data may be forwarded along the routed path.
- NHS learns about hosts via manual configuration or registration

Summary

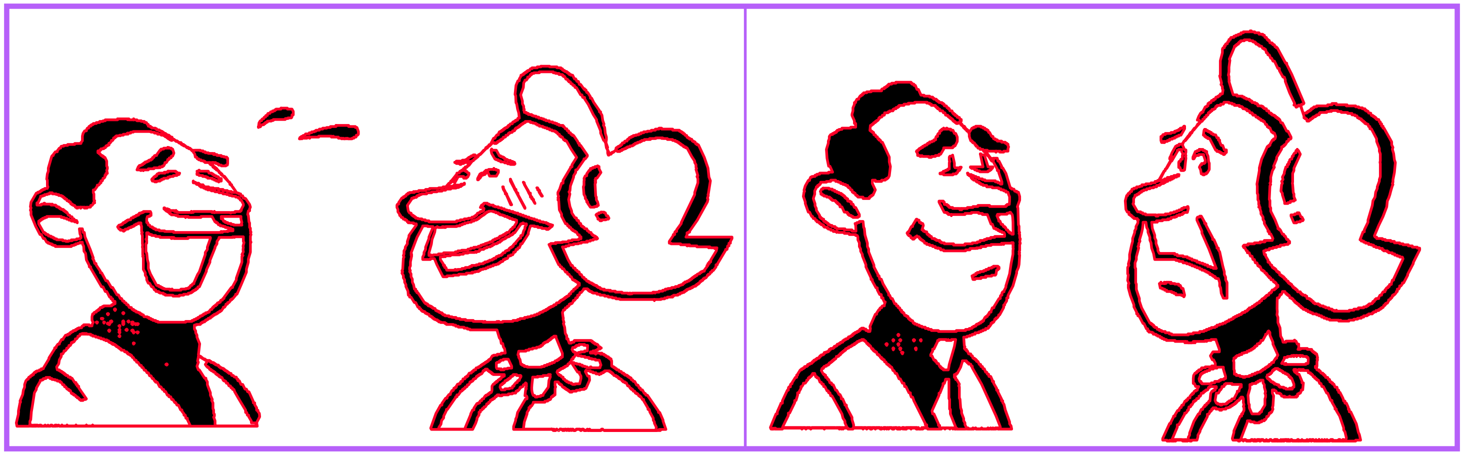


- LANE allows current applications to run on ATM
- Classical IP allows ARP using LIS servers
- NHRP allows shortcuts between ATM hosts

Legacy Protocols over ATM: Key References

- RFC 1577, “Classical IP and ARP over ATM,” 1/20/94.
- RFC 1483, "Multiprotocol Encaptulation over ATM Adaptation Layer 5," July 1993.
- "NBMA Next Hop Resolution Protocol (NHRP)", 07/18/1996, <draft-ietf-rolc-nhrp-09.txt>
- Ipsilon, "IP Switching: The intelligence of Routing, the Performance of Switching," February 1996.
- G. Armitage, "Multicast and Multiprotocol Support for ATM Based Internets," Computer Communications Review, April 1995.

ATM Networking: Issues and Challenges Ahead



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- Requirements for Success
- Economy of Scale
- High Performance
- Simplicity

Ref: R. Jain, “ATM Networks: Issues and Challenges head,” Networld+interOP Engineering Conference, March 1995. Available on http://www.cis.ohio-state.edu/~jain/

Networking: Failures vs Successes

- 1980: Broadband (vs baseband)
- 1981: PBX (vs Ethernet)
- 1984: ISDN (vs Modems)
- 1986: MAP/TOP (vs Ethernet)
- 1988: OSI (vs TCP/IP)
- 1991: DQDB
- 1992: XTP (vs TCP)

Requirements for Success

- Low Cost
- High Performance
- Killer Applications
- Timely completion
- Manageability
- Interoperability
- Coexistence with legacy LANs
  Existing infrastructure is more important than new technology

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Challenge: Economy of Scale

- Technology is far ahead of the applications.
  Invention is becoming the mother of necessity.
  We have high speed fibers, but no video traffic.
- Low-cost is the primary motivator. Not necessity.
  $\Rightarrow$ Buyer's market (Like $99 airline tickets.)
  Why? vs Why not?
- Ten 100-MIPS computer cheaper than a 1000-MIPS
  $\Rightarrow$ Parallel computing, not supercomputing
- Ethernet was and is cheaper than 10 one-Mbps links.
- No FDDI if it is 10 times as expensive as Ethernet.
  10/100 Ethernet adapters = $50 over 10 Mbps

Challenge: Tariff

- Phone company's goal: How to keep the voice business and get into data too?
- Customer's goal: How to transmit the data cheaper?
- Tariff Today:
  - 64 kbps voice line = \$300/year
  - 45 Mbps line (\$45/mile/month)
    Coast to coast = \$180 k-240 k/year
    $\Rightarrow$ 155 Mbps line = \$540 k - \$720 k/year
- Tomorrow: 155 Mbps = \$1k/month+ \$28/G cells
  $\Rightarrow$ \$13k - \$45k/year

Challenge: Performance

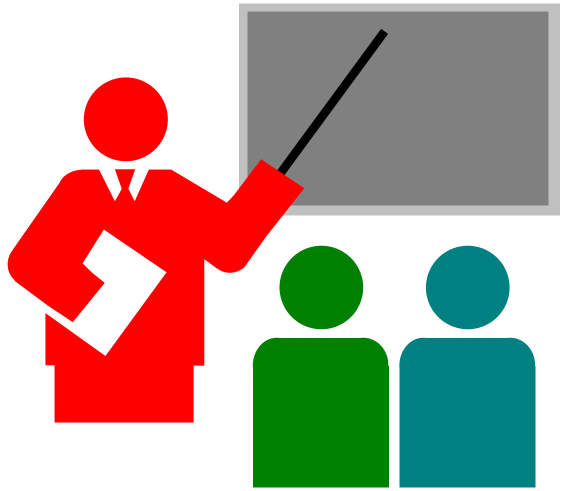
Application Designers	Video Coding, FTP
Protocol Architects/Implementers	TCP/IP, UDP
O/S Architects/Implementers	UNIX, DOS
CPU, Memory, Disk Designers	Pentium, Alpha
LAN Interface Designers	Adapters
Media Access (LAN) Architects	FDDI, ATM
Optic Device Designers	Fibers, Lasers

- Faster link ≠ Faster applications
- Need to consider trends of all layers

Challenge: Simplicity

- No equal competition ⇒ Complexity
  Ethernet vs Token ring war ⇒ improvements
- One size fits all ⇒ Complexity
  Too many options too soon. Should work for
  - CBR and ABR LAN and WAN
  - Private and Public Low speed and High speed
- Switches have to do connection setup, route determination, address translation, anycasting, multicasting, flow control, congestion control, ...
- Many independent forums (ITU vs ATM Forum) ⇒ People energy divided

Summary



- High speed networking iff economy of scale
- Solving all problems can lead to complexity and failure.
- To succeed, ATM has to solve today's problem (data) well.

Multimedia: An Introduction

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Overview

- Local Multimedia
- Video Fundamentals
- Compression methods
- Compression Standards: JPEG, MPEG,...

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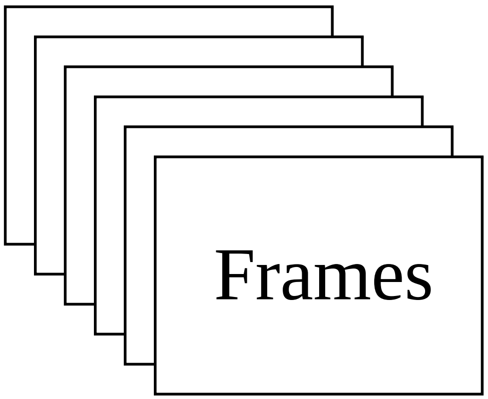
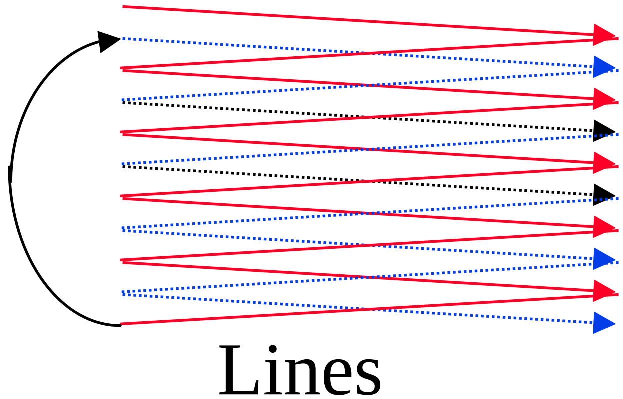
Television Formats





- US/Japan: 525/60 NTSC (Nat. Television Stds Comm.)
  Europe: 625/50 PAL (Phase Alternating Line),
  French/E. Europe: 625/50 SECAM(Seq. Color & Mem)
- 525 lines/frame (481 contain video, others can be used for teletext, caption, timestamp, etc.)
- 60 Fields/sec. Fields = Odd lines, even lines (Interlaced)
  30 frames/sec

Video Compression Considerations

- High compression
  - 100-200 normal, 2500 possible with fractal methods
- Decoding must be simple ⇒ Asymmetric
  - H.261, JPEG, AVI, QuickTime are Symmetric
  - DVI, MPEG are asymmetric
- Allow real time encoding/decoding
- Implementable in software, if possible
- Allow random-access, fast forward/reverse
- Scalable: Allow a range of video quality

Video Compression Techniques

- Reducing the frame rate, lines/frame, pixels/line, bits/pixel Used for teleconferencing.
  Redundancies: Spatial, Spectral, Temporal
- No loss entropy coding:
  - Run-length coding:
    000011111111..100000=$0^4 1^{35} 0^5$
  - Huffman coding: Frequent patterns ⇒ fewer bits
- Discrete Cosine Transform:
  Only low frequency components are quantized
- Motion Compensation (Inter-frame):
  Differences from predicted motion are quantized

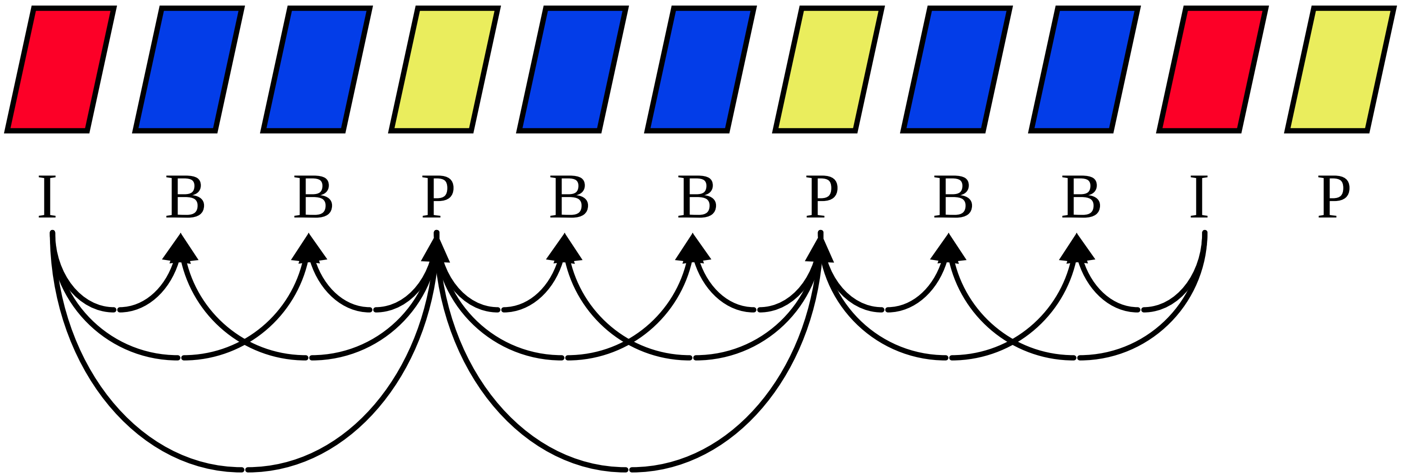
JPEG

- Joint Picture Experts Group.
  Joint $\Rightarrow$ ISO + CCITT
- DCT + Quantization + Entropy
- Entropy = Huffman or Arithmetic
- S/W coding possible:
  10 s for 640X480X30 image on 68040

Motion JPEG

- Many vendors use JPEG for video
- Although designed only for images
- No interframe coding
  $\Rightarrow$ Fast random access
- 221.184 Mbps for 640X480X30X24
- 1:50 compression $\Rightarrow$ 4.4 Mbps
- Quarter window $\Rightarrow$ 1 Mbps

MPEG-1



- MPEG = Motion Pictures Expert Group
- Inter-frame Coding
- I = Intraframe coded $\Rightarrow$ Allows random access
- P = Predicted from previous P or I
- B = Bidirectional prediction
- Uses Motion prediction

MPEG-1 (Continued)

- Combined audio + video bit rate for VCR quality should be 1.5 Mbps (single speed CD-ROM)
- Asymmetric: coding more complex than decoding
- Specifies rules for multiplexing audio/video streams
- 32 kbps to 384 kbps mono/stereo audio

MPEG-2

- MPEG Phase 2: Broadcast quality or better
- 15 Mbps for NTSC, 60 Mbps for HDTV, 4-15 Mbps for VCR
- Compatibility: Backward/forward. Superset of MPEG1
- Spatial scalability: Hierarchical coding
- Temporal Scalability:
  Same signal can be displayed at different frame rates
- Signal-to-Noise Ratio Scalability:
  Different levels of decoding quality
- Data Partitioning: Two priority transmission.
  More critical information at higher priority.

