Overview
B-ISDN, ATM and SONET

- What is STM and ATM?
- Why Do We Need ATM?
- Characteristics of ATM
- How Does ATM Work?
- ATM/BISDN Reference Model and Protocols
- SONET
- B-ISDN Switch Architectures

Synchronous Transfer Mode
(Same as TDM)

- Synchronous Transfer Mode (SDM)
  - Fixed rates
  - Lacks flexibility
  - Example
    - Application characteristic
      - Min. rate = 1kbps
      - Max. rate = 70 kb/s
      - Call duration = 100-1000 sec
      - Burstyness = .1

B-ISDN

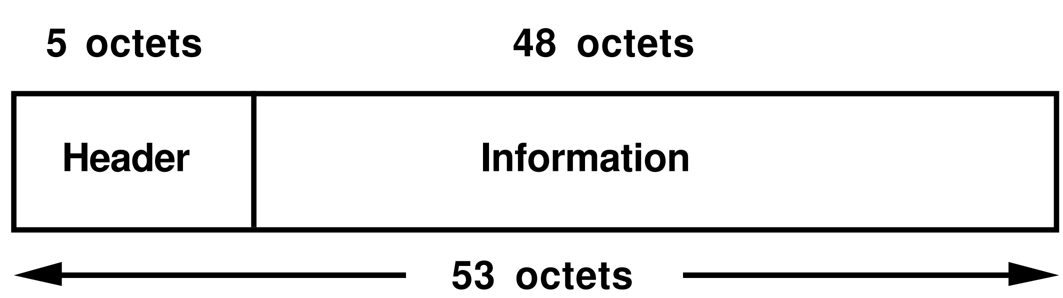
- Transfer Mode
  - Asynchronous Transfer Mode (ATM)
- Transport technology
  - Synchronous Optical Network (SONET)

ATM

- ATM is a high-speed, low-delay switching technology using short, fixed-size packets called cells
- It combines the benefits of both circuit switching (low and constant delay, guaranteed capacity) and packet switching (flexibility, efficiency for bursty traffic) by using the cell switching technique to support the transmission of multimedia traffic such as voice, video, image, and data

ATM

- Key Attributes
  - Fixed length frames
  - Virtual circuit operation
  - Support dynamic bandwidth allocation
  - Same technology for ATM LANs and WANs
  - High Capacity (Gb/s)
  - Scalability
  - Dedicated bandwidth
  - Suitable for voice, data and video
- ATM cell format:

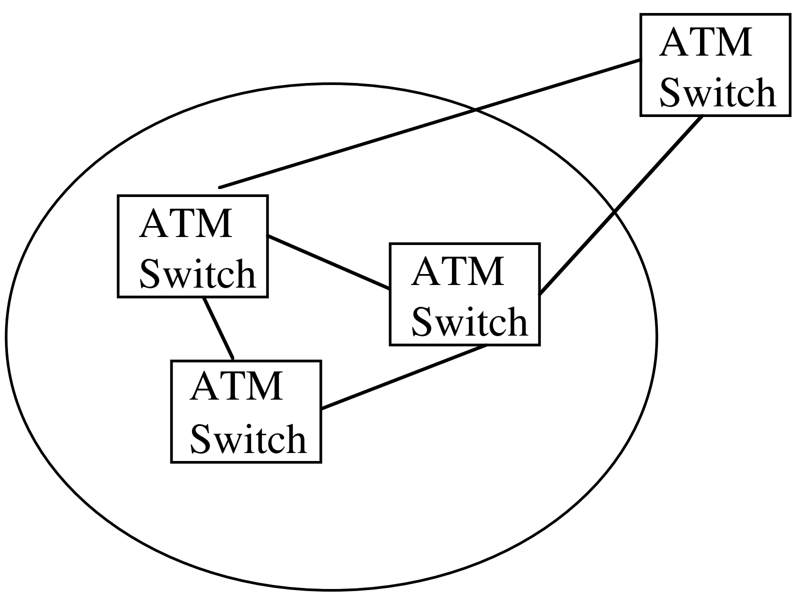


ATM

- Bandwidth on Demand

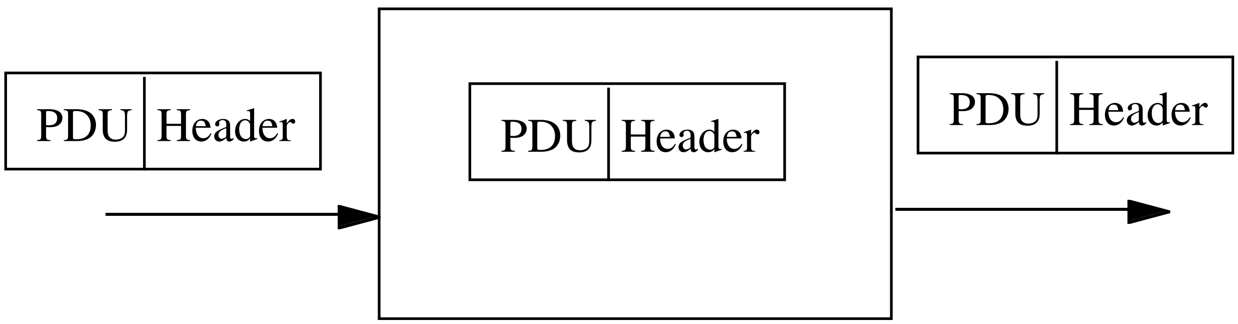
Payload	VC=1	Payload	VC=1	Payload	VC=2

- Scalable Networking
  - Add capacity by adding ATM switches

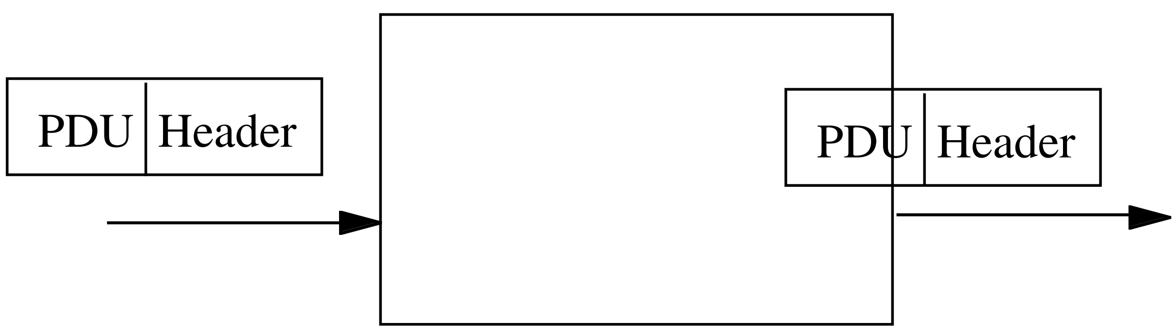


ATM

Store & Forward Switching



Cut-Through Switching



Segmenting large PUDs into ATM cells and using cell switching provides *cut-through* like performance.

