ATM
Asynchronous Transfer Mode

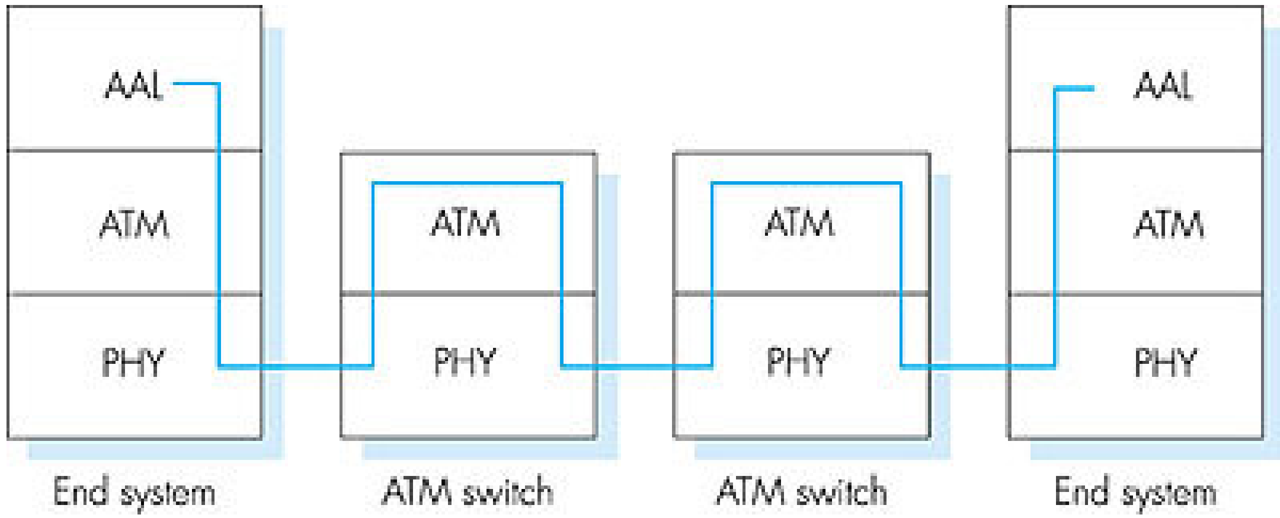
Outline

- ATM layer overview
- Cell switching
- Segmentation and reassembly

Asynchronous Transfer Mode: ATM

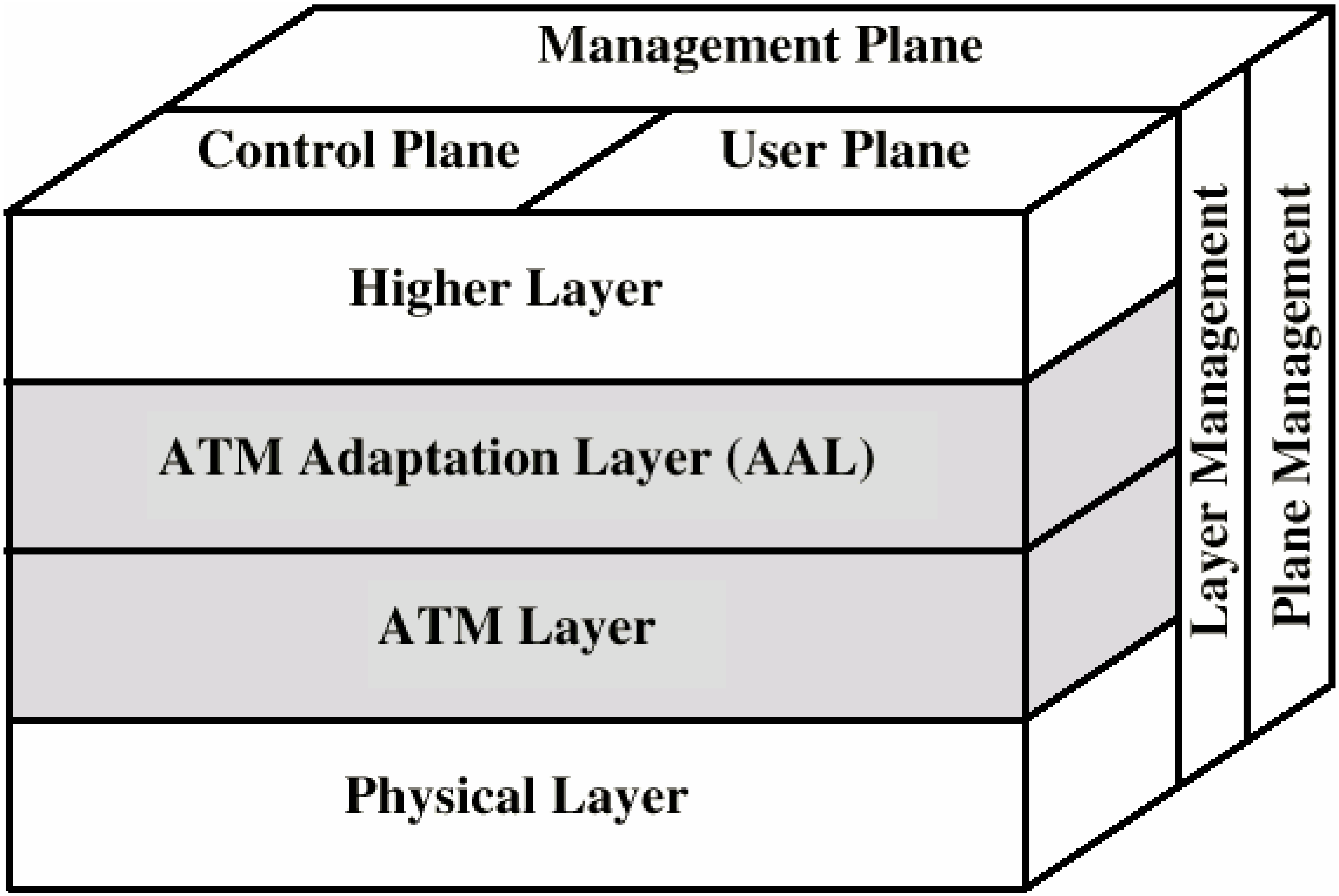
- **1980s/1990's standard for high-speed** (155Mbps to 622 Mbps and higher) *Broadband Integrated Service Digital Network* architecture
- Goal: *integrated, end-end transport to carry voice, video, data*
  - meeting timing/QoS requirements of voice, video (versus Internet best-effort model)
  - "next generation" telephony: technical roots in telephone world
- Similarities between ATM and packet switching
  - Transfer of data in discrete chunks
  - Multiple logical connections over single physical interface