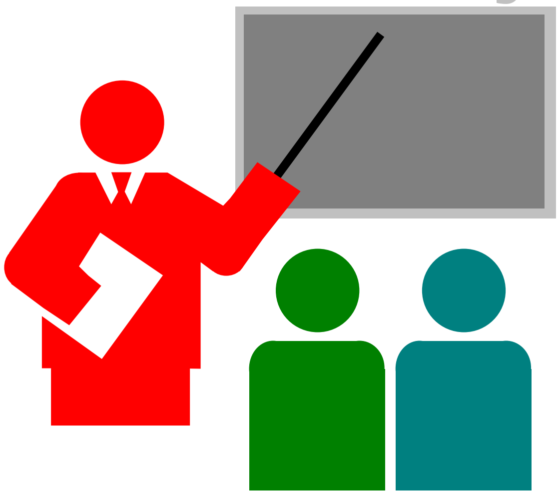
MPEG-2 (Cont)

- Several levels of decoders and several profiles of sources
- Strict superset of MPEG-1
  $\Rightarrow$ MPEG-2 decoders can decode MPEG-1

ITU-T H.261 Standard

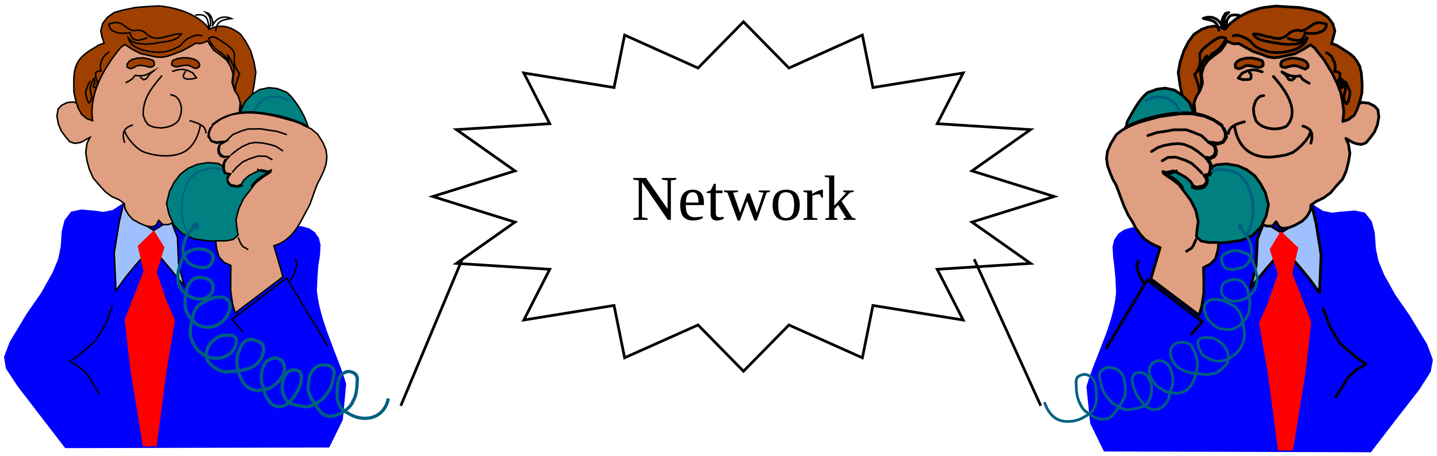
- Started in 1984 for m×384 kbps
- Later p×64 kbps p = 1, 2,...,30
- VCR quality video
- Resynchronization at receiver ⇒ Allows transmission over independent parallel channels
- DCT + Quantization + Motion-predicted compression
- p = 1 or 2 ⇒ Face only (Video Phone)
- p = 6 for teleconferencing

Summary



- Video formats: Lines, pixels
- Compression techniques: Huffman, run-length, DCT, Motion prediction
- Compression Standards: JPEG, MPEG, H.261

Multimedia Networking



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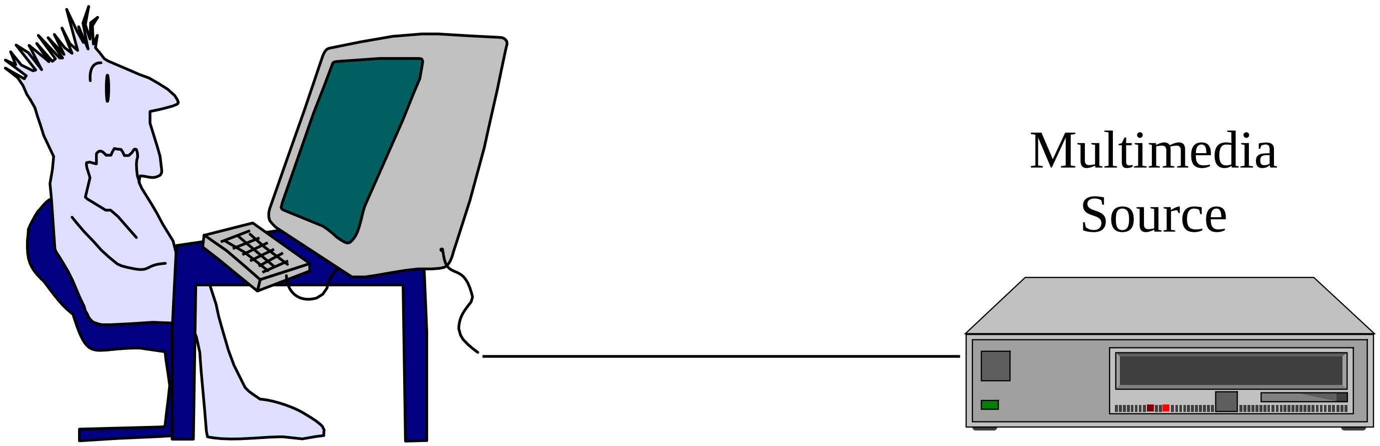
- Media Synchronization
- Multimedia over ATM
- Multimedia over IP: MBONE, RSVP,...
- Interesting applications on Internet

Local Multimedia



- No bandwidth sharing ⇒ Constant bit rate
- Circuit switching ⇒ No buffering
  No delay variation
  No (negligible) loss

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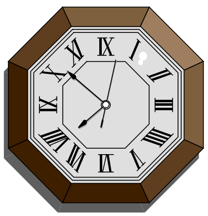
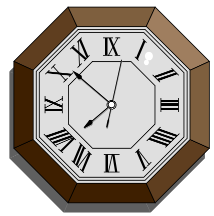
Timestamps



Open at
10:30:3.123



Open at
10:30:3.223

. . .

- **Bits**: 10, 32, 33, 64.
  Wrap around may cause confusion
- MPEG uses 33-bit clock of 90 kHz
  Divisible by 24 Hz, 25 Hz, 29.97 HZ, and 30 Hz
  However, 33-bits are one too many
- Network video protocol (NVP) uses 10-bit timestamps.
  For 20-ms audio packets, it wraps around in 20.5 s.

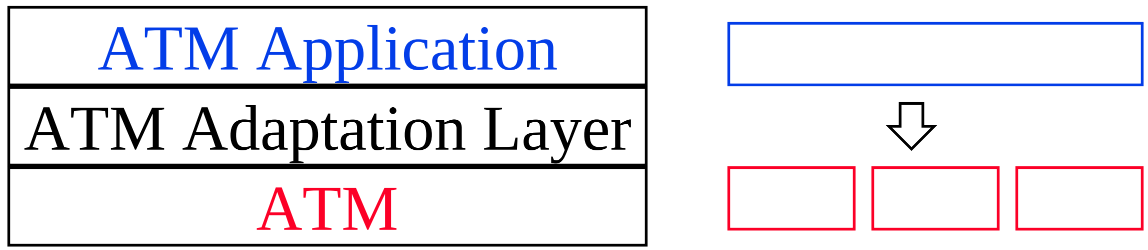
Multimedia over ATM

- Service Aspects and Applications (SAA) Group
  - Audiovisual Multimedia Services Phase 1: MPEG-2 over ATM
- Key Issues:
  - What Applications?
  - Which Service? CBR or VBR?
  - Transport stream or program stream?
  - Which ATM Adaptation Layer (AAL)?
  - What QoS parameter values to signal?

What Applications?

- MPEG-1 for VCR-quality video/audio
- MPEG-2 for theater-quality video/audio
- Video on Demand $\Rightarrow$ High-quality $\Rightarrow$ MPEG-2

Which AAL?



- AAL1: Designed for CBR.
  - Sequence numbers for lost cell detection
  - Forward error correction option
  - Less overhead than AAL5 for small PDUs
  - Ideal fit: 188 byte MPEG-2 transport packet = 4 cells

- AAL5: Used for signaling and LAN emulation
  Implemented universally ⇒ Low cost
- ATM Forum chose AAL5 for MPEG-2 over ATM
  ETSI chose AAL1 for MPEG-2 over ATM
  ⇒ ITU-T H.222.1 allows both options

AMS Phase 1: Key Decisions

- First application = Video on demand ⇒ High quality
- CBR encoded MPEG-2 transport stream over AAL5 CBR
- N MPEG-2 transport stream packets on a single AAL5 PDU.
  N negotiated using signaling. Default = 2.
- Optionally corrupted AAL5 PDUs are passed on to application with indication

AMS Phase 2

- Video conferencing, distance learning, multimedia desktop
- VBR-encoded MPEG-2 over ATM

Integrated Services on the Internet

- Specify source traffic and/or receiver requirements
- Protocols to create and maintain resource reservations
- Routing protocols that support QoS and multicast
- Transport protocols for error and flow control
- Access control
- Packet scheduler to provide QoS:

Integrated Services on the Internet

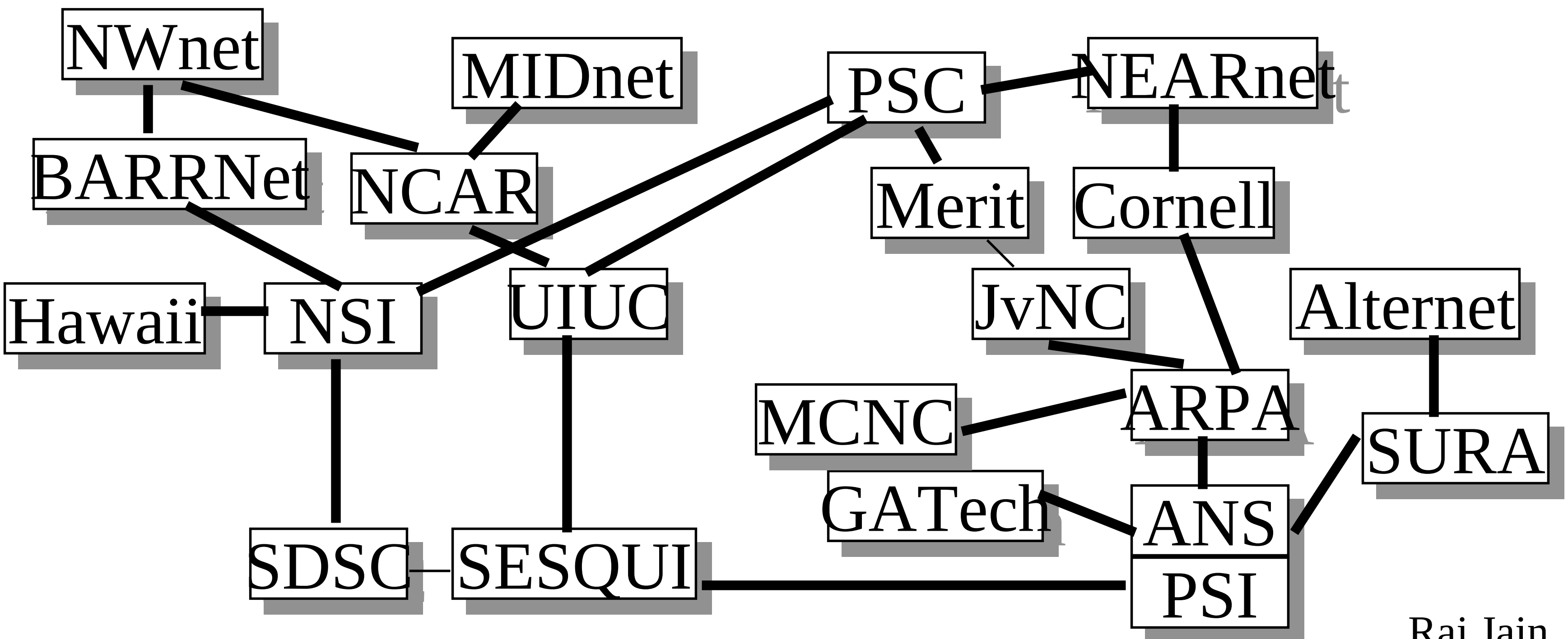
- Specify source traffic and/or receiver requirements
  Flow specs from INTSERV working group
- Protocols to create and maintain resource reservations: *RSVP*
- Routing protocols that support QoS and multicast
  Mrouted, ST2+
- Transport protocols for error and flow control: *RTP*
- Access control: Connection *admission based on usage, packet dropping*
- Packet scheduler to provide QoS:
  Weighted Fair Queueing

Multimedia over IP

- Multicast Backbone: MBone
- Protocols:
  - RSVP
  - RTP
  - ST2
- Applications:
  - CU-SeeMe
  - Internet Talk Radio
  - INETphone servers
- Other Audio-Visual Tools: vat, nv, ivs, ...

MBone

- Internet Multicast backbone
- A set of routers that implement IP multicasting
- IP multicast address: start with 1110... (binary), 224.0.0.0 to 239.255.255.255 (decimal)

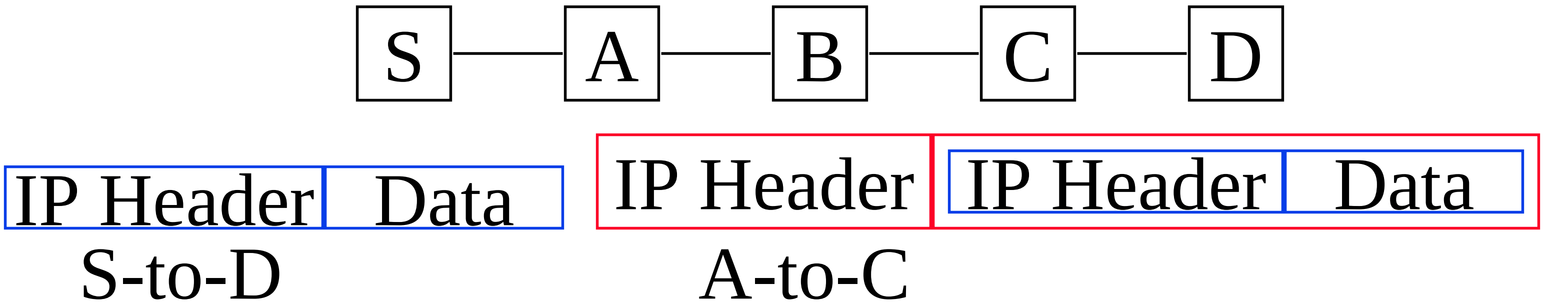


MBone (Cont)

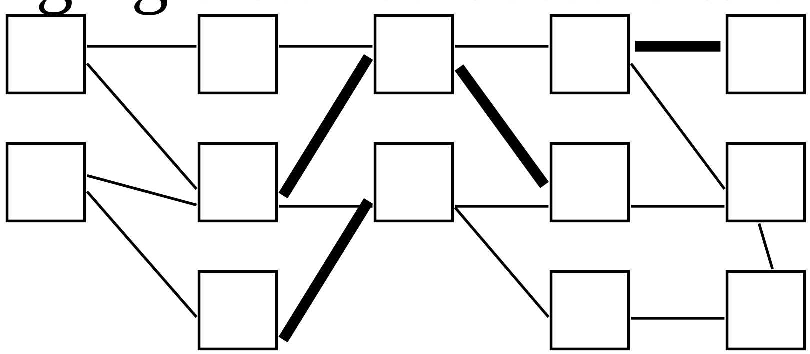
- Uses radio/TV station paradigm: Sender is allocated a multicast address. It starts transmitting on that address
- Anyone can listen by tuning into the multicast address by sending an Internet Group Management Protocol (IGMP) request to router to join the multicast
- The router provides a connection to the nearest point
- Sender has no idea of who is listening
  Sender controlled multicasts does not scale well.
- First audiocast in March 1992: IETF meeting to 20 sites
- Now over 600 hosts in over 15 countries

- Programs include space shuttle, conferences, IETF,...
- President Clinton and VP Gore have appeared
- Is a source of heavy traffic, congestion, and complaints
- Many vendors implement IP multicast
- Multicast routers setup tunnels between them. Tunnel = direct connection
- Routers on the path of the tunnel do not need to know multicasting.

Tunnels



- Implemented by encapsulating the entire packet in another IP header.
- Each tunnel has a cost. Least cost path is found by exchanging distance-vectors with neighbors.



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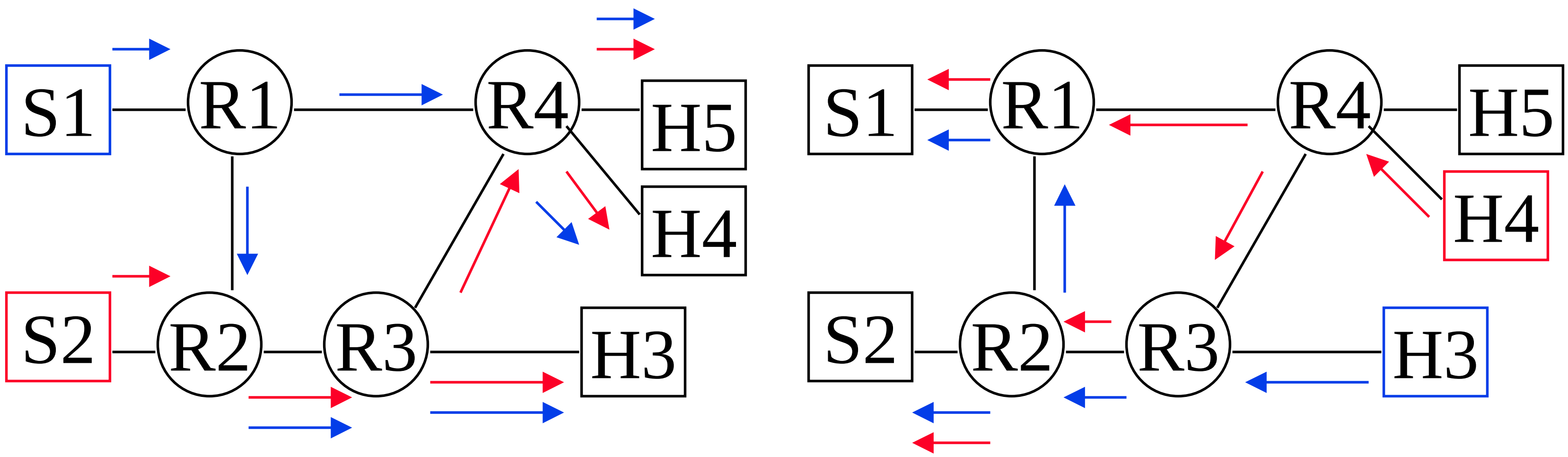
Tunnels Are Expensive

- Each video stream requires 100 to 300 kbps.
  Use 500 kbps for design.
  A few streams can saturate the host.
  Four on SPARC 1, six on SPARC 10.
  Maximum two streams over T1.
- Each packet has a time to live (TTL).
  TTL is decremented at each router.
  The packet is forwarded iff its TTL is over a threshold.
- Pruning: If a multicast router gets a packet for which it has no listeners, it sends a message to the upstream multicast router to stop sending.

RSVP



- ReSource Reservation Protocol
- Simplex streams between sources and receivers
- Receiver initiated $\Rightarrow$ Scalable
- Receiver requests are propagated upstream towards the senders
- Routers may merge requests from many receivers

RSVP (Cont)

- Routers maintain a soft state. The receivers have to refresh periodically.
- Routers have a packet classifier and a scheduler
- Provides many different reservation styles
  - Any source but a given multicast destination
  - List of sources (fixed or dynamic)
    Allows receivers to switch channels
- Routing trees from sources
- Sink trees from receivers

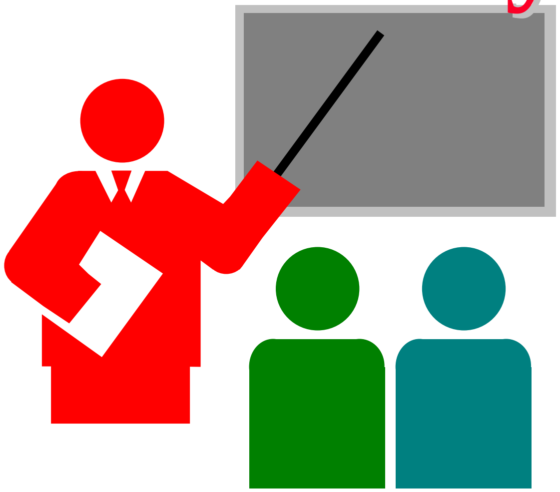
RSVP vs UNI

Category	RSVP	ATM UNI 3.0
Orientation	Receiver based	Sender based
State	Soft state	Hard state
QoS Setup time	Separate from route establishment	Concurrent with route establishment
QoS Changes	Dynamic	Static
Directionality	Unidirectional	Bi-directional unicast, unidirectinal multicast
Heterogeneity	Receiver heterogeneity	Uniform QoS to all receivers

IP Integrated Services

- **Guaranteed Delay Service**: Max delay with high probability, No Loss, Rate reserved
- **Predictive Service**: Max delay with high probability, Low Loss, Rate reserved
- **Controlled Delay Service**: Several delay categories, no quantitative bounds, rough max bounds
- **Best Effort Service**
- **Controlled Load Service**: Service similar to best effort on unloaded network

Summary



- Constant bit rate MPEG2 video on demand
- Uses AAL5 for CBR video
- TCP/IP protocols suite is being extended to allow multimedia on Internet.
- Multicast backbone (MBone), RSVP

Wireless Data Networking

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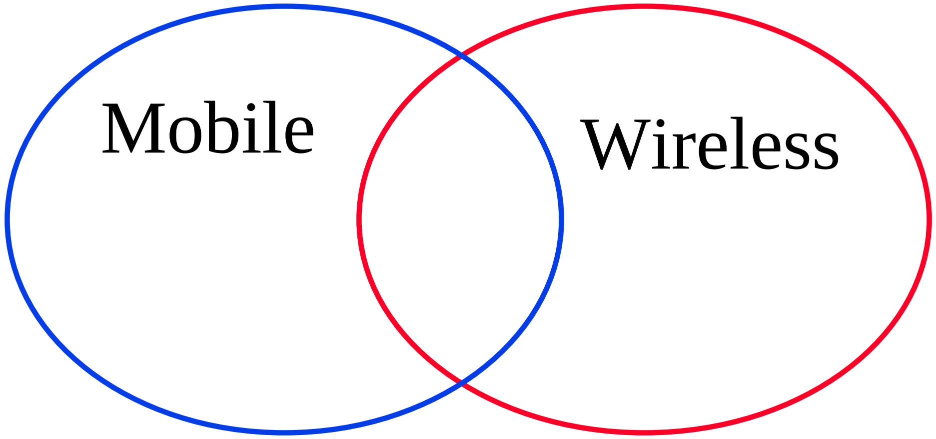
- Spread Spectrum
- Wireless local area networks
- Wireless wide area networks: CDPD and Metricom
- IEEE 802.11 Wireless LAN standard
- Mobile IP

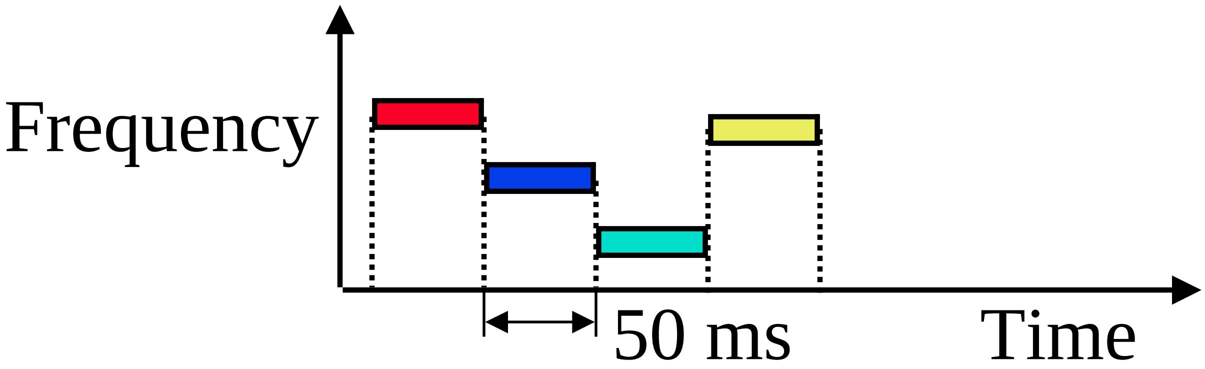
Note: wireless phone services and standards not covered.