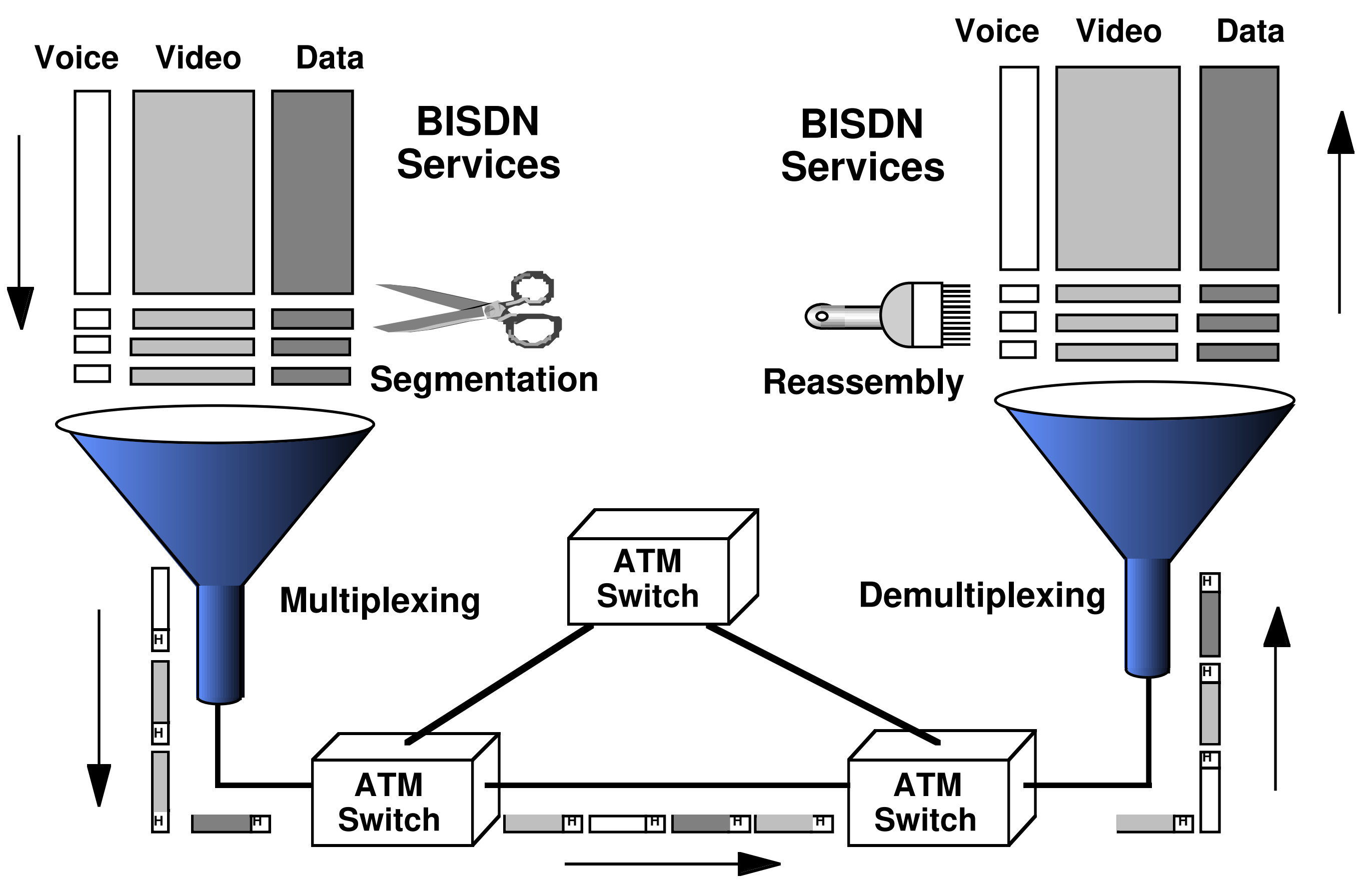
Why ATM

- Ever-faster desktop workstations
- Increased demand for multimedia transmission
- Client/server and distributed computing applications
- High bandwidth network for distributed CAD/CAM systems and medical imaging (telemedicine) applications
- High-speed, low-delay networks for real-time computing and command and control environments
- High-speed network to interconnect LANs over wide area
- High-speed, high-capacity LANs and/or backbone networks
- Performance limitations of existing networks

How Does ATM Work? (1 of 2)

- All traffic, whether voice, video, image, or data, is divided into 53-octet cells and routed in sequence across the ATM network
- Routing information is carried in the header of each cell
- Routing decisions and switching are performed by hardware in the ATM switches
- ATM is connection-oriented -- an end-to-end connection must be established and routing tables set up prior to cell transmission
- Cells are reassembled into voice, video, image, or data at the destination

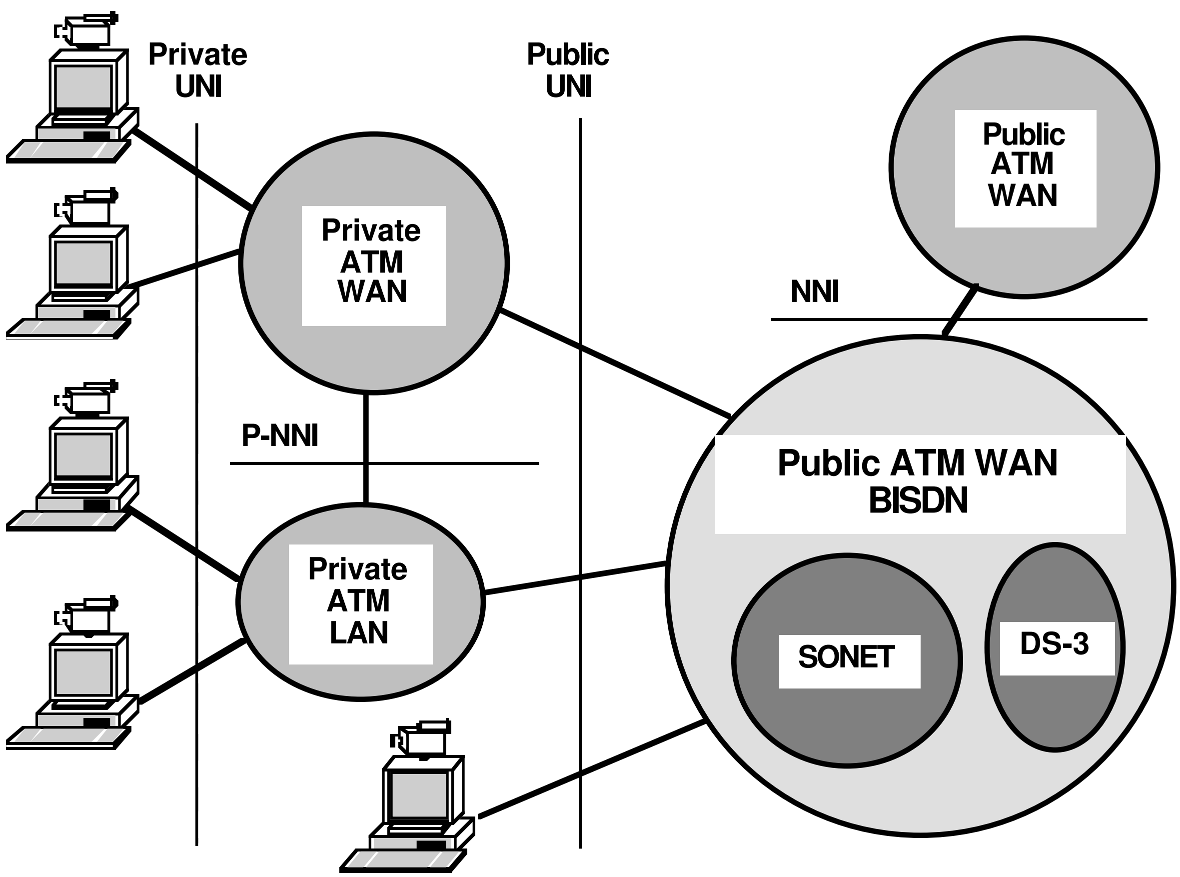
How Does ATM Work? (2 of 2)



