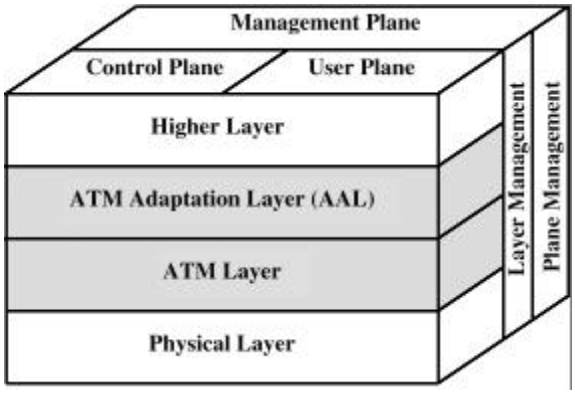
ATM: Asynchronous Transfer Mode

- ATM and FR (Frame Relay) are recent developments
  - node-node transfer techniques
  - used where error rates are lower
  - (But still must cope with congestion)
- ATM is a form of packet switching
  - Transfer of data in discrete chunks
  - Multiple logical connections over single physical interface
- In ATM flow on each logical connection is in fixed sized packets called cells
- Minimal error and flow control

Protocol Architecture (diag)



Reference Model Planes

- 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

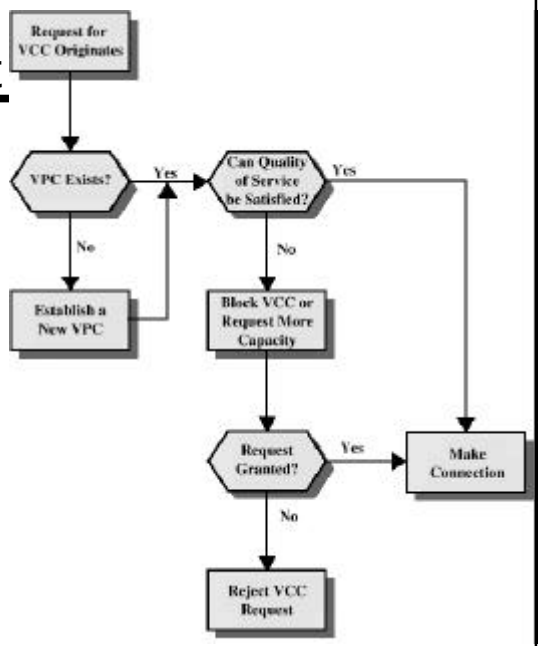
ATM Logical Connections

- 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

Advantages of Virtual Paths

- Simplified network architecture
- Increased network performance and reliability
- Reduced processing
- Short connection setup time
- Enhanced network services

Call Establishment Using VPs



VP/VC Characteristics

- Quality of service
- Switched and semi-permanent channel connections
- Call sequence integrity
- Traffic parameter negotiation and usage monitoring

- VPC only
  - Virtual channel identifier restriction within VPC

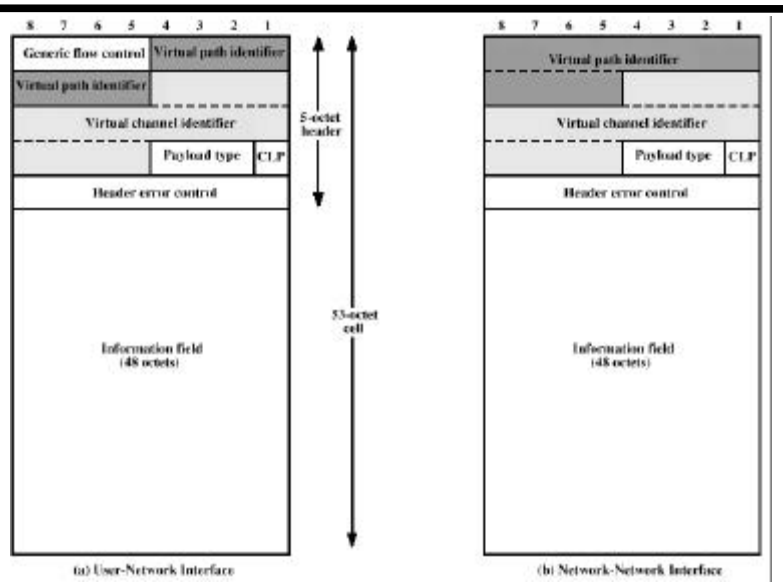
Control Signaling - VCC

- Done on separate connection
- Semi-permanent VCC
- Meta-signaling channel
  - Used as permanent control signal channel
- User to network signaling virtual channel
  - For control signaling
  - Used to set up VCCs to carry user data
- User to user signaling virtual channel
  - Within pre-established VPC
  - Used by two end users without network intervention to establish and release user to user VCC