ATM architecture



- **adaptation layer: only at edge of ATM network**
  - data segmentation/reassembly
  - roughly analogous to Internet transport layer
- ATM layer: “network” layer
  - cell switching, routing
- physical layer

Protocol Architecture



User plane

Provides for user information transfer

Control plane

Call and connection control

Management plane

Plane management

whole system functions

Layer management

Resources and parameters in protocol entities

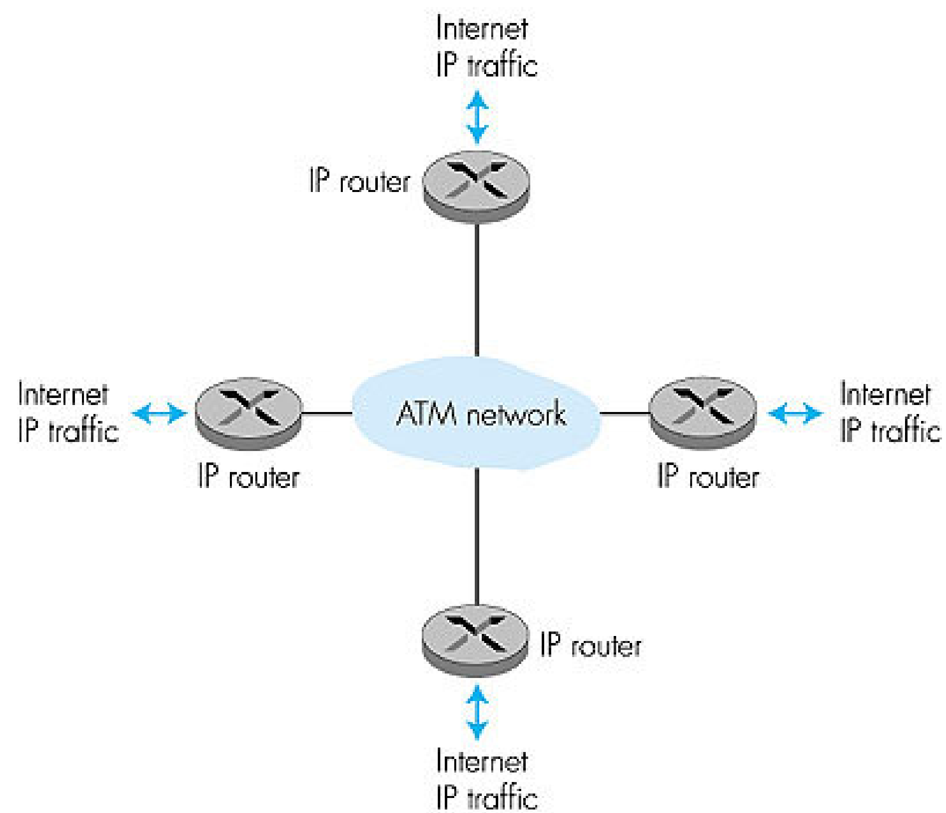
ATM: network or link layer?

<u>Vision:</u> end-to-end transport: "ATM from desktop to desktop"

- ATM *is* a network (layer 3) technology

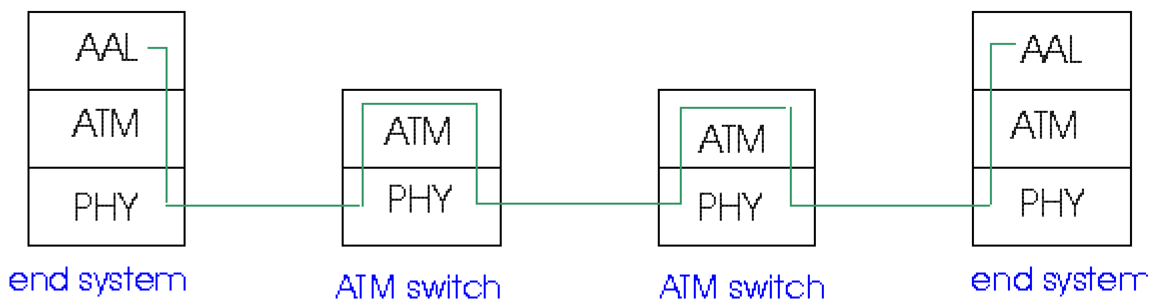
<u>Reality:</u> used to connect IP backbone routers

- "IP over ATM": network, used as link layer for the IP network
- ATM as switched link layer (layer 2), connecting IP routers



ATM Adaptation Layer (AAL)

- ATM **Adaptation Layer** (AAL): “adapts” upper layers (IP or native ATM applications) to ATM layer below
- AAL present **only in end systems**, not in switches
- AAL layer segment (header/trailer fields, data) fragmented across multiple ATM cells
  - – analogy: TCP segment in many IP packets