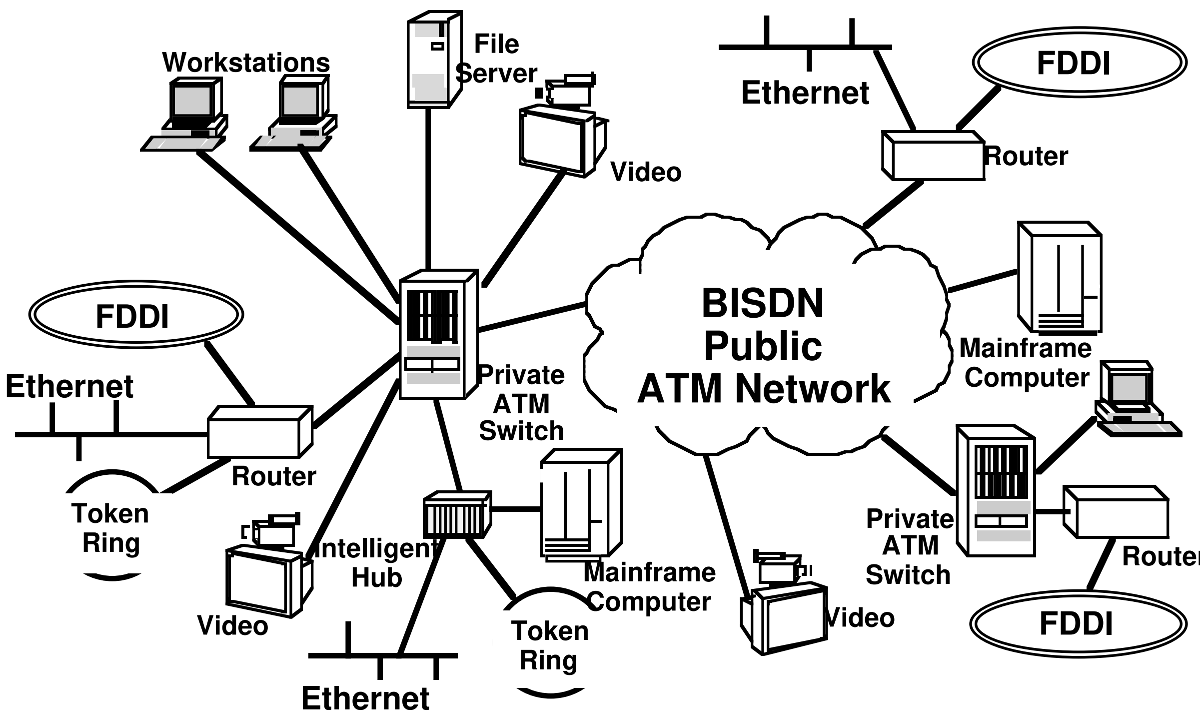
ATM Network Architecture (1 of 2)

- Public ATM Network:
  - Provided by public telecommunications carriers (e.g., AT&T, MCI, Sprint)
  - Interconnects private ATM networks
  - Interconnects remote non-ATM LANs
  - Interconnects individual users
- Private ATM Network:
  - Owned by private organizations
  - Interconnects low-speed/shared medium LANs (e.g., Ethernet, Token Ring, FDDI) as a backbone network
  - Interconnects individual users as the front-end LAN for high-performance or multimedia applications

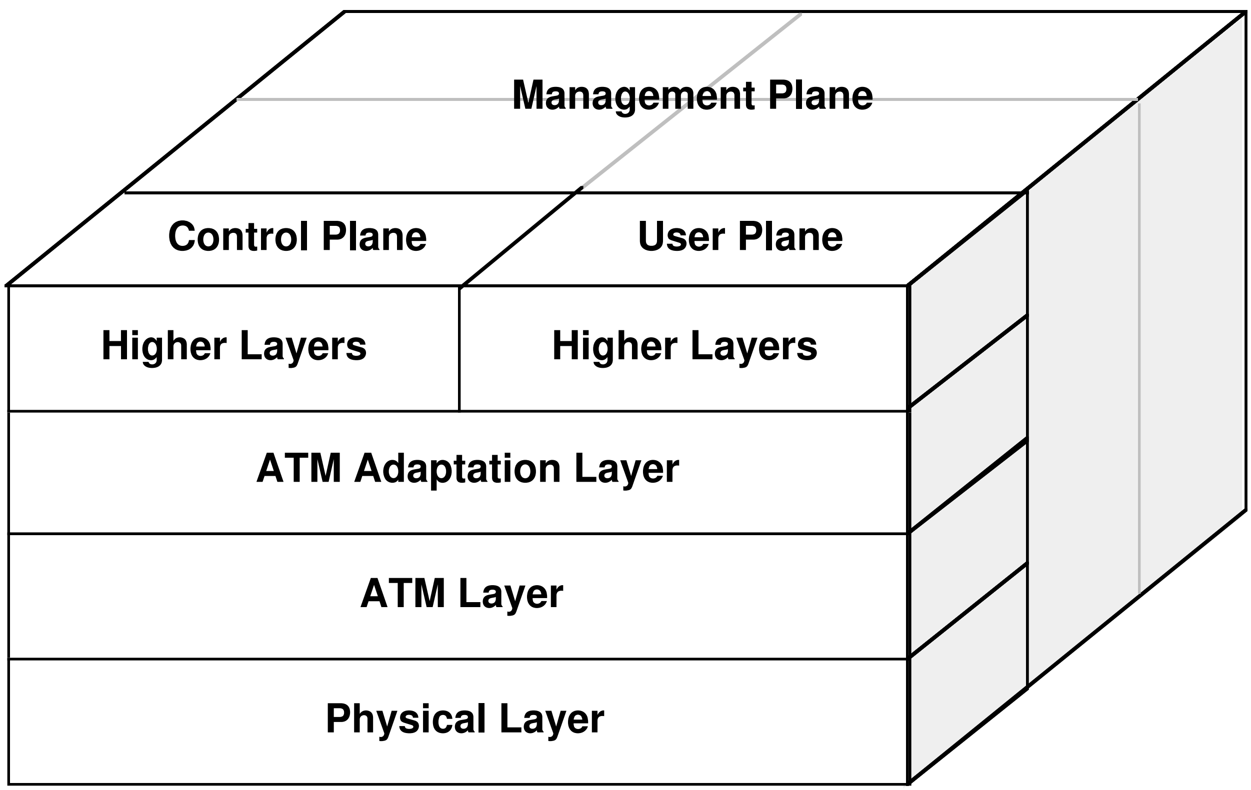
ATM Network Architecture (2 of 2)