Mobile vs Wireless



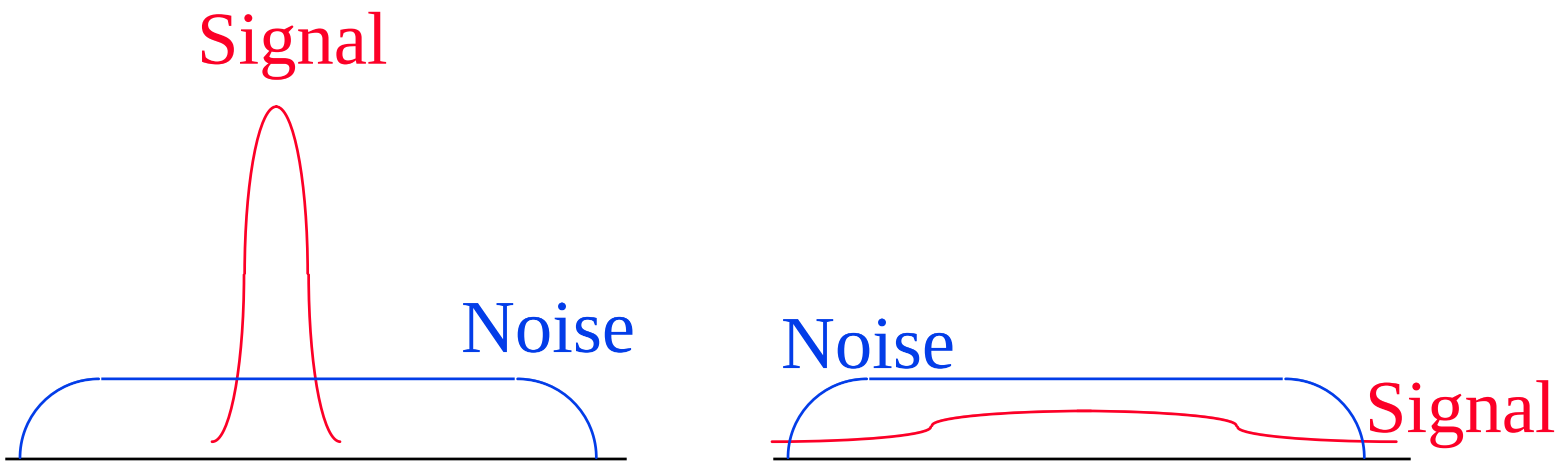
- Mobile vs Stationary
- Wireless vs Wired
- Wireless $\Rightarrow$ media sharing issues
- Mobile $\Rightarrow$ routing, addressing issues

Frequency Hopping Spread Spectrum



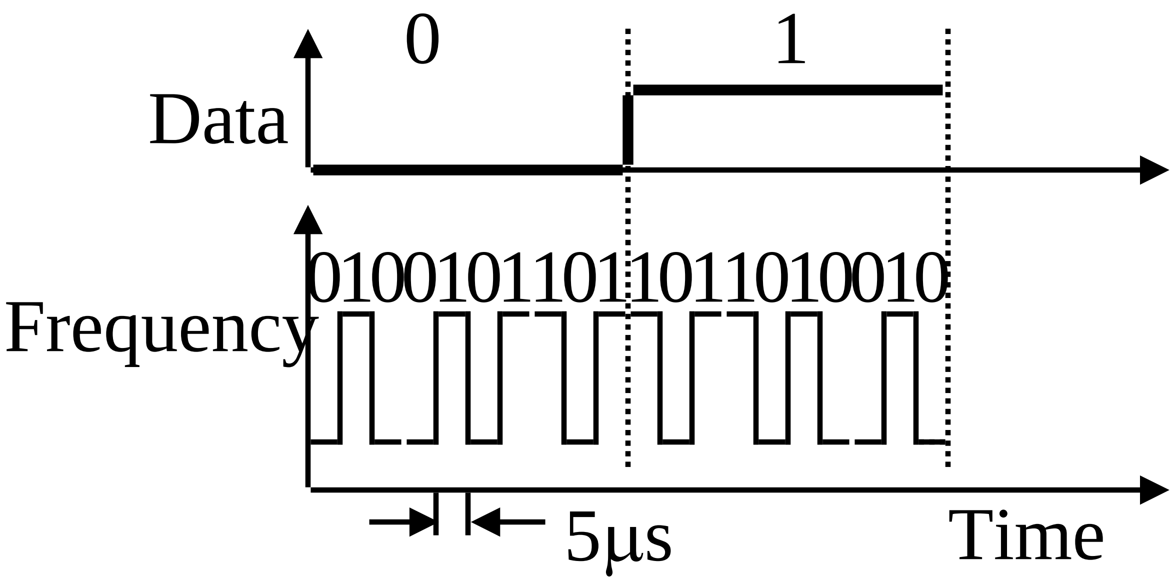
- Pseudo-random frequency hopping
- Spreads the power over a wide spectrum
  ⇒ Spread Spectrum
- Developed initially for military
- Patented by actress Hedy Lamarr
- Narrowband interference can't jam

Spectrum



(a) Normal (b) Frequency Hopping

Direct-Sequence Spread Spectrum



- Spreading factor = Code bits/data bit, 10-100 commercial (Min 10 by FCC), 10,000 for military
- Signal bandwidth >10 × data bandwidth
- Code sequence synchronization
- Correlation between codes ⇒Interference⇒ Orthogonal

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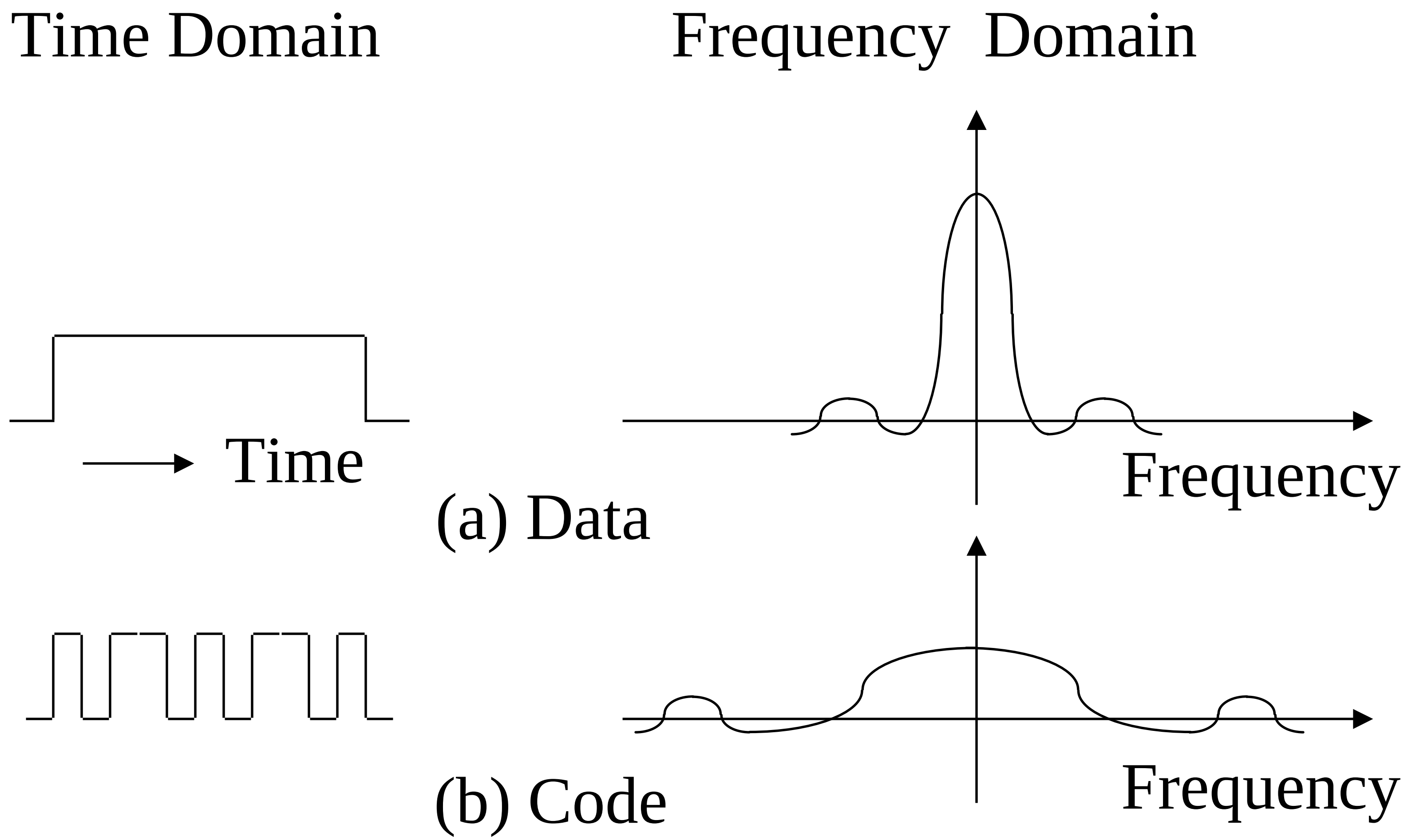
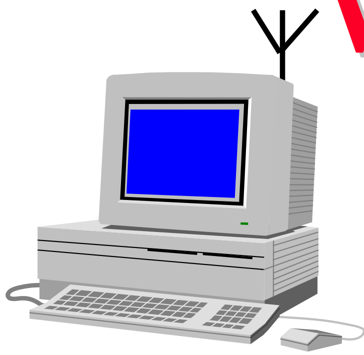
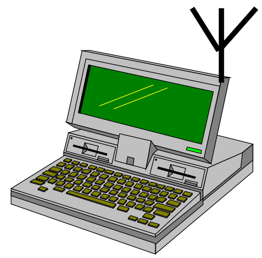
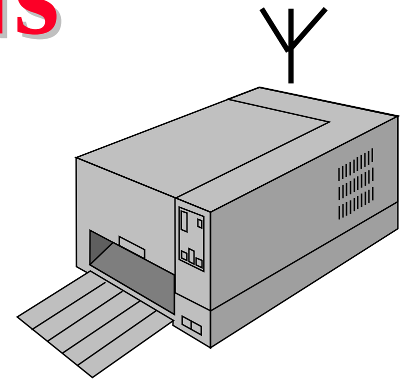
DS Spectrum