ATM Service Models

Service: transport cells across ATM network

- analogous to IP network layer
- very different services than IP network layer

Network Architecture	Service Model	Guarantees ? Bandwidth	Loss	Order	Timing	Congestion feedback
Internet	best effort	none	no	no	no	no (inferred via loss)
ATM	CBR	constant rate	yes	yes	yes	no congestion
ATM	VBR	guaranteed rate	yes	yes	yes	no congestion
ATM	ABR	guaranteed minimum	no	yes	no	yes
ATM	UBR	none	no	yes	no	no

ATM Service Categories

- Real time
  - Constant bit rate (CBR)
  - Real time variable bit rate (rt-VBR)

- Non-real time
  - Non-real time variable bit rate (nrt-VBR)
  - Available bit rate (ABR)
  - Unspecified bit rate (UBR)
  - Guaranteed frame rate (GFR)

CBR

Fixed data rate continuously available
Tight upper bound on delay
Uncompressed audio and video

- Video conferencing
- Interactive audio
- A/V distribution and retrieval

rt-VBR

Time sensitive application

- Tightly constrained delay and delay variation

rt-VBR applications transmit at a rate that varies with time
Compressed video

- Produces varying sized image frames
- Original (uncompressed) frame rate constant
- So compressed data rate varies

Can statistically multiplex connections

nrt-VBR

May be able to characterize expected traffic flow

Improve QoS considering loss and delay

End system specifies:

- Peak cell rate
- Sustainable or average rate
- Measure of how bursty traffic is

Airline reservations, banking transactions

UBR

Additional capacity over and above that used by CBR and VBR traffic

- Not all resources dedicated
- Bursty nature of VBR

For application that can tolerate some cell loss or variable delays

- e.g. TCP based traffic

Cells forwarded on FIFO basis

Best efforts service

ABR

Application specifies peak cell rate (PCR) and minimum cell rate (MCR)

Resources allocated to give at least MCR

Spare capacity shared among all ARB sources (LAN interconnect.)

General Frame Rate (GFR)

Designed to support IP backbone subnetworks

Better service than UBR for frame based traffic (IP and Ethernet)

Optimize handling of frame based traffic passing from LAN through router to ATM backbone

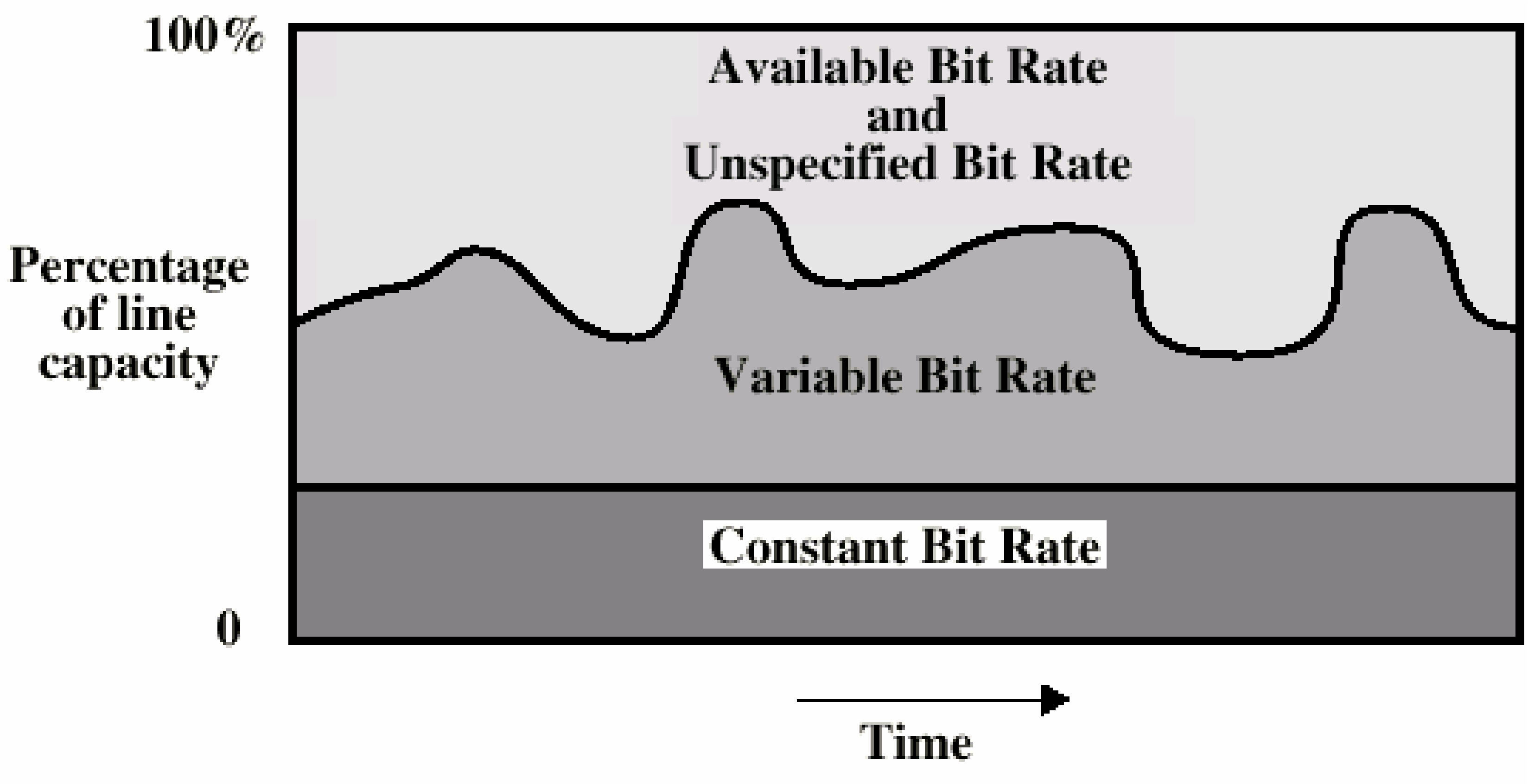
- Used by enterprise, carrier and ISP networks
- Consolidation and extension of IP over WAN