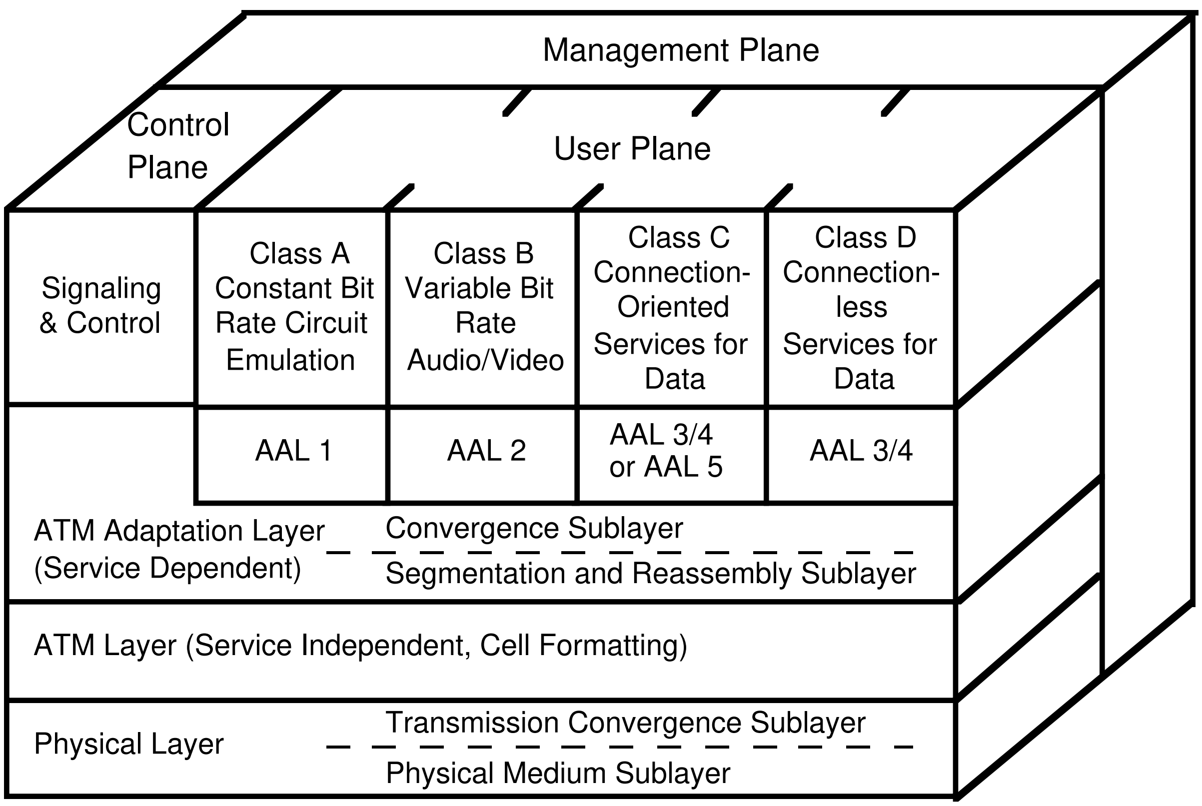
ATM and Legacy Networks



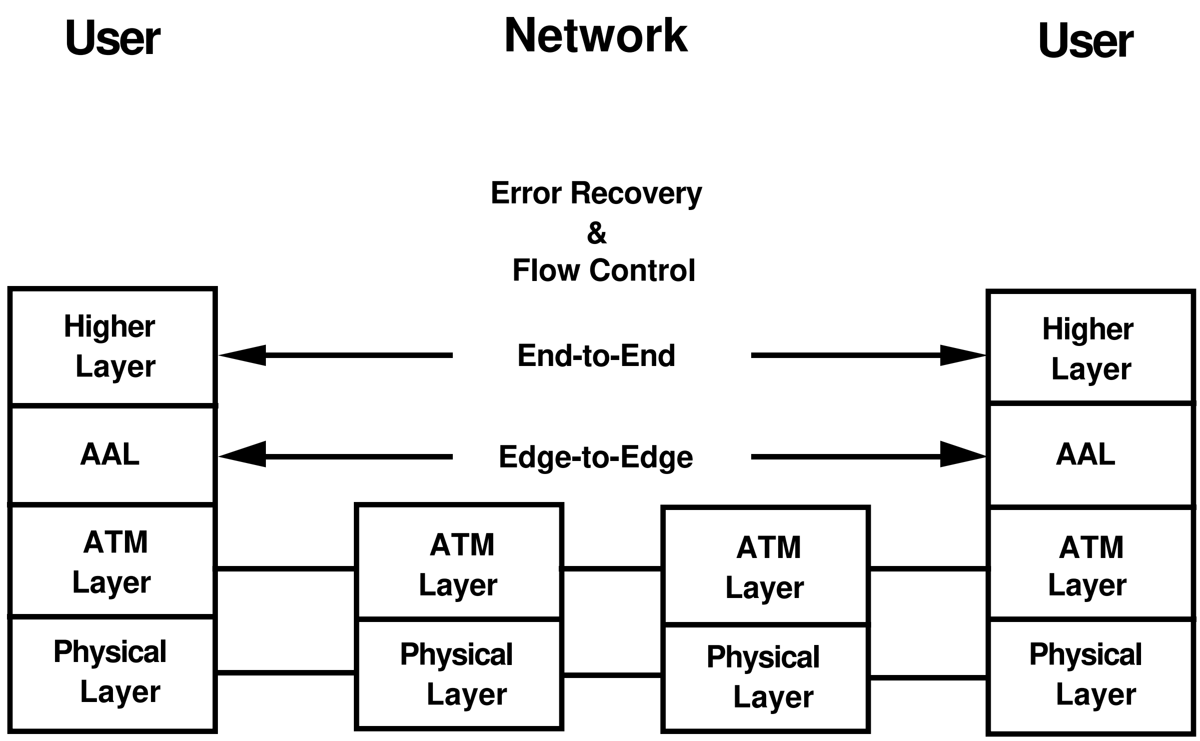
BISDN/ATM Protocol Reference Model (1 of 2)



BISDN/ATM Protocol Reference Model (2 of 2)



ATM Information Transport Protocol



Functions of the ATM Layers

Layer	Sublayer	Functions
Higher layers		High layer functions
ATM Adaptation Layer	Convergence Sublayer	Convergence
	Segmentation and Reassembly Sublayer	Segmentation and reassembly
ATM Layer		General flow control Cell Header generation/extraction Cell VPI/VCI translation Cell multiplexing
Physical Layer	Transmission Convergence Sublayer	Cell rate decoupling HEC sequence generation/verification Cell delineation Transmission frame adaptation Transmission frame generation/ recovery
	Physical Medium Sublayer	Bit timing Physical medium

ATM Physical Layer Media

- Media
  - Fiber
    - Single Mode
    - Multimode
  - UTP-3
  - UTP-5
  - Wireless

ATM Physical Layer Rates

- Two access rates defined by ITU-T (CCITT):
  - 155.52 Mbps SONET (OC-3)
  - 622.20 Mbps SONET (OC-12)
- Four interfaces specified by the ATM Forum:
  - 44.736 Mbps (DS-3) (public and private UNI)
  - 155.52 Mbps SONET (OC-3) single mode fiber (public and private UNI)
  - 100 Mbps multimode fiber (TAXI) (private UNI)
  - 155.52 Mbps multimode fiber OC-3 or STP (private UNI)
- Other interfaces to be specified:
  - 34.368 Mbps (E-3), 139.264 Mbps (E-4)
  - 51.84 Mbps (UTP-3), 25.92 Mbps (UTP-3)
  - 155 Mbps STS-3 format over UTP-5
  - Low speed for wireless