ATM Cells

- Fixed size
- 5 octet header
- 48 octet information field
- Small cells reduce queuing delay for high priority cells
- Small cells can be switched more efficiently
- Easier to implement switching of small cells in hardware
- low level

ATM Cell Format



Header Format

- Generic flow control
  - Only at user to network interface
  - Controls flow only at this point
- Virtual path identifier
- Virtual channel identifier
- Payload type
  - e.g. user info or network management
- Cell loss priority
- Header error control

Generic Flow Control (GFC)

- Control traffic flow at user to network interface (UNI) to alleviate short term overload
- Two sets of procedures
  - Uncontrolled transmission
  - Controlled transmission
- Every connection either subject to flow control or not
- Subject to flow control
  - May be one group (A) default
  - May be two groups (A and B)
- Flow control is from subscriber to network
  - Controlled by network side

Transmission of ATM Cells

- 622.08Mbps
- 155.52Mbps
- 51.84Mbps
- 25.6Mbps
- Cell Based physical layer
- SDH based physical layer

Cell Based Physical Layer

- No framing imposed
- Continuous stream of 53 octet cells
- Cell delineation based on header error control field

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)

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
- e.g. 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 in loss and delay
- End system specifies:
  - Peak cell rate
  - Sustainable or average rate
  - Measure of how bursty traffic is
- e.g. Airline reservations, banking transactions

UBR

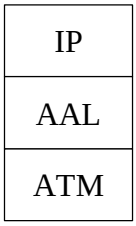
- May be additional capacity over and above that used by CBR and VBR traffic
  - Not all resources dedicated
  - Bursty nature of VBR
- For application that can tolerate some cell loss or variable delays
  - e.g. TCP based traffic
- Cells forwarded on FIFO basis
- Best efforts service

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
- e.g. LAN interconnection

ATM Adaptation Layer: AAL

- Support for information transfer protocol not based on ATM
- PCM (voice)
  - Assemble bits into cells
  - Re-assemble into constant flow
- IP
  - Map IP packets onto ATM cells
  - Fragment IP packets
  - Use LAPF over ATM to retain all IP infrastructure



Adaptation Layer Services

- Handle transmission errors
- Segmentation and re-assembly
- Handle lost and misinserted cells
- Flow control and timing

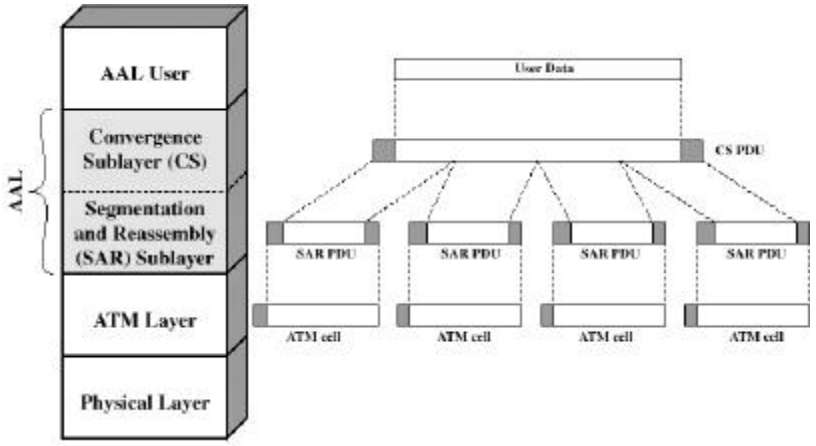
Supported Application types

- Circuit emulation
- VBR voice and video
- General data service
- IP over ATM
- Multiprotocol encapsulation over ATM (MPOA)
  - IPX, AppleTalk, DECNET)
- LAN emulation