Time Domain
Frequency Domain
Time
Frequency
(a) Data
(b) Code
Frequency

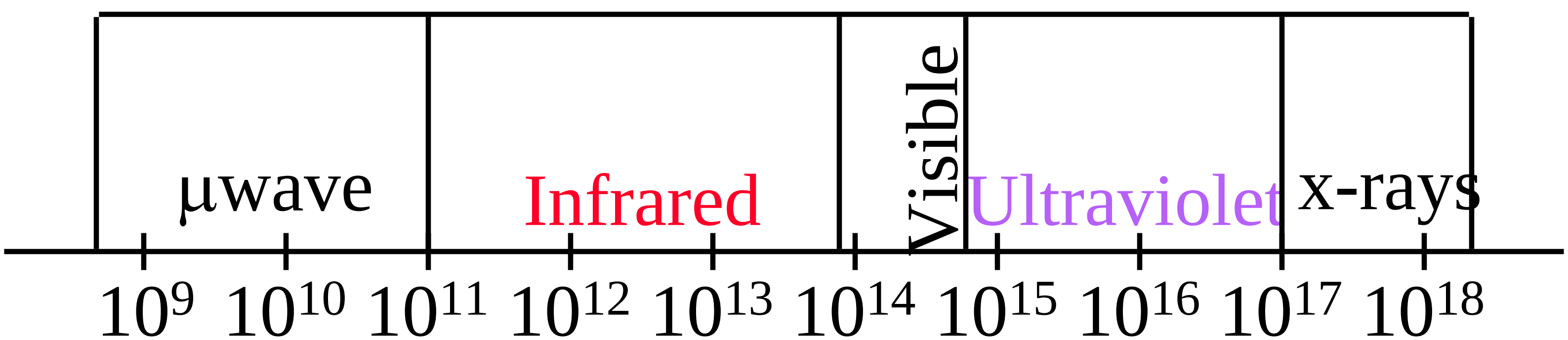
Wireless LANs







- IR ⇒ Line of sight, short range, indoors
- RF ⇒ Need license
- Spread-Spectrum: Resistance to interference



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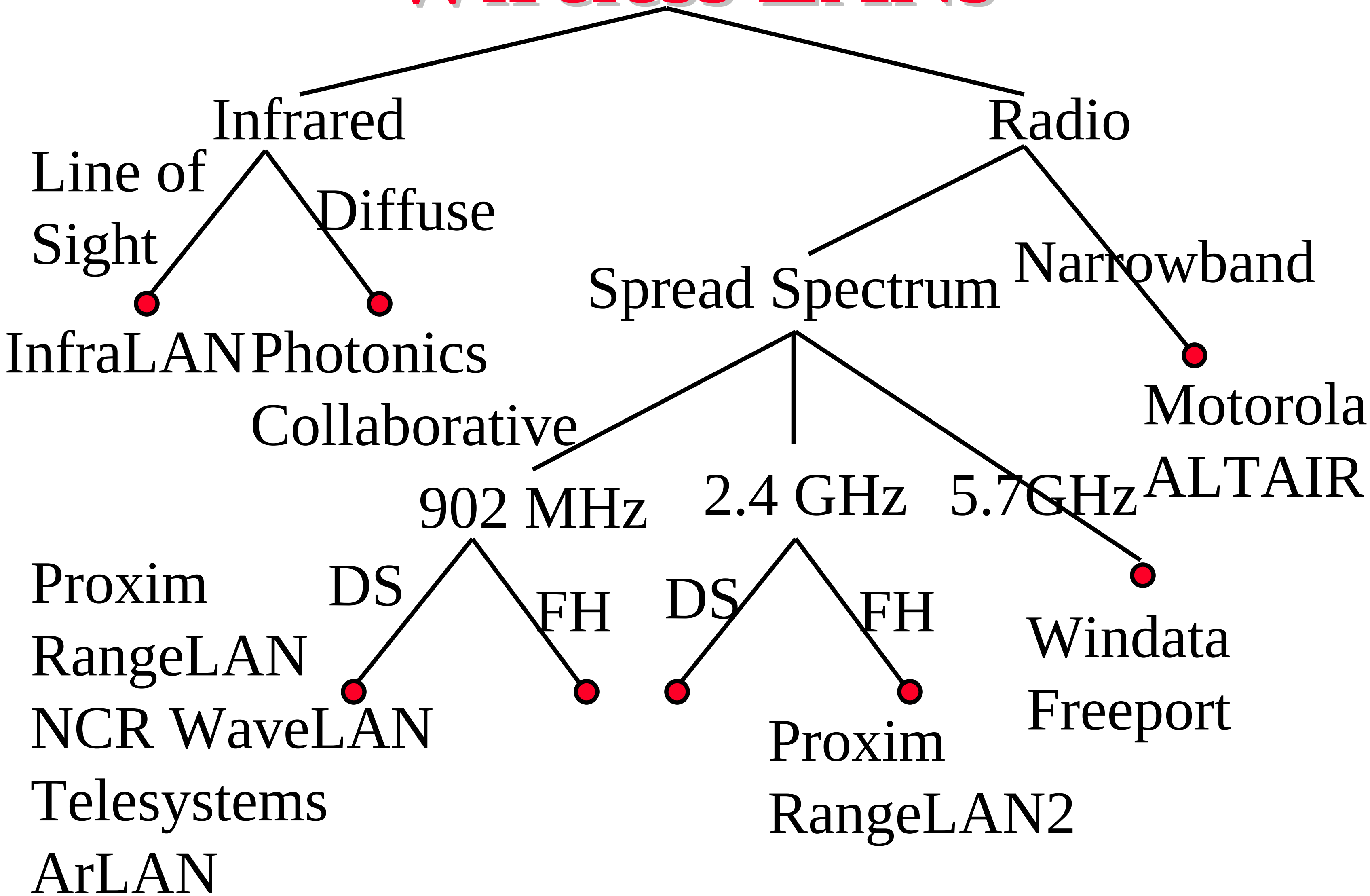
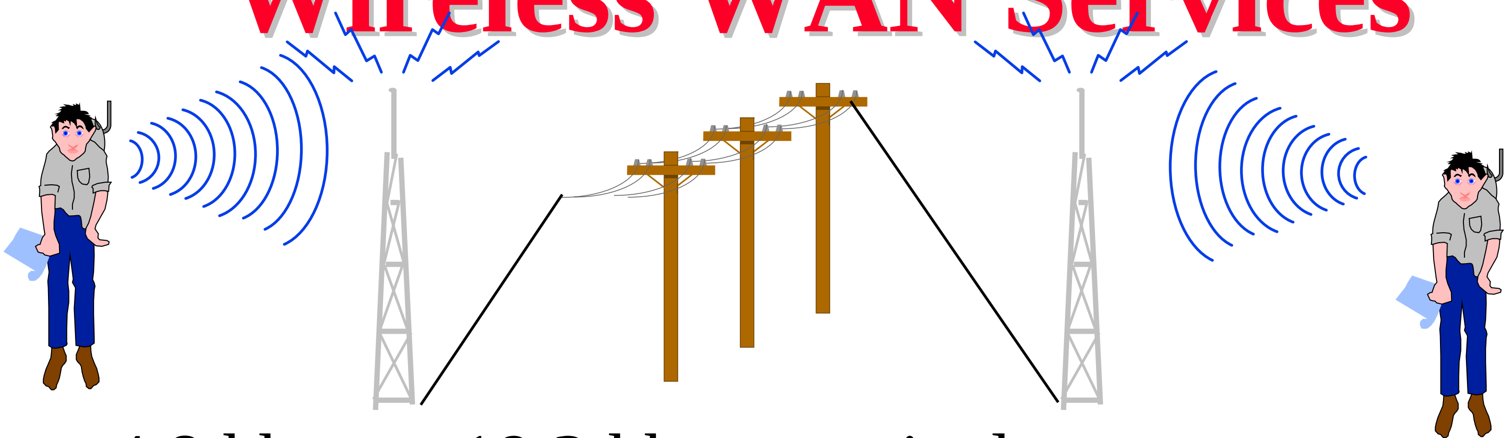
Wireless LANs



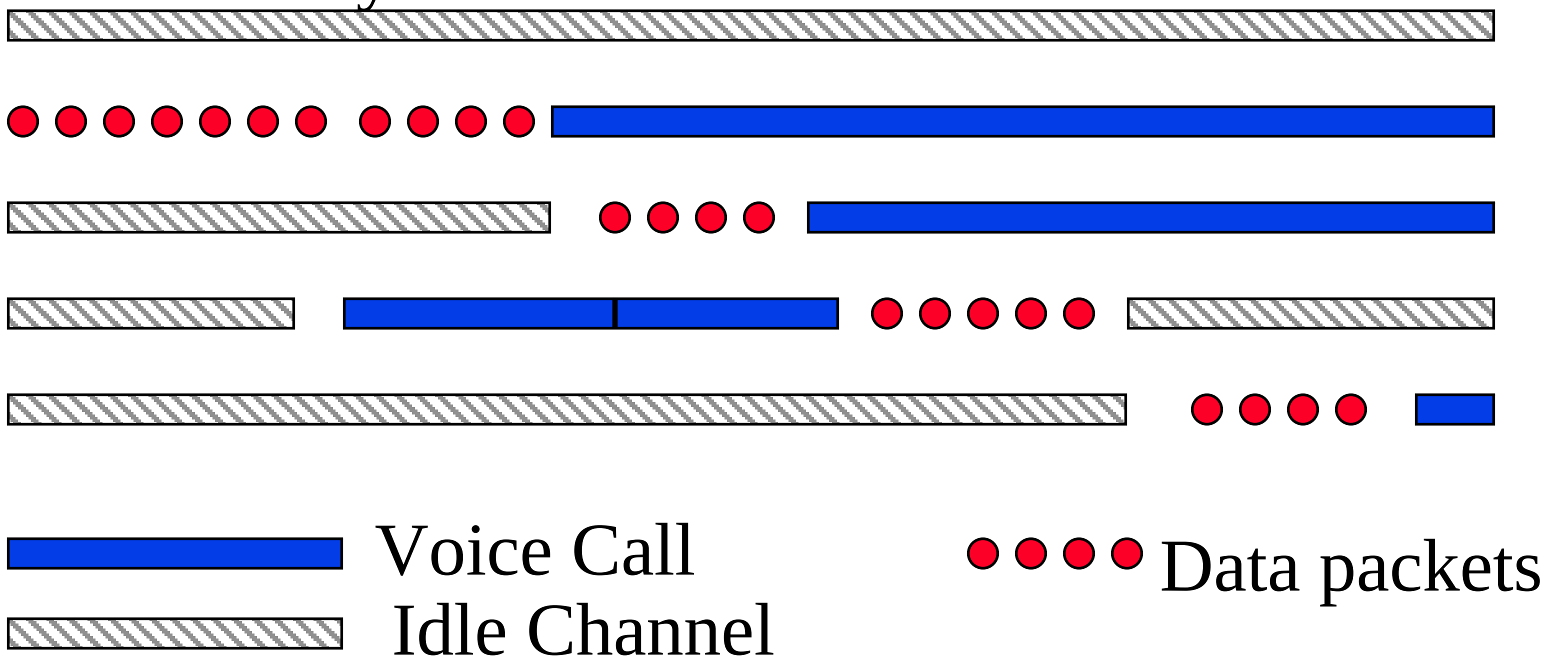
Wireless WAN Services



- 4.8 kbps to 19.2 kbps nominal
- Throughput 2 to 8 kbps
- Wired backbone using leased lines
- Packetized short transmission
- Email, stock quotes, weather
- Options: ARDIS, RAM Mobile Data, Cellular, Cellular Digital Packet Data (CDPD), and Metricom

Cellular Digital Packet Data (CDPD)

- Originally named "Celluplan" by IBM
- Allows data to use idle channels on cellular system
- Data hops from one channel to next as the channels become busy or idle



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CDPD

- Backed by 9 major service providers
- Nationwide cellular packet data service
- Connectionless and connection-oriented service
  Connectionless ⇒ No ack, no guarantees
  Connection-oriented ⇒ reliable delivery, sequencing, flow control
- Point-to-point and multipoint connections
- Quickly hops-off a channel grabbed by cellular system. Currently, dedicated channels.