ATM Layer

Cell Header Structure

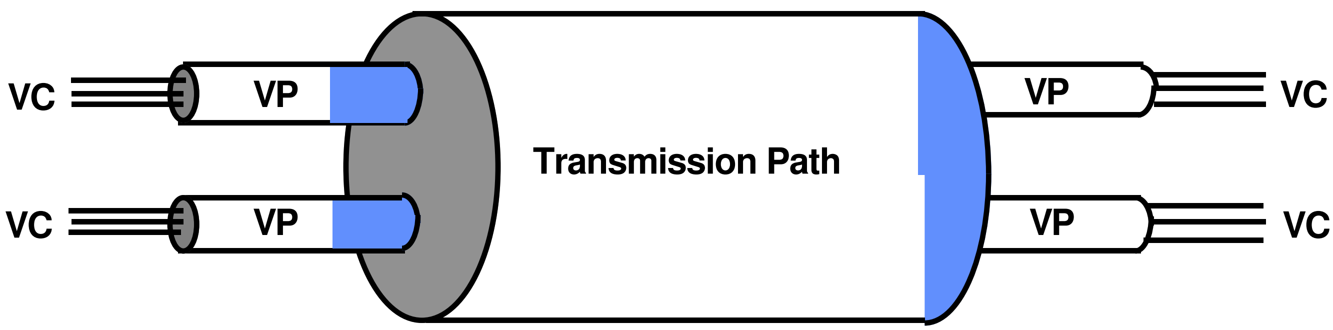
8	7	6	5	4	3	2	1
Generic Flow Control (GFC) *				Virtual Path Identifier (VPI)			
VPI				Virtual Channel Identifier (VCI)			
VCI							
VCI				Payload Type (PT)			CLP
Header Error Control (HEC)							

*** At the NNI the GFC field becomes part of the VPI field**

CLP: Cell Loss Priority

ATM Layer

- Virtual Paths/Virtual Circuits



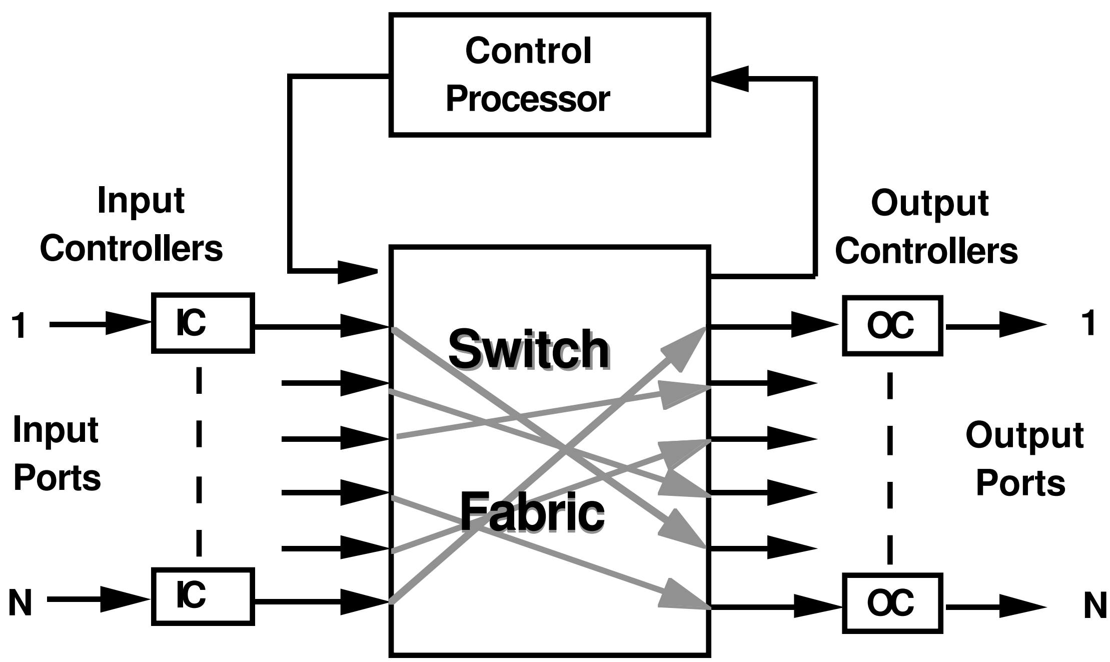
ATM Layer

Payload Type Indicator Encoding

PTI Coding	Interpretation
000	User data cell, congestion not experienced, SDU-type = 0
001	User data cell, congestion not experienced, SDU-type = 1
010	User data cell, congestion experienced, SDU-type = 0
011	User data cell, congestion experienced, SDU-type = 1
100	Segment OAM F5 flow-related cell
101	End-to-end OAM F5 flow-related cell
110	Reserved for future traffic control and resource man
111	Reserved for future functions

ATM Layer

ATM Switch Architecture



ATM Layer

- Management Information Flows

- The ATM Layer management information is carried via F4 - F5 OAM cells
- The OAM cell flow used for end-to-end management functions may be carried through the private ATM switch and made available to the users
- The F4 flow is used for segment (link between ATM nodes) or VP end-to-end management at the VP level using VCIs 3 and 4
- The F5 flow is used for segment (link between ATM nodes) or VC end-to-end management at the VC level using PTI code points 4 and 5

ATM Adaptation Layer

- AAL Services

Service	Class A	Class B	Class C	Class D
Timing Between Source and Destination	Related		Not Related	
Bit Rate	Constant	Variable		
Connection Mode	Connection Oriented			Connectionless
Examples of Services	Circuit Emulation Constant Bit Rate Video and Audio	Variable Bit Rate Video and Audio	Connection-Oriented Data Transfer	Connectionless Data Transfer
AAL TYPE	AAL 1	AAL 2	AAL 3/4 AAL 5	AAL 3/4

ATM Adaptation Layer

- Supports constant bit rate data with specific requirements for delay, delay jitter, and timing, e.g., PCM voice, CBR video, and emulation of T-carrier circuits
  (DS-1, DS-3)
- Receives constant bit rate stream with a well defined clock from source and delivers the same to the destination
- Provides for timing recovery (using SRTS), synchronization, and indication of lost information
- Convergence Sublayer: blocking/deblocking of AAL-SDUs, bit count integrity, generation/ recovery of timing information
- Segmentation and Reassembly Sublayer: transport and bit error detection of CS Protocol Control Information (PCI)
- AAL1 supports Class A (connection-oriented) traffic

ATM Adaptation Layer
AAL1

- Consists of 1 octet header (PCI) and 47 octets of payload
- Sequence Number (SN): A 1-bit Convergence Sublayer Indication and 3-bit sequence count to detect deletion or incorrect insertion of cells
- Sequence Number Protection (SNP): 3-bit CRC with even parity for detecting and correcting SN error

4 bits	4 bits	47 octets
SN	SNP	SAR-PDU Payload

ATM Adaptation Layer

AAL1

- Two CS PDU formats:
  - Non-P Format: no CS header (CS PCI), 47 octet user information for transfer of unstructured data such as DS1 or DS3
  - P Format: 1 octet header (Structure Pointer, SP), and 46-octet user information for transfer of octet-aligned