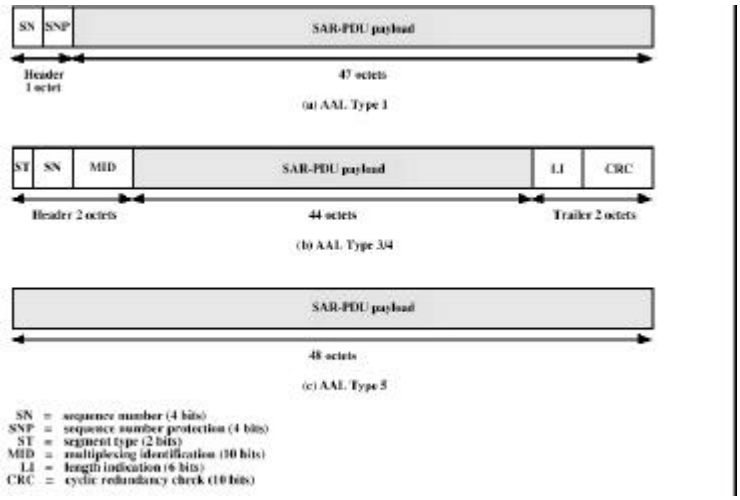
AAL Protocols

- 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
- Four types
  - Type 1: Constant bit rate source
  - Type 2,3,4: really for telecomms industry
  - Type 5: used for IP

AAL Protocols



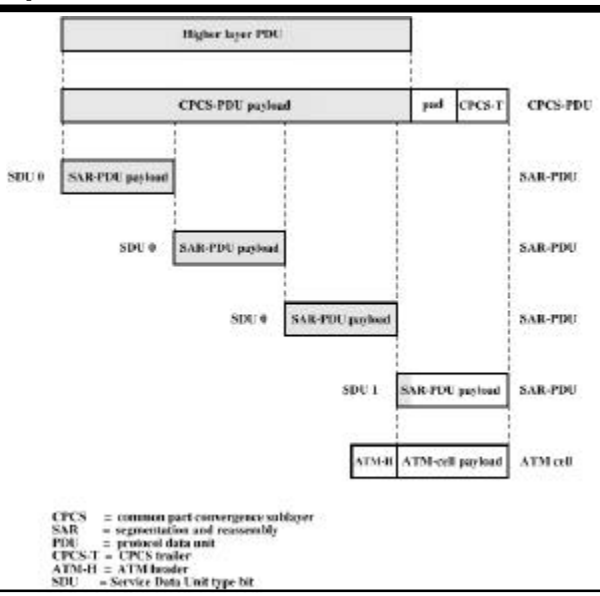
Segmentation and Reassembly PDU



AAL Type 1

- CBR source
- SAR packs and unpacks bits
- Block accompanied by sequence number

Example AAL 5 Transmission



Frame Relay

- Designed to be more efficient than X.25
- Developed before ATM
- Larger installed base than ATM
- ATM now of more interest on high speed networks

Frame Relay Background - X.25

- Call control packets, in band signaling
  - protocol used for both data and control
- Multiplexing of virtual circuits at layer 3
- Layer 2 and 3 include flow and error control
- Considerable overhead, particularly for error detection & correction
- Not appropriate for modern digital systems with high reliability

Frame Relay - Differences

- Call control carried in separate logical connection
- Multiplexing and switching at layer 2
  - Eliminates one layer of processing
- No hop by hop error or flow control
- End to end flow and error control (if used) are done by higher layer
- Single user data frame sent from source to destination and ACK (from higher layer) sent back

Advantages and Disadvantages

- Lost link by link error and flow control
  - Increased reliability makes this less of a problem
- Streamlined communications process
  - Lower delay
  - Higher throughput
- ITU-T recommend frame relay above 2Mbps

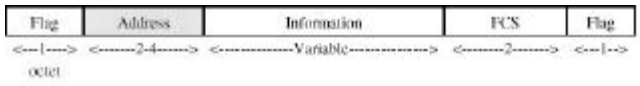
Control Plane

- Between subscriber and network
- Separate logical channel used
  - Similar to common channel signaling for circuit switching services
- Data link layer
  - LAPD (Q.921)
  - Reliable data link control
  - Error and flow control
  - Between user (TE) and network (NT)
  - Used for exchange of Q.933 control signal messages

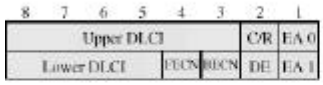
User Plane

- End to end functionality
- Transfer of info between ends
- LAPF (Link Access Procedure for Frame Mode Bearer Services) Q.922
  - Frame delimiting, alignment and transparency
  - Frame mux and demux using addressing field
  - Ensure frame is integral number of octets (zero bit insertion/extraction)
  - Ensure frame is neither too long nor short
  - Detection of transmission errors
  - Congestion control functions