ABR difficult to implement between routers over ATM network

GFR better alternative for traffic originating on Ethernet

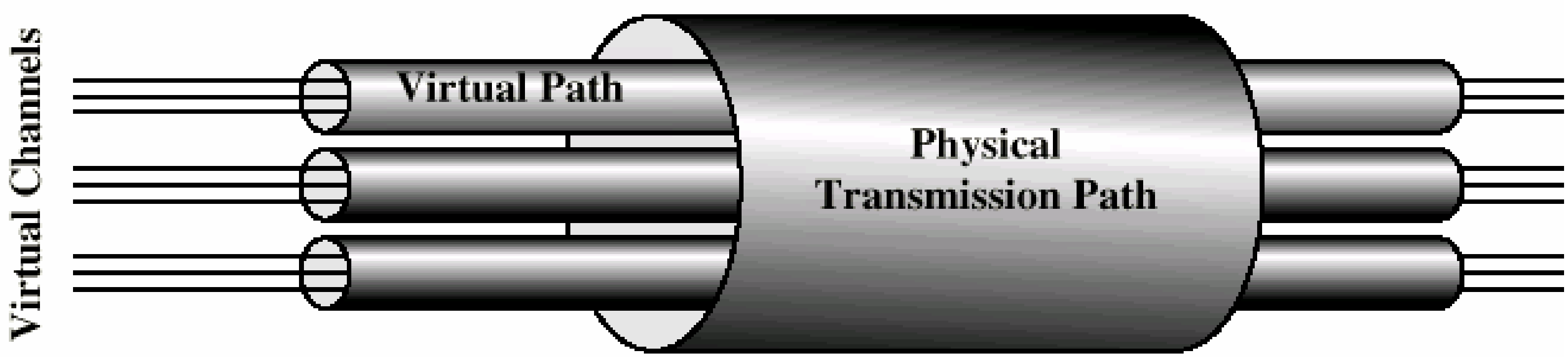
- Network aware of frame/packet boundaries
- When congested, all cells from frame discarded
- Guaranteed minimum capacity
- Additional frames carried of not congested

ATM Bit Rate Services



ATM Layer: Virtual Circuits

Virtual channel connections (VCC)
Analogous to virtual circuit in X.25
Basic unit of switching
Between two end users
Full duplex
Fixed size cells
Data, user-network exchange (control) and network-network exchange (network management and routing)
Virtual path connection (VPC)
- Bundle of VCC with same end points



ATM Layer: Virtual Circuits

- VC transport: cells carried on VC from source to destination
  - call setup, for each call *before* data can flow
  - each packet carries VC identifier (not destination ID)
  - *every* switch on source-destination. path maintain “state” for each passing connection
  - link, switch resources (bandwidth, buffers) may be *allocated* to VC: to get circuit-like performance
- Permanent VCs (PVCs)
  - long lasting connections
  - typically: “permanent” route between to IP routers
- Switched VCs (SVC):
  - dynamically set up on per-call basis
- PVCs dominate today
  - Because of ATM’s typical use: as a link layer under IP

ATM VCs

Advantages of ATM VC approach:

- QoS performance guarantee for connection mapped to VC (bandwidth, delay, delay jitter)
- Simplified network architecture; Increased network performance and reliability; Reduced processing

Drawbacks of ATM VC approach:

- Inefficient support of datagram traffic
- one PVC between each source/dest. pair) does not scale (N*2 connections needed)
- SVC introduces call setup latency, processing overhead for short lived connections