47 Octets AAL User Info.

CS-PDU Non-P Format

1-Octet SP	**46 Octets AAL User Info.**

CS-PDU P Format

ATM Adaptation Layer

AAL2

- Supports variable bit rate data where a strong timing relationship between source and destination is required, e.g., VBR audio and video
- Data passed to AAL2 from higher layers at the source at fixed intervals and must be passed to the destination at the same rate
- The amount of data passed to AAL2 may vary with each transfer
- AAL2 supports Class B (connection-oriented) traffic
- ITU-T (CCITT) standards for AAL2 yet to be defined

ATM Adaptation Layer

AAL3/4

- Supports variable bit rate data where there is no timing relationship between source and destination, e.g., X.25, frame relay, and TCP/IP data
- Supports Class C (connection-oriented) and Class D (connectionless) traffic
- Convergence Sublayer divided into two parts:
    - Common Part Convergence Sublayer (CPCS)
    - Service Specific Convergence Sublayer (SSCS)
- SSCS layer may provide assured or non-assured services, or may be null
    - Assured service provides retransmission of missing or corrupted SSCS-PDUs and flow control is mandatory
    - AAL-SDUs may be lost or corrupted for non-assured service and flow control is optional
- CPCS provides message mode or streaming mode services

ATM Adaptation Layer

AAL3/4 CPCS-PDU

4-octet header and 4-octet trailer

CPI Common Part Indicator
Btag Beginning Tag
BA Size Buffer Allocation Size
PAD Padding
AL Alignment
Etag End Tag
Length Length of CPCS-PDU Payload

1	1	2		0 - 3	1	1	2
CPI	Btag	BASize	CPCS-PDU Payload	PAD	AL	Etag	Length

ATM Adaptation Layer

AAL3/4 SAR-PDU

2-octet header, 44-octet payload, and 2-octet trailer

ST	**Segment Type**
SN	**Sequence Number**
MID	**Multiplexing Identifier**
LI	**Length Indication**
CRC-10	**CRC Code**

2 bits	4 bits	10 bits	352 bits	6 bits	10 bits
ST	SN	MID	SAR-PDU Payload	LI	CRC-10

ATM Adaptation Layer

AAL5

- AAL5 is a simple and efficient AAL (SEAL) to perform a subset of the functions of AAL3/4
- AAL5 is designed to support only message mode, non-assured operation
- The CPCS-PDU payload length can be up to 65,535 octets and must use PAD (0 to 47 octets) to align CPCS-PDU length to a multiple of 48 octets

	0 - 47	1	1	2	4
CPCS-PDU Payload	**PAD**	**CPCS UU**	**CPI**	**Length**	**CRC-32**

PAD	**Padding**
CPCS-UU	**CPCS User-to-User Indicator**
CP I	**Common Part Indicator**
Length	**CPCS-PDU Payload Length**
CRC-32	**Cyclic Redundancy Check**

ATM Adaptation Layer

AAL5

- The CPCS-PDU is divided into 48 octets SAR-PDUs
- Since CPCS-PDU is 48-octet aligned, there is no need for a length field in the SAR-PDU
- The AAL5 SAR-PDU is 48 octets of data with no overhead of SAR-PDU header or trailer
- The PTI field of the cell header identifies the beginning or end of the CPCS-PDU
  - PTI = 0X1: End-of-Message (EOM)
  - PTI = 0X0: Beginning-of-Message (B0M), or Continuation-of-Message (COM)

ATM Signaling

- Used for dynamically establishing, maintaining, and clearing ATM connections at the User-Network Interface
- Based on ITU-T (CCITT) Q.2931 protocol
- A specific VPCI/VCI value (VPCI = 0, VCI = 5) is used for the connection/call control signaling (out-of-band Signaling)
- Will support point-to-point and point-to-multipoint switched channel connections
- The user specifies the desired bandwidth and QoS to establish a connection
- Signaling AAL (SAAL) is AAL5
- The SAAL provides reliable delivery

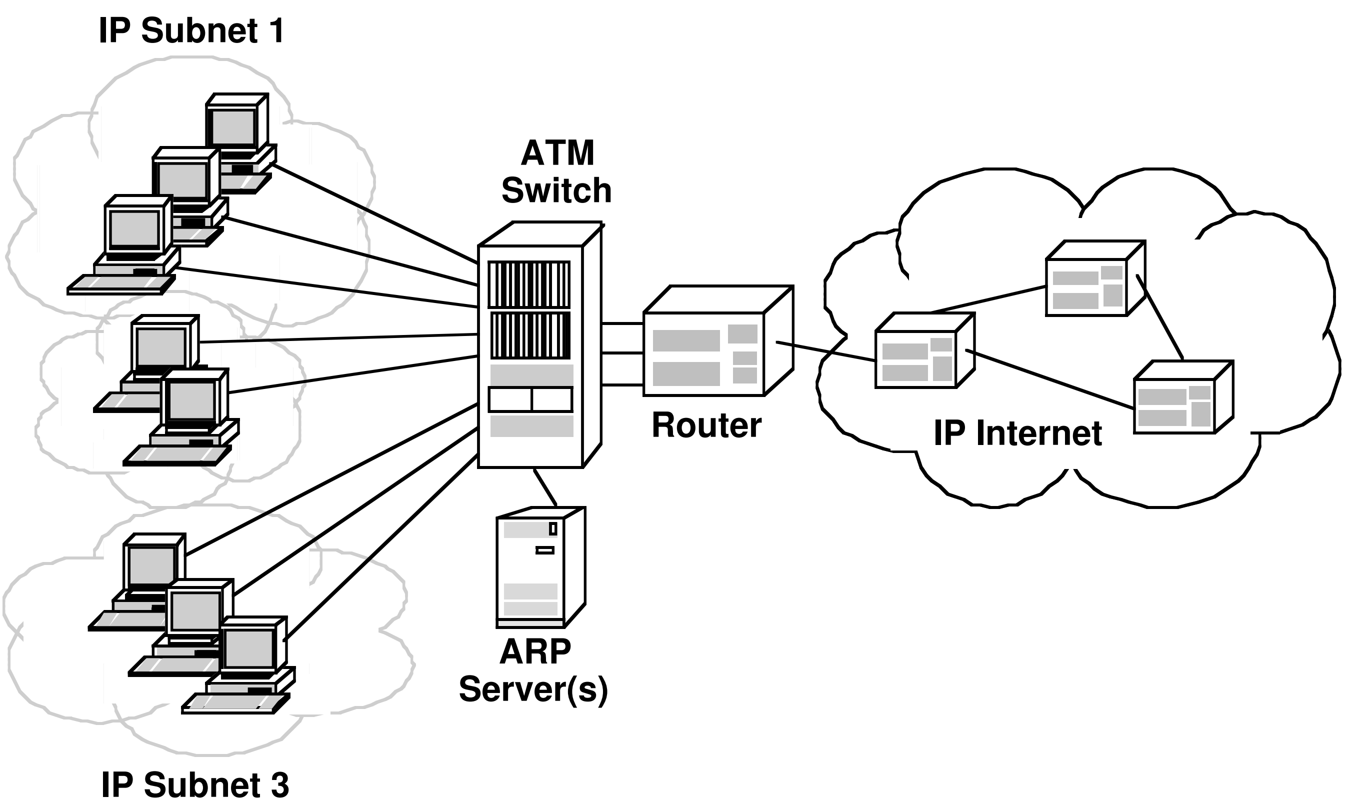
ATM Connection Establishment, Management, and Addressing