LAPF Core Formats

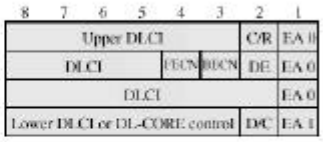


(a) Frame format



(b) Address field - 2 octets (default)

(c) Address field - 3 octets



(d) Address field - 4 octets

EA	Address field extension bit
C/R	Command/response bit
FECN	Forward explicit congestion notification
BECN	Backward explicit congestion notification
DLCI	Data link connection identifier
D/C	DLCI or DL-CORE control indicator
DE	Discard eligibility

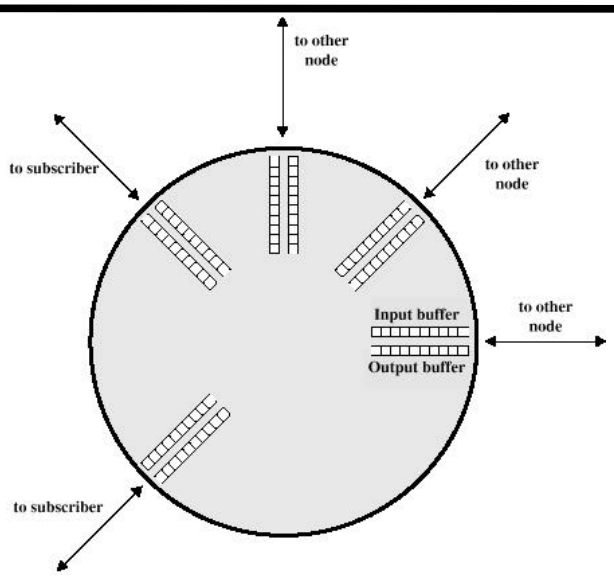
User Data Transfer

- One frame type
  - User data
  - No control frame
- No inband signaling
- No sequence numbers
  - No flow nor error control
- All sequencing etc is end-to-end

Congestion

- Congestion occurs when the number of packets being transmitted through the network approaches the packet handling capacity of the network
- Congestion control aims to keep number of packets below level at which performance falls off dramatically
- Data network is a network of queues
- Generally 80% utilization is critical
- Finite queues mean data may be lost

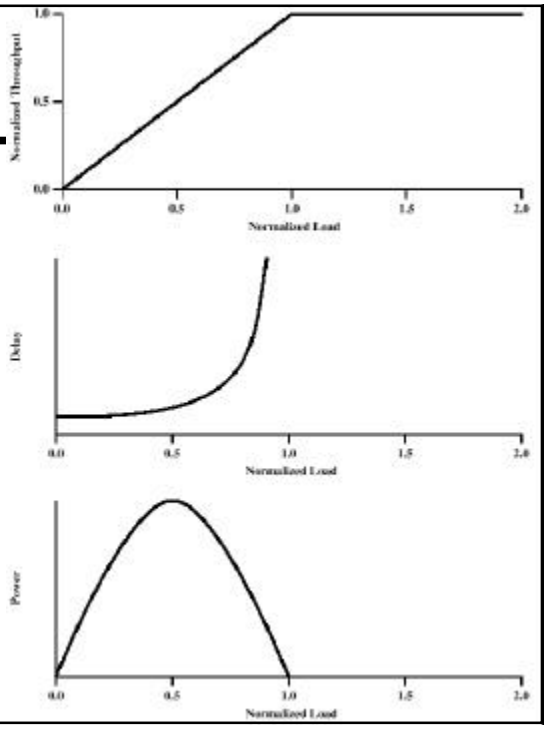
Queues at a Node



Effects of Congestion

- Packets arriving are stored at input buffers
- Routing decision made
- Packet moves to output buffer
- Packets queued for output transmitted as fast as possible
  - Statistical time division multiplexing
- If packets arrive to fast to be routed, or to be output, buffers will fill
- Can discard packets
- Can use flow control
  - Can propagate congestion through network