Metricom

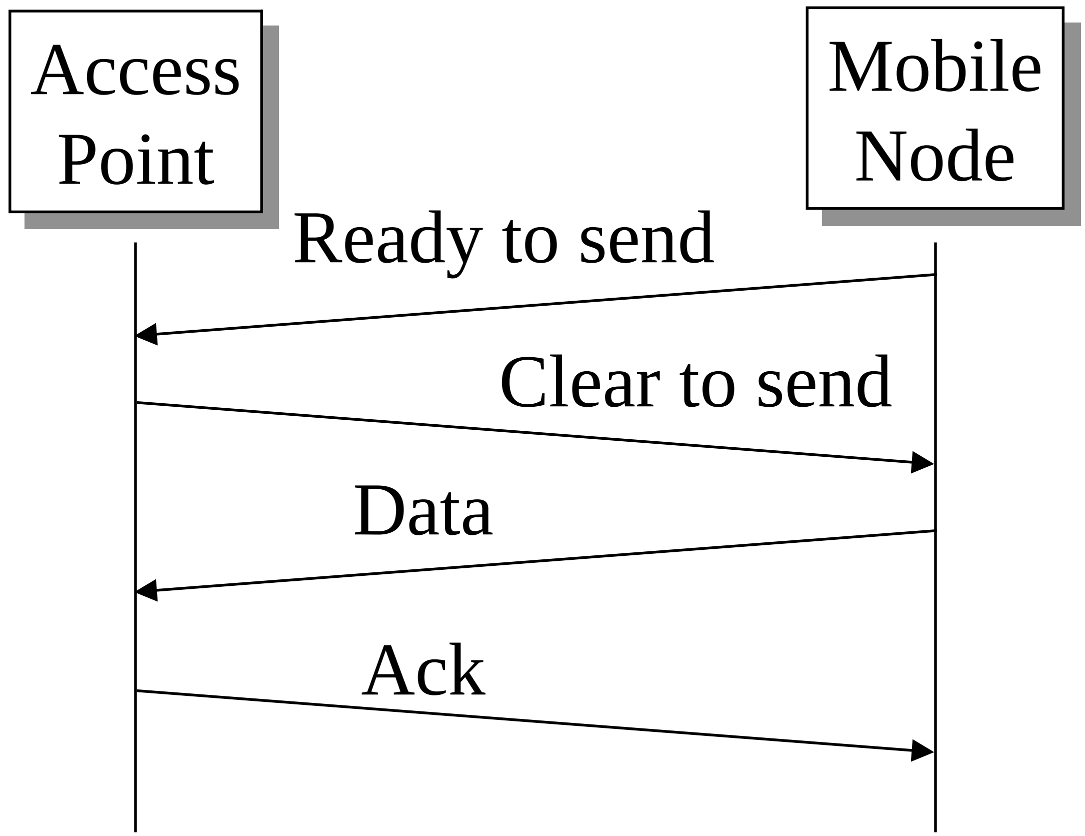
- Spread-Spectrum in the 902-928 MHz band
- In-building, campus, and metropolitan area networking
- Nearby units can communicate directly.
- If the intended destination is not directly reachable, go via a "node" through the network. Up to 56 kbps.
- Nodes are cheap (less than $1,000)
- You can have a campus network of your own with a connection to the Metricom's metropolitan area net
- Flat monthly rate based on speed only

Ref: http://www.metricom.com/ricohom.html

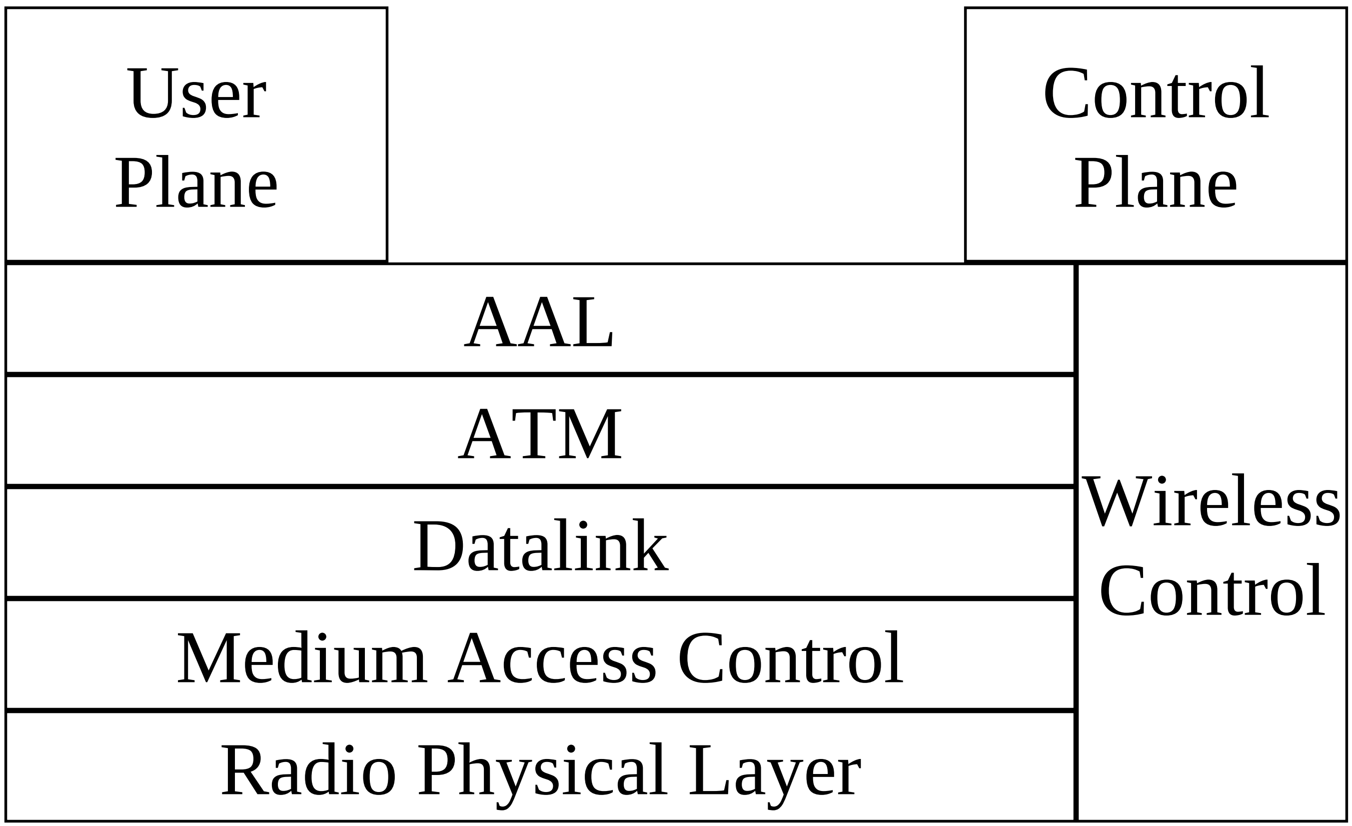
IEEE 802.11 MAC: CSMA/CA

- Carrier Sense Multiple Access with Collision Avoidance
- Listen before you talk.
- If the medium is busy, the transmitter backs off for a random period.
- Avoids collision by sending a short message:
  Ready to send (RTS)
  RTS contains dest. address and duration of message.
  Tells everyone that they should backoff for the duration.
- Destination sends: Clear to send (CTS)
- Can not detect collision $\Rightarrow$ Each packet is acked.
- MAC level retransmission if not acked.

4-Way Handshake



WATM Protocol Architecture



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Wireless ATM: Plans

- Radio access protocols including
  - Radio physical layer
  - MAC/Datalink for wireless channel
  - Wireless control protocol for radio resource mgmt
- Mobile ATM Protocol extensions including:
  - Handoff control
  - Location mgmt/routing for mobile connections
  - Traffic/QoS control for mobile connections
  - Wireless Network Management
- Group officially began August 96

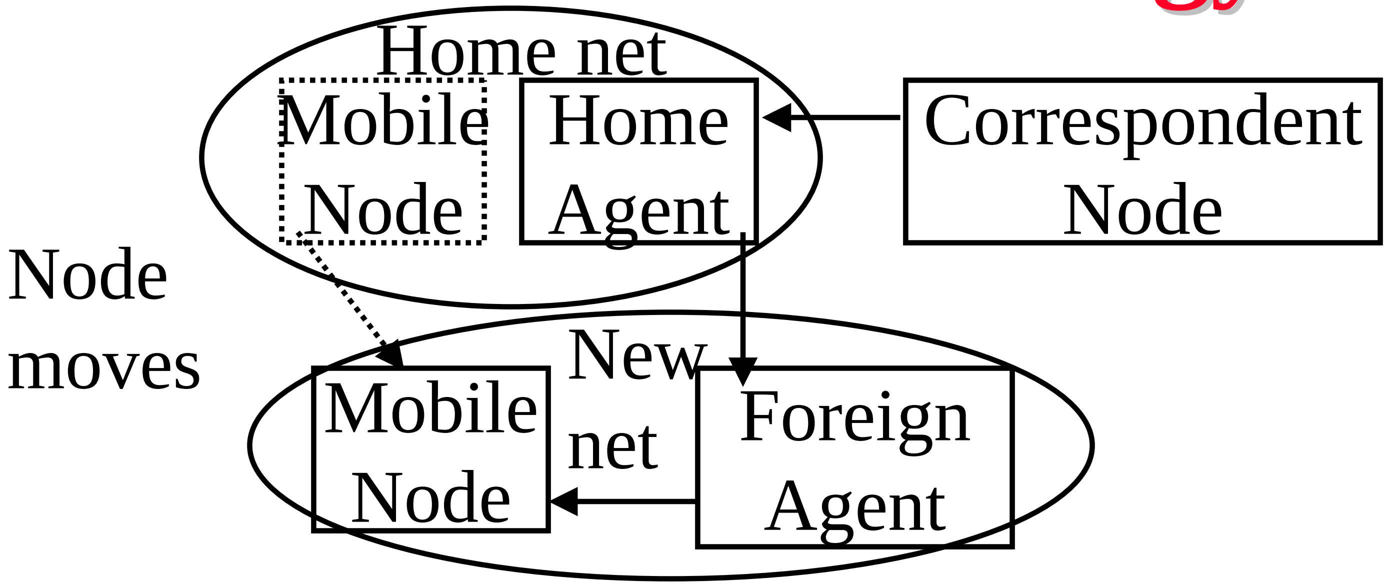
Mobile IP: Features

- You can take you notebook to any location
- Finds nearby IP routers and connects *automatically*
  You don't even have to find a phone jack
- Only "Mobility Aware" routers and mobile units need new s/w
- Other routers and hosts can use current IP
- No new IP addresses or address formats
- Secure: Allows authentication
- Also supports mobile networks
  (whole airplane/car load of mobile units)

Impact

- Your Email is continuously delivered
- You can start a telnet or x-window session as if local
- Continuous access to your home resources
- Access to local resources: Printers
- Airports, Hotels, Hospitals will provide "Mobile IP connectivity"
- Better connectivity
  $\Rightarrow$ More productive meetings and conferences
- Cities will feature "Mobile IP Accessways"
- You can compute while driving

Mobile IP: Terminology



- Mobile Node (MN)
- Home Agent (HA), Foreign Agent (FA)
- Care-of-address (COA): Address of the end-of-tunnel towards the mobile node
- Correspondent Node (CN)
- Home Address: Mobile's permanent IP address

Mobile IP: Processes

- Agent Discovery: To find agents
  - Home agents and foreign agents advertise periodically on network layer and optionally on datalink
  - They also respond to solicitation from mobile node
  - Mobile selects an agent and gets/uses care-of-address
- Registration
  - Mobile registers its care-of-address with home agent. Either directly or through foreign agent
  - Home agent sends a reply to the mobile node via FA

Processes (Cont)

- Each "Mobility binding" has a negotiated lifetime limit
- To continue, reregister within lifetime

- Return to Home:
  - Mobile node deregisters with home agent sets care-of-address to its permanent IP address
  - Lifetime = 0 $\Rightarrow$ Deregistration
- Deregistration with foreign agents is not required. Expires automatically
- Simultaneous registrations with more than one COA allowed (for handoff)

Encaptulation/Tunneling

- Home agent intercepts mobile node's datagrams and forwards them to care-of-address
- Home agent tells local nodes and routers to send mobile node's datagrams to it
- Decaptulation: Datagram is extracted and sent to mobile node