- Establish connection between public and private networks
- International connections
- Monitor call operation
- Orderly disconnect
- Reserved VPI/VCI for management and control ATM Switch
- Proprietary setup for most switches
- Standard Q.931 or Q.93B or Q.2931
- Addressing based on OSI Network Service Access Point (NSAP)

IP and ARP Over ATM

- RFC-1577 specifies IP and ARP over the ATM network
- The ATM network is configured as a Logical IP Subnetworks (LISs)
- The ATM network is used as a direct replacement for LANs and inter-router links
- All LIS members (hosts and routers) are directly connected to the ATM network
- All LIS members have the same IP network/ subnetwork number and address mask
- All LIS members use ATM protocols to communicate with each other
- All non-LIS members are accessed via an IP router
- ARP/InARP mechanisms

IP and ARP Over ATM



SONET

(Synchronous Optical Network)

- Open standard for optical transmission and interfaces
- It defines standard optical signals, a synchronous frame structure for multiplexed digital traffic, and operations procedures
- SONET (Synchronous Optical Network) is an interface specification developed by Bellcore in 1985 for optical transmission networks
- ITU-T (CCITT) also adopted a set of SONET interface standards
- By the end of the 1980s, ITU-T (CCITT) adopted SONET as one of the physical layer standards for BISDN
- Framing overhead not in the cell structure
- Transport overhead distributed throughout the frame
- Frame time = 125us

SONET

- Extensive management, performance monitoring, and fault detection
- Synchronous multiplexing
- Compatible with DS0, DS1, and DS3 transport mechanism as well as ATM
- Software control and access to DS0, DS1, and DS3, Add/Drop multiplexers
- Transport of future services

SONET
Layered Architecture

- Photonic Layer --> Light transfer
- Section Layer ----> Frame transport
- Line Layer --------> Multiplexing
- Path Layer --------> Map services into synchronous payload

SONET

- SONET Rates

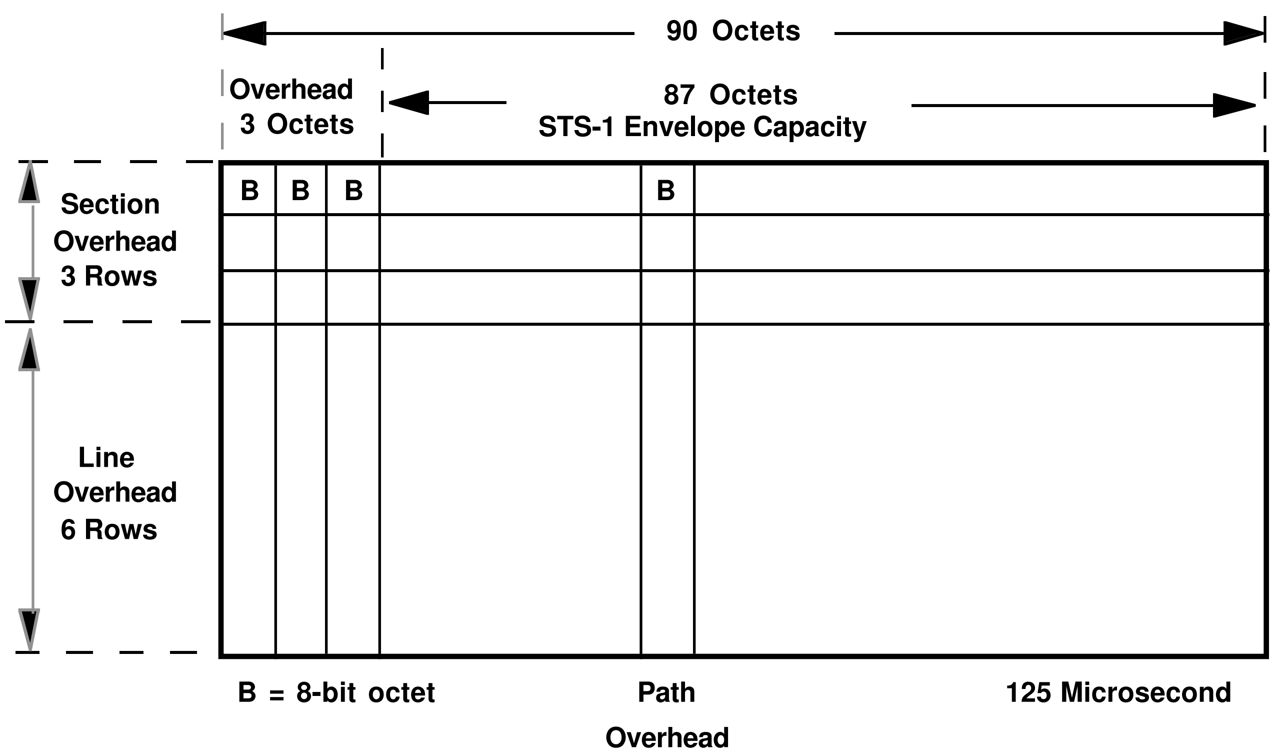
Line Rate (Mbps)	CCITT Designation	ANSI Designation	Optical Level
51.84		STS-1	OC-1
155.52	STM-1	STS-3	OC-3
466.56	STM-3	STS-9	OC-9
622.08	STM-4	STS-12	OC-12
933.12	STM-6	STS-18	OC-18
1244.16	STM-8	STS-24	OC-24
1866.24	STM-12	STS-36	OC-36
2488.32	STM-16	STS-48	OC-48

SONET

- STS ==> Synchronous Transport Signal (Electrical)
- OC ==> Optical Transport Signal (Optical)
- OC- # c ==> Concatenated