Cell Switching

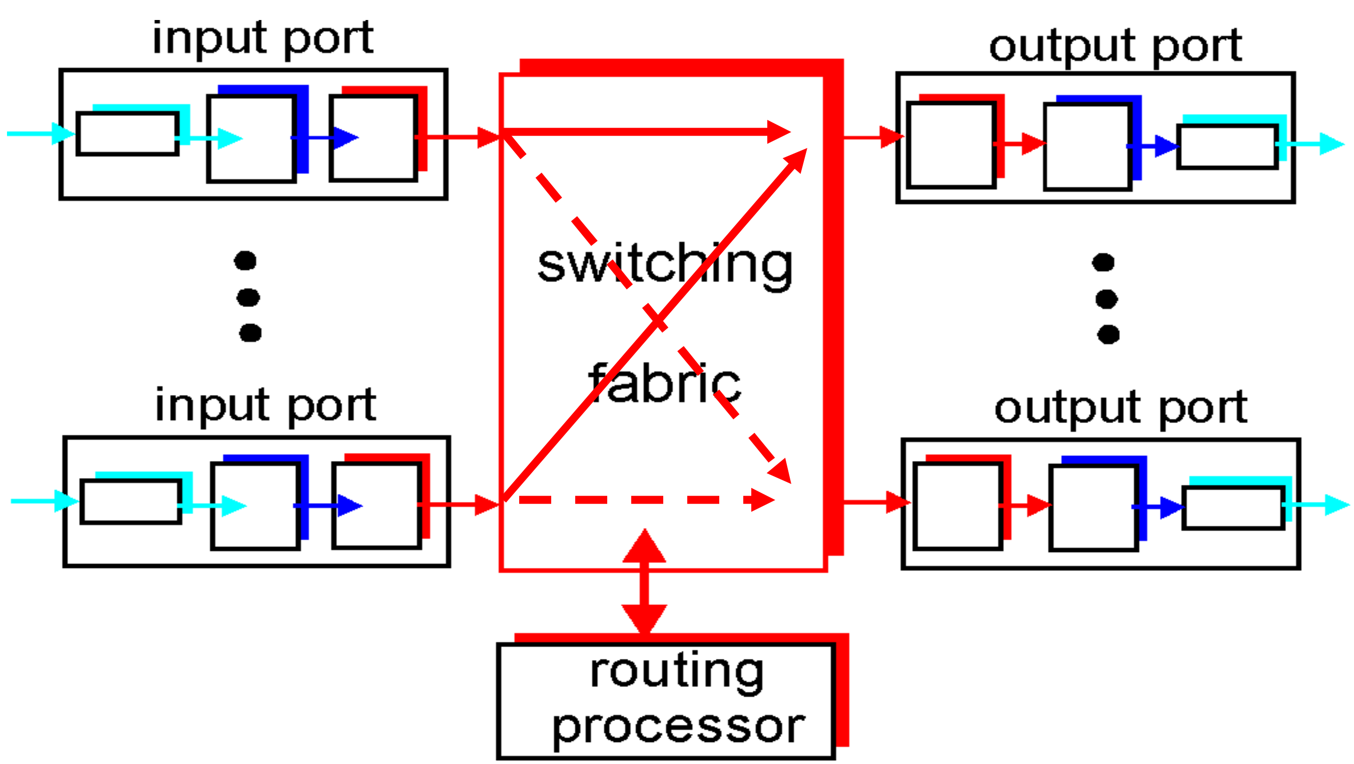
- Connection-oriented packet-switched network
- Used in both WAN and LAN settings
- Signaling (connection setup) protocol: Q.2931
- Specified by ATM forum
- Packets are called *cells*
  - 5-byte header + 48-byte payload
- Commonly transmitted over SONET
  - other physical layers possible

Variable vs Fixed-Length Packets

- No Optimal Length
  - if small: high header-to-data overhead
  - if large: low utilization for small messages
- Fixed-length easier to switch in hardware
  - simpler
  - enables parallelism

Switch Architecture Overview and queuing on output ports

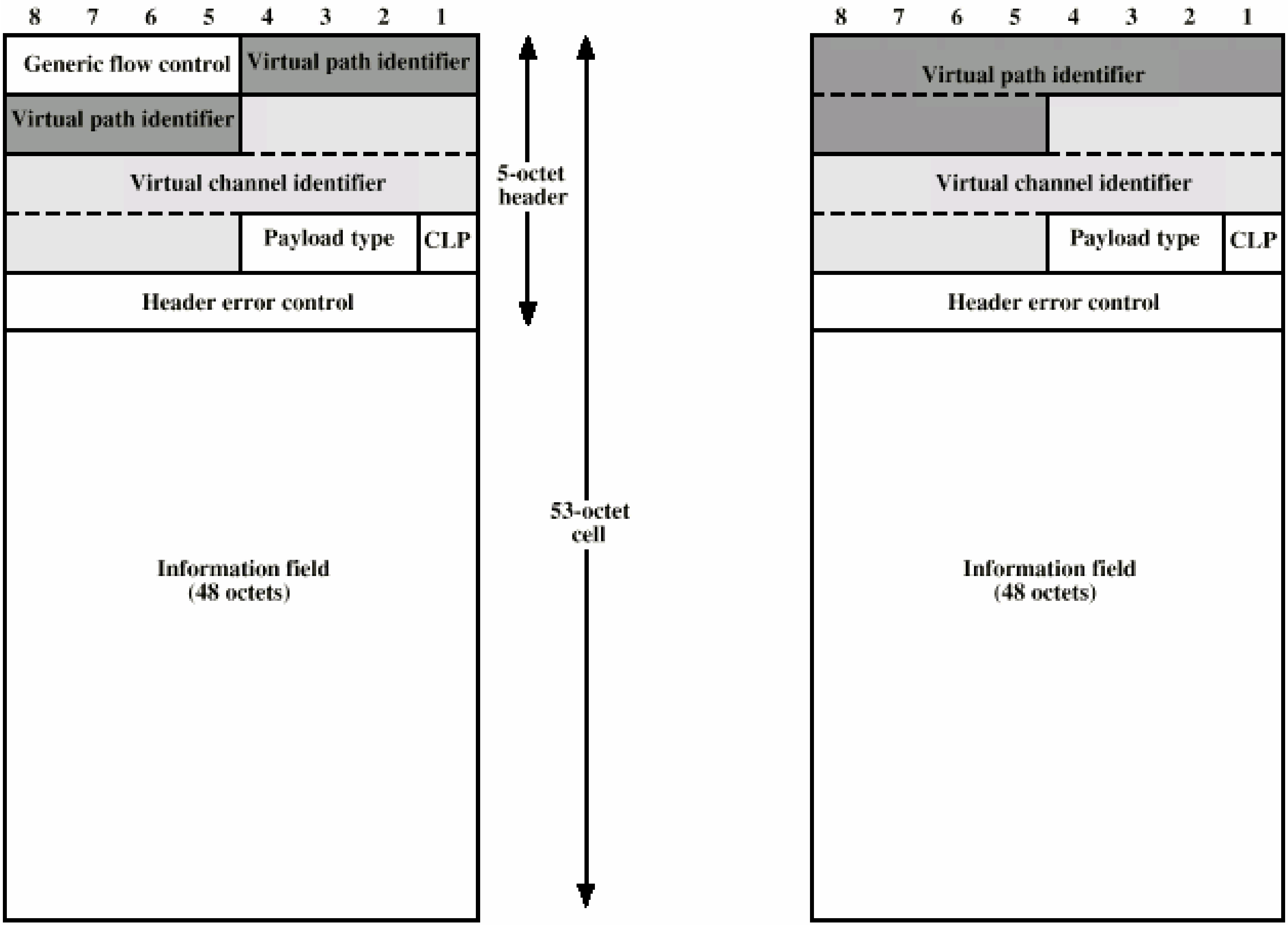
- *switching* datagrams from incoming to outgoing link, where can get queues