Correspondent → Home Agent → Intermediate Routers → Foreign Agent → Mobile Host

IP Header *To: COA*	IP Header *To: Mobile*	Info

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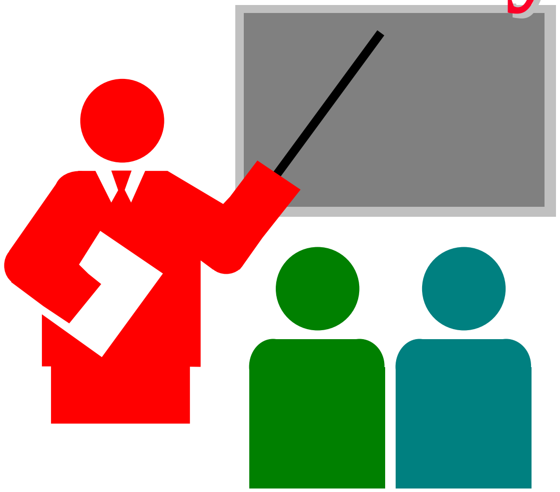
Summary



- CDMA = Spread spectrum: Frequency hopping or direct sequence
- LANs: Photonics, RangeLan, ALTAIR
- WANs: ARDIS, RAM, Cellular, CDPD, Metricom
- IEEE 802.11: 1 to 2 Mbps, CSMA/CA
- IP: Transparent mobility via home/foreign agents

Technologies for High-Speed Access To Homes

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Overview

- ADSL, VDSL
- HFC, FTTC, FTTH
- Cable Modems
- IEEE 802.14 standard

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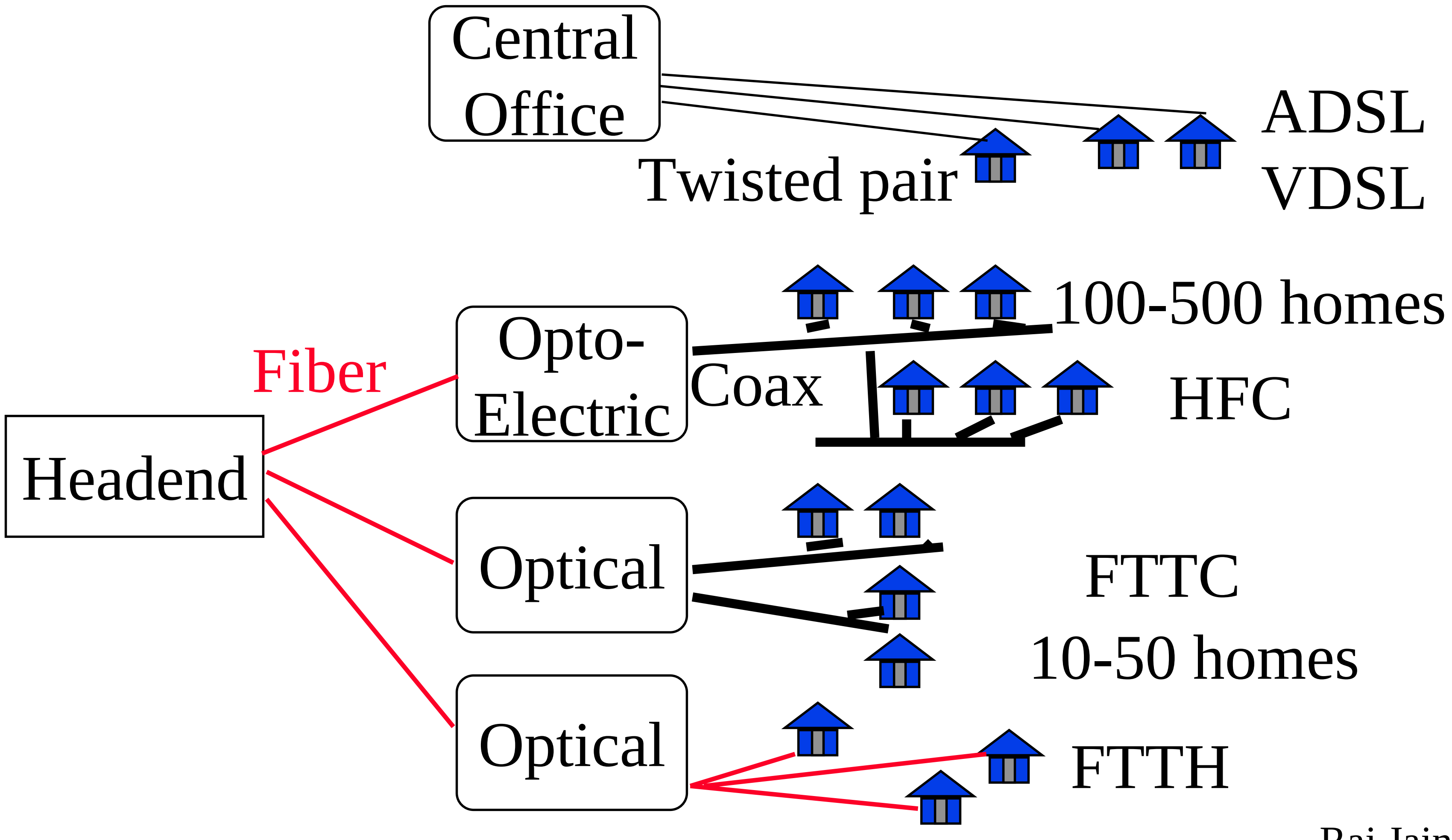
Potential Applications

- 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

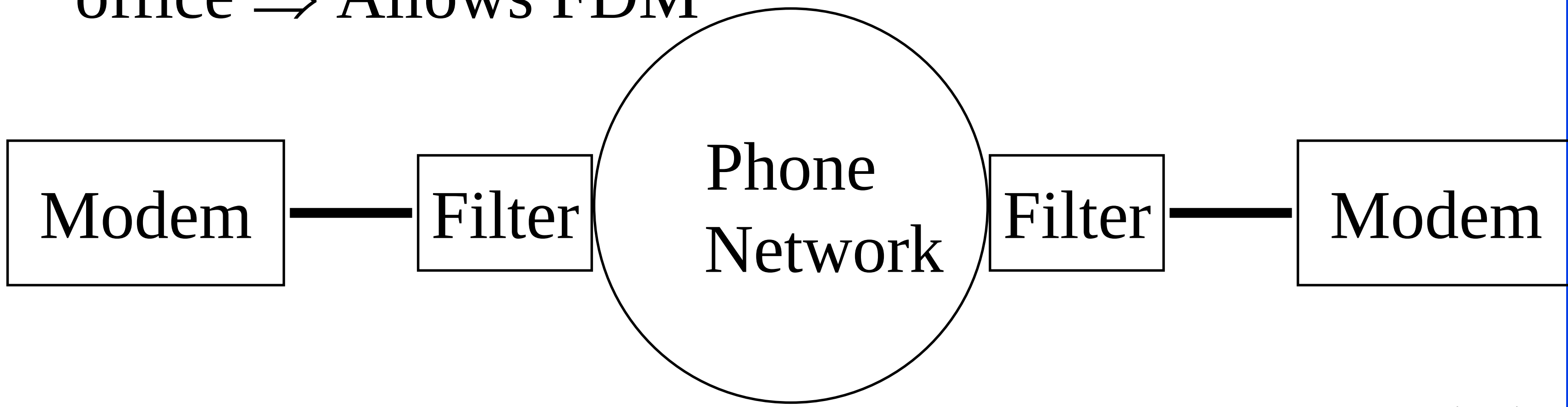
Existing phone service has switching but not enough bandwidth

Residential Access Networks (RANs)



Why Modems are Low Speed?

- Telephone line bandwidth = 3.3 kHz
- V.34 Modem = 28.8 kbps $\Rightarrow$ 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 $\Rightarrow$ Allows FDM



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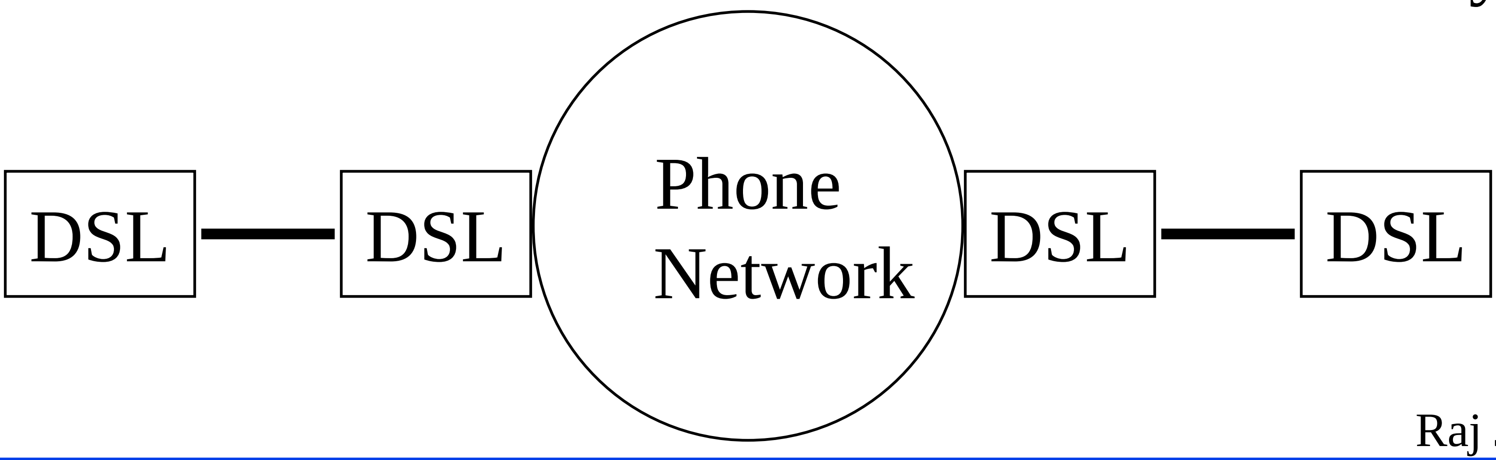
DSL

- Digital Subscriber Line = ISDN
- $64 \times 2 + 16$ + overhead = 160 kbps up to 18,000 ft
- DSL requires two modems (both ends of line)
- Symmetric rates $\Rightarrow$ transmission and reception on same wire $\Rightarrow$ Echo cancellation
- Use 0 to 80 kHz $\Rightarrow$ Can't use POTS simultaneously



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

ADSL Status

- ADSL modems have been tested successfully by over 30 phone companies
- InterAccess Inc (Internet service provider) offers 1.5 Mbps/64 kbps ADSL in downtown Chicago. $200 per PC or $1000 per LAN.
- Microsoft + Westell to support ADSL in Windows NT server ⇒ MS Public Network Platform
- Microsoft + General Instrument, Zenith, and Motorola to support cable modems

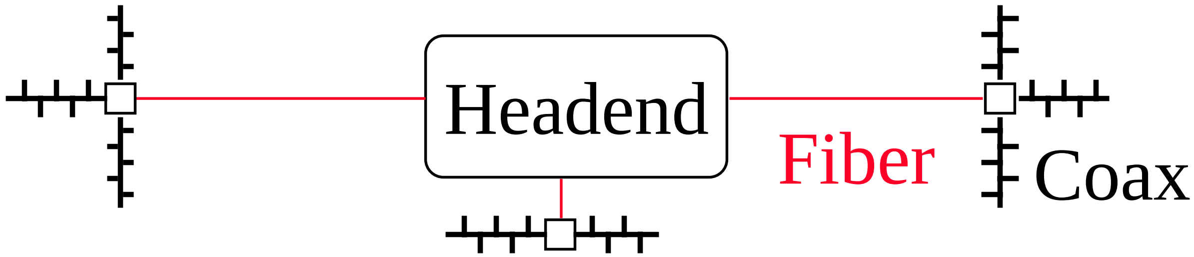
VDSL

- 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

Hybrid Fiber Coax (HFC)



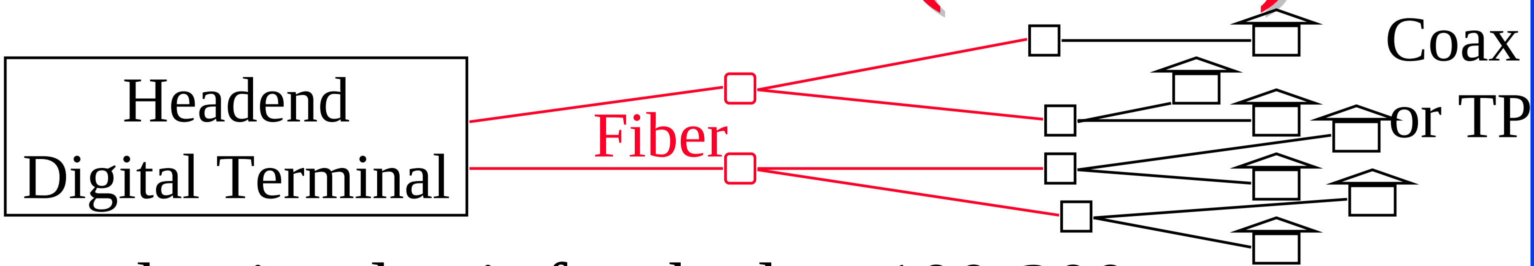
- Reuse existing cable TV coax
- Replace trunks to neighborhoods by fibers
- 45 Mbps downstream, 1.5 Mbps upstream
- MAC protocol required to share upstream bandwidth
- 500 to 1200 homes per HFC link
- Sharing ⇒ Security issues
- IEEE 802.14 is standardizing MAC and PHY