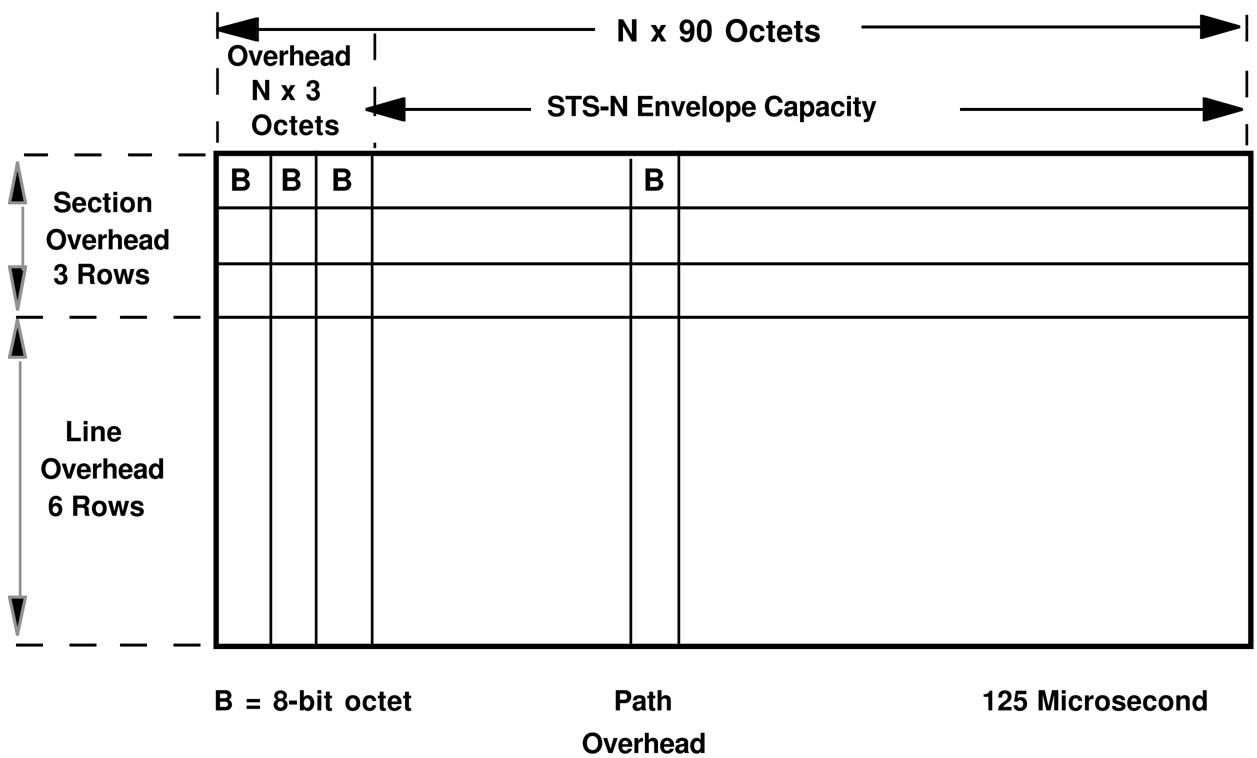
SONET

- Frame Structure (STS-1/OC-1)
  - 9 Bytes Section
  - 18 Bytes Line
  - 9 Bytes Path
  - 774 Bytes Payload



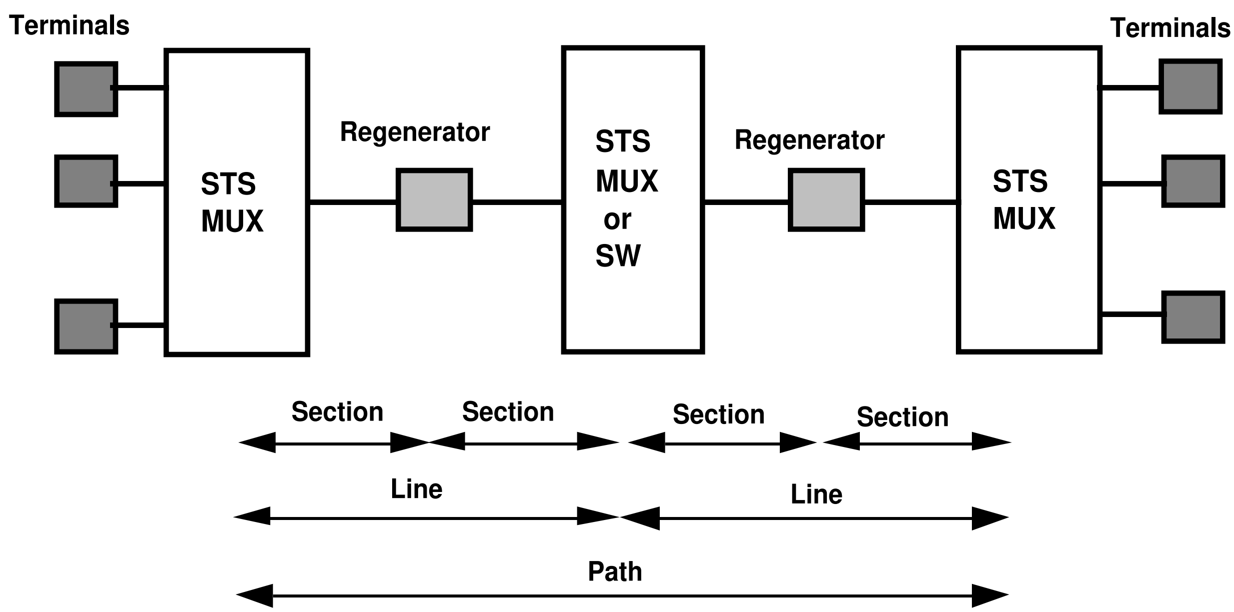
SONET

- Frame Structure (STS-N/OC-N)



SONET

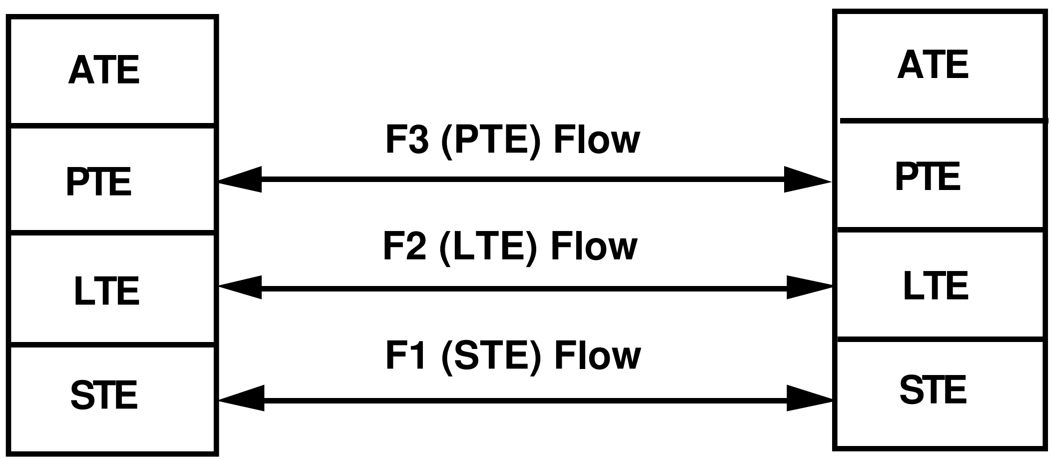
Physical Hierarchy



- Section: Basic building block, a single run of optical cable between transmitter/ receiver
- Line: Sequence of sections connected by repeaters; line end points are muxes or switches
- Path: Sequence of lines connecting the end terminals

SONET

Operation, Administration, and Maintenance (OAM)



ATE: ATM Terminating Equipment
PTE: SONET Path Terminating Equipment
LTE: SONET Line Terminating Equipment
STE: SONET Section Terminating Equipment

Switch Architectures for B-ISDN
Fast Packet Technology

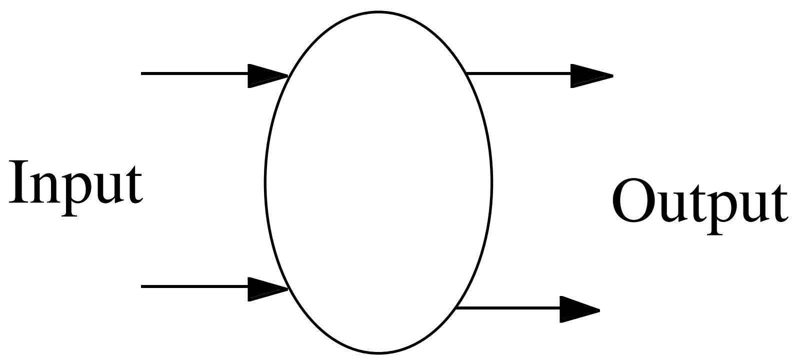
- Requirements
  - Support bursty traffic
  - Support wide variety of QoS specifications
  - Support very high speeds
- Constraints
  - Time
    - Real-time (voice/video)
    - Near-real-time (human/machine interaction)
    - No time constraint (e-mail/ftp)
  - Space
    - Conferencing (Multicast)
    - Geographic transparancy

Evolution of Packet Switches