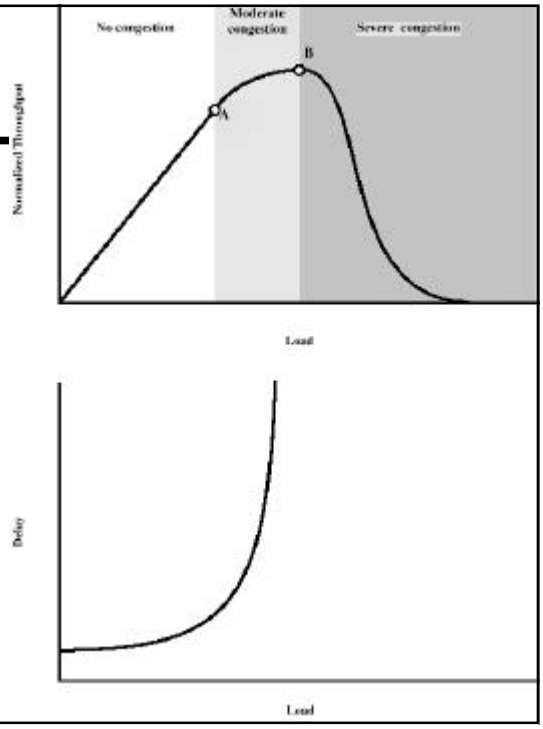
Ideal Performance



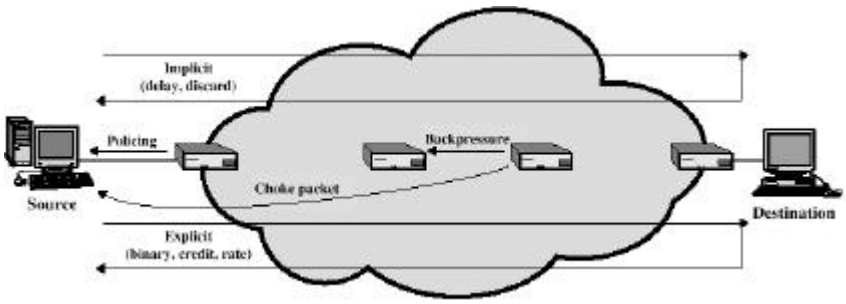
Practical Performance

- Ideal assumes infinite buffers and no overhead
- Buffers are finite
- Overheads occur in exchanging congestion control messages
- Actual performance is not as good

Effects of Congestion - No Control



Mechanisms for Congestion Control



Backpressure

- If node becomes congested it can slow down or halt flow of packets from other nodes
- May mean that other nodes have to apply control on incoming packet rates
- Propagates back to source
- Can restrict to logical connections generating most traffic
- Used in connection oriented that allow hop by hop congestion control (e.g. X.25)
- Not used in ATM nor frame relay
- Only recently developed for IP

Choke Packet

- Control packet
  - Generated at congested node
  - Sent to source node
  - e.g. ICMP source quench
    - From router or destination
    - Source cuts back until no more source quench message
    - Sent for every discarded packet, or anticipated
- Rather crude mechanism

Implicit Congestion Signaling

- Transmission delay may increase with congestion
- Packet may be discarded
- Source can detect these as implicit indications of congestion
- Useful on connectionless (datagram) networks
  - e.g. IP based
    - (TCP includes congestion and flow control)
- Used in frame relay LAPF

Explicit Congestion Signaling

- Network alerts end systems of increasing congestion
- End systems take steps to reduce offered load
- Backwards
  - Congestion avoidance in opposite direction to packet required
- Forwards
  - Congestion avoidance in same direction as packet required
- Used in Frame Relay

Categories of Explicit Signaling

- Binary
  - A bit set in a packet indicates congestion
- Credit based
  - Indicates how many packets source may send
  - Common for end to end flow control
- Rate based
  - Supply explicit data rate limit
  - e.g. ATM

Traffic Management

- Fairness
- Quality of service
  - May want different treatment for different connections
- Reservations
  - e.g. ATM
  - Traffic contract between user and network

Virtual Private Networks (VPNs)

- Many companies are multi-site operations
- They want to have effective ***private*** communication between their sites
- They do not want to build their own wide-area networks
- VPNs are **private networks constructed within a public network infrastructure**

  Ferguson and Huston, 1998

Building VPNs

- These can be built from Permanent Virtual Circuits
  - X25 or Frame Relay
- or Permanent Virtual Path Connections
  - ATM
- or from Tunnels
  - using Generic Routing Encapsulation
- Growth area in networking.
  - See http://www.employees.org/~ferguson/vpn.pdf