HFC Spectrum

Upstream Video	Upstream Telephony	Analog Broadcast Video	Digital Video	Downstream Telephony
5-15	22-42	54-552	552-672	672-700

- Use 0-50 MHz for upstream, 50-450 MHz for analog broadcasts, 450-750 MHz for downstream
- Can use phone, TV, and Internet simultaneously
- Low upstream band ⇒ more noise
- Broadband ⇒ frequency multiplexing ⇒ Each home tunes to its channel
- Quadrature amplitude modulation (QAM-64) can give 27 Mbps over 6 MHz channel

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

Raj Jain

FTTC MAC

- Downstream uses periodic frames
- Upstream should consist of fixed size slots containing one ATM cell
- One upstream slot per n downstream frames
- Some slots are reserved, others are for contention
- Contention slots are used by devices undergoing activation

Cable Modems

- Modulate RF frequencies into cable
- Signal received at the headend and converted to optical
- Cost \$395 to \$995
- If cable is still one-way, upstream path through POTS
- \$30 to \$40 per month flat service charge
- Successful trials in Canada using 500 kbps modems
- After the trial 75% users kept the service and paid
- TCI formed @Home http://www.home.net
- Servers at headend to avoid Internet bottleneck
- Plans to create high-speed cable backbone across US

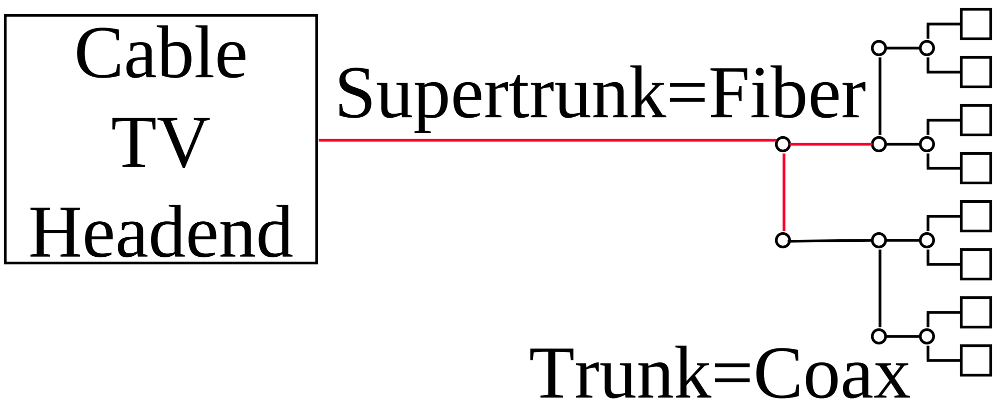
Fiber to the Home (FTTH)

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

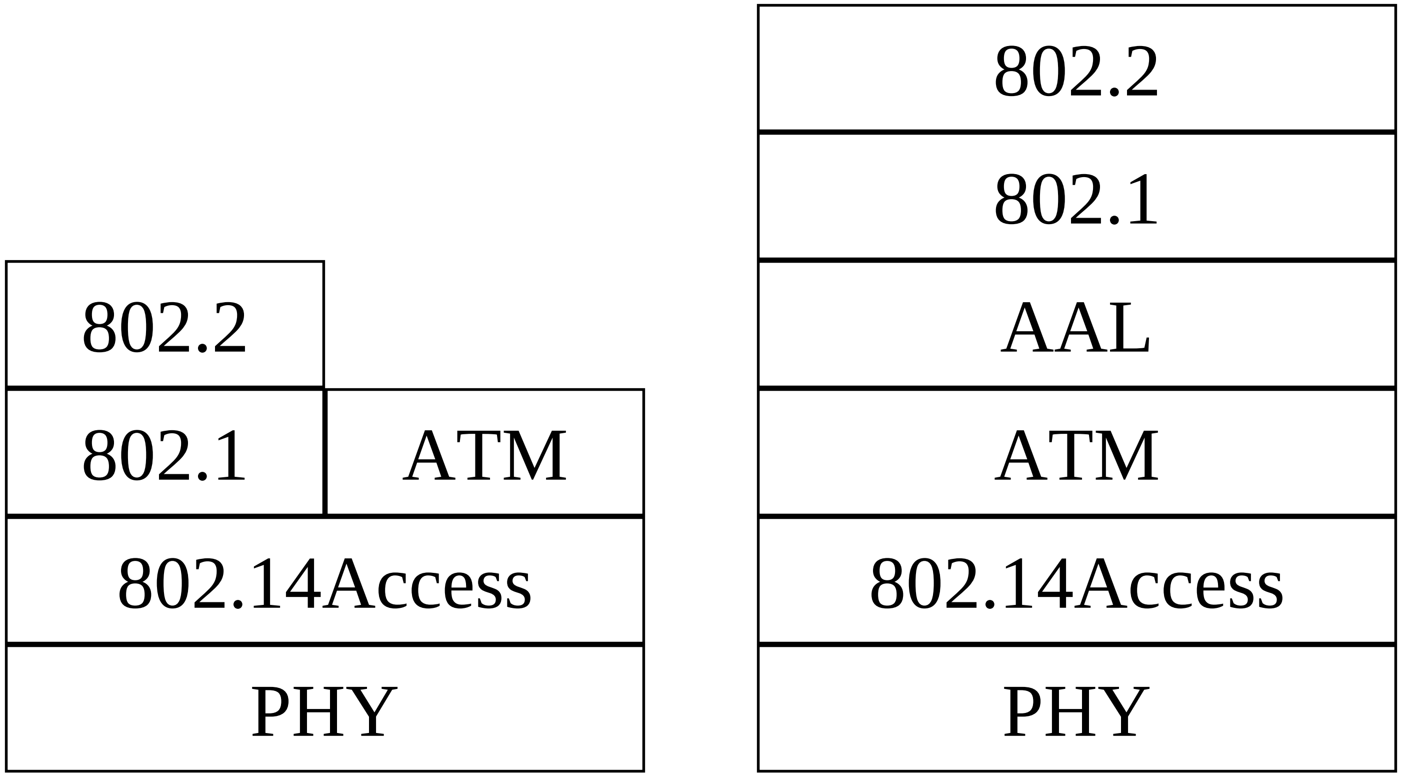
ADSL	**Cable Modems**
Phone company	Cable company
Switching experience but low bandwidth circuits	No switching but high bandwidth infrastructure
Point-to-point ⇒ Data privacy	Broadcast
	Sharing ⇒ More cost effective
Currently 1.5 to 8 Mbps	10 to 30 Mbps
Performance depends upon location	Independent of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

IEEE 802.14

- CATV MAC and PHY Protocol working group
- Started November 1994
- Defining PHY and MAC for 2-way HFC
- Downstream PHY: 1-to-n broadcast
- Upstream PHY: n-to-1
- Up to 50 miles (80 km) $\Rightarrow$ 400 microsecond one-way



IEEE 802.14 Protocol Stack



ATM Friendly

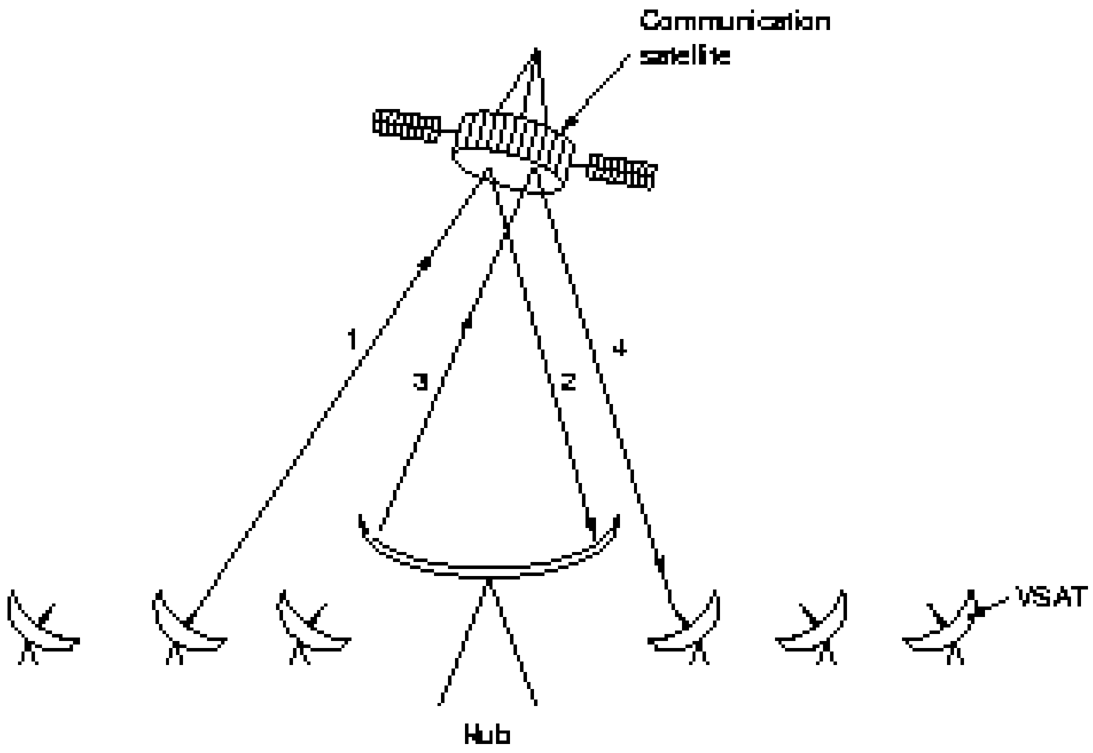
All ATM

IEEE 802.14 Issues

- ATM based?
- Which forward error correction algorithm?
- Size of slots?
- Upstream sharing requires ranging of homes. How precise?
- Security and encryption
- Error handling by MAC
- Station addressing

VSATs

- Very Small Aperture Terminals
- DirecTV success ⇒ DirecPC from Hughes



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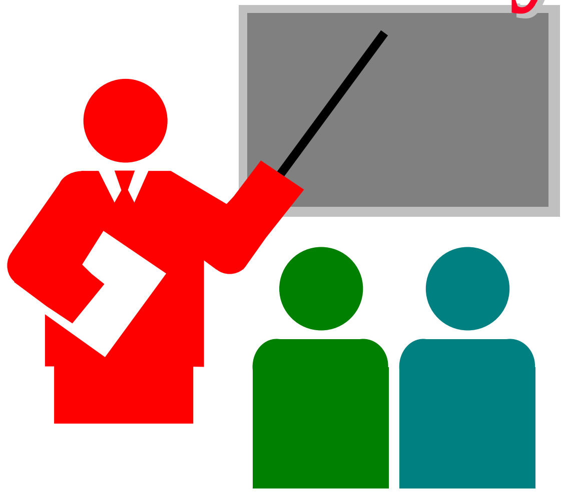
Summary



- 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

Final Review: 13 Hot Facts

1. Networking is critical and growing exponentially.
2. Shared switching rather than shared media
3. LAN Emulation allows current applications to run on ATM
4. Classical IP allows ARP using LIS servers
5. NHRP allows shortcuts between ATM hosts
6. To succeed, ATM has to solve today's problem (data) at a price competitive to LANs.
7. Compression Standards: JPEG, MPEG-1, H.261

8. ATM Forum standardized CBR MPEG2 on AAL5
9. TCP/IP protocols suite is being extended to allow multimedia on Internet.
10. Spread spectrum allows multiple users on the same frequency band $\Rightarrow$ No licensing required.
11. IEEE 802.11 LANs run at 1 to 2 Mbps and uses CSMA/CA
12. Mobile IP provides transparent mobility via home/foreign agents
13. Multimegabit access via ADSL, VDSL, HFC, FTTC, FTTH coming soon to your home.