Big vs Small Packets

- Small Improves Queue behavior
- near cut-through behavior
- Small Improves Latency (for voice)
- ATM Compromise: 48 bytes = (32+64)/2;   +5 hdr = 53
  - Nothing a power of 2!

ATM Cell Format



(a) User-Network Interface

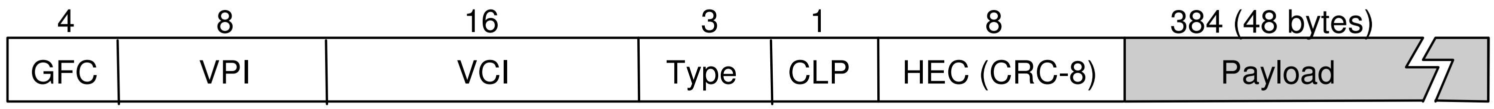
(b) Network-Network Interface

Interfaces: Packet Format

- "User-to-Network": UNI
- "Network-to-Network": NNI
- Only differ in one 4 bit field!
- Sacrificed uniformity, easy extensibility… for what? (Contrast with IP.)

Cell Format

- User-Network Interface (UNI)



  - host-to-switch format
  - GFC: Generic Flow Control (still being defined)
    - Arbitrate access to the link at local site
  - VCI: Virtual Circuit Identifier
  - VPI: Virtual Path Identifier
  - Type: management, congestion control, AAL5 (later)
  - CLP: Cell Loss Priority
  - HEC: **Header** Error Check (CRC-8); detect & 1-bit correction

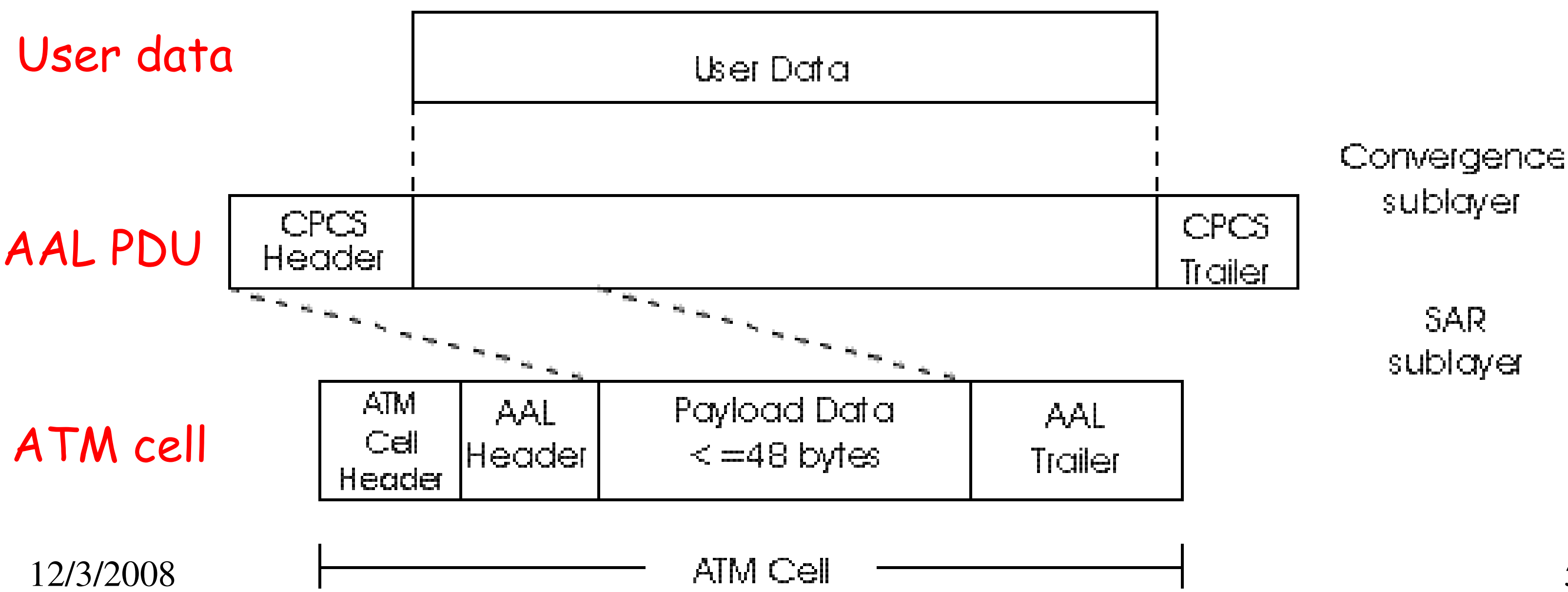
- Network-Network Interface (NNI)
  - switch-to-switch format
  - GFC becomes part of VPI field

Encapsulation

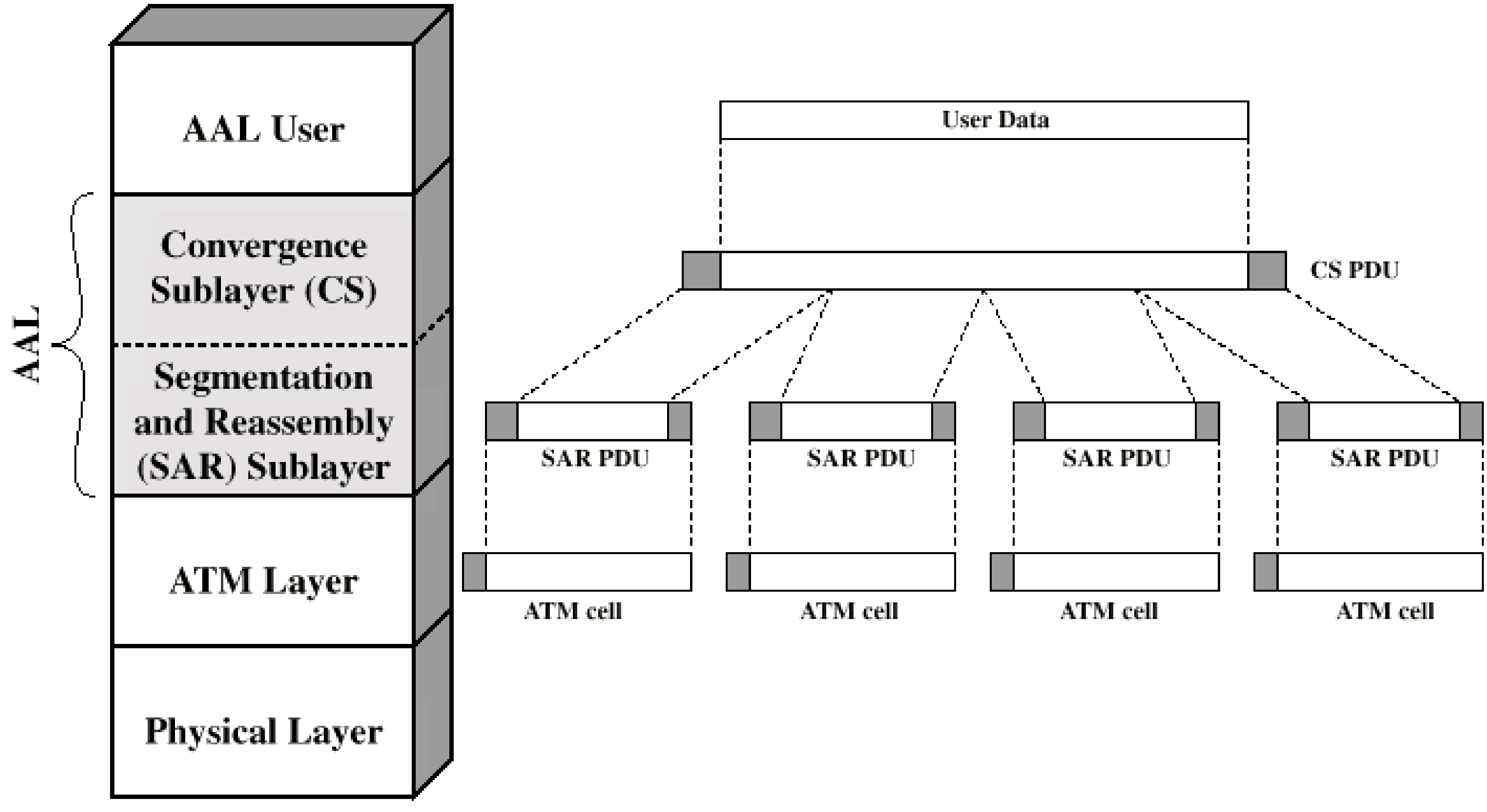
- Outgoing:
  - Take chunk of data from layer above (eg, IP)
  - Slap a header on the front
  - Maybe tack something on the back (CRC)
  - Pass to next lower layer
- But… ATM can only handle 48 byte data chunks!
- Therefore need data Fragmentation and Reassembly
- … at the link layer!
- Question: where should this be done? (OS in software, device card in hardware/firmware?)

ATM Adaption Layer (AAL)

- Convergence sublayer (CS)
  - Support for specific applications
  - AAL user attaches at SAP
- Segmentation and re-assembly sublayer (SAR)
  - Packages and unpacks info received from CS into cells

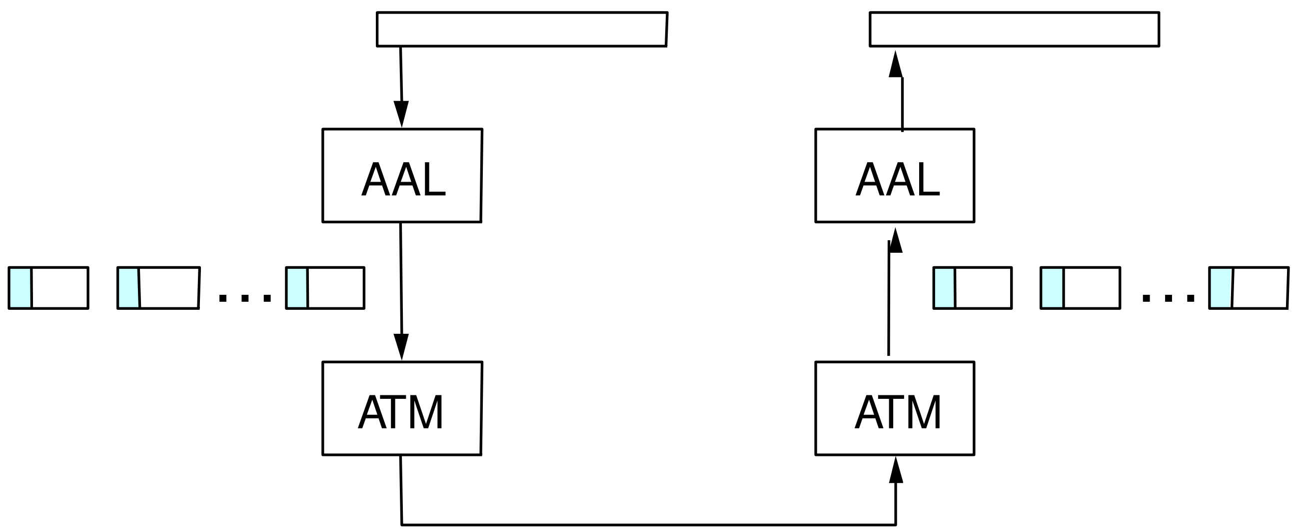


AAL Protocols



AAL Protocol Types

- ATM Adaptation Layer (AAL)
  - AAL 1 and 2 designed for applications that need guaranteed bit rate (e.g., voice, video) (constant, variable)
  - AAL 3/4 designed for packet data (connection/connectionless)
  - AAL 5 is an alternate “simple” standard for packet data



AAL 3/4

- Main job: convert variable length packet to fixed-length cells
- “Convergence Sublayer Protocol Data Unit” (CS-PDU)

8	8	16	< 64 KB	0– 24	8	8	16
CPI	Btag	BASize	User data	Pad	0	Etag	Len

  - CPI: common part indicator (version field)
  - Btag/Etag: beginning and ending tag
  - BAsize: hint on amount of buffer space to allocate
  - Length: size of whole PDU

Special Cell Format

40	2	4	10	352 (44 bytes)	6	10
ATM header	Type	SEQ	MID	Payload	Length	CRC-10

- Type
  - BOM: beginning of message
  - COM: continuation of message
  - EOM end of message
- SEQ: sequence of number
- MID: message id
- Length: number of bytes of PDU in this cell

Efficiency

- AAL ¾ makes it even worse
- Best possible is 1 - (5 + 4)/53 = 83%
- Often much worse due to CS-PDU header and partial last cell

AAL5: “Simple”

- CS-PDU Format

< 64 KB	0– 47 bytes	16	16	32
Data	Pad	Reserved	Len	CRC-32

  - pad so trailer always falls at end of ATM cell
  - Length: size of PDU (data only)
  - CRC-32 (detects missing or misordered cells)
- Cell Format
  - end-of-PDU bit in Type field of ATM header
  - This is the key
- Stronger protection

ATM Physical Layer (more)

Two pieces (sublayers) of physical layer:

- Transmission Convergence Sublayer (TCS): adapts ATM layer above to PMD sublayer below
- Physical Medium Dependent (PMD): depends on physical medium being used

TCS Functions:

- Header **checksum** generation: 8 bits CRC
- Cell **delineation**
- With "unstructured" PMD sublayer, transmission of **idle cells** when no data cells to send

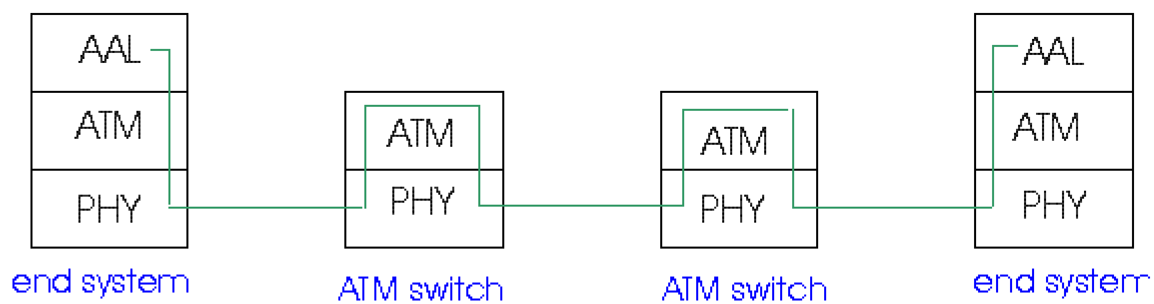
ATM Physical Layer

Physical Medium Dependent (PMD) sublayer

- **SONET/SDH**: transmission frame structure (like a container carrying bits);
  - bit synchronization;
  - bandwidth partitions (TDM);
  - several speeds: OC1 = 51.84 Mbps; OC3 = 155.52 Mbps; OC12 = 622.08 Mbps
- **TI/T3**: transmission frame structure (old telephone hierarchy): 1.5 Mbps/ 45 Mbps
- **unstructured**: just cells (busy/idle)

Datagram Journey in IP-over-ATM Network

- at Source Host:
  - IP layer finds mapping between IP, ATM destination address (using ATM ARP)
  - passes datagram to AAL5
  - AAL5 encapsulates data, segments to cells, passes to ATM layer
- ATM network: moves cell along VC to destination
- at Destination Host:
  - AAL5 reassembles cells into original datagram
  - if CRC OK, datagram is passed to IP



ARP in ATM Nets

- ATM network needs destination ATM address
  - just like Ethernet needs destination Ethernet address
- IP/ATM address translation done by ATM ARP (Address Resolution Protocol)
  - ARP server in ATM network performs broadcast of ATM ARP translation request to all connected ATM devices
  - hosts can register their ATM addresses with server to avoid lookup

Final remarks

ATM – toward an end!

ATM switches ran at much faster speeds than IP Routers, but that has changed.

Doing IP over WDM – bypass ATM.

IP will extend end-to-end.

Question is whether ATM will stay in the backbone, or IP will dominate there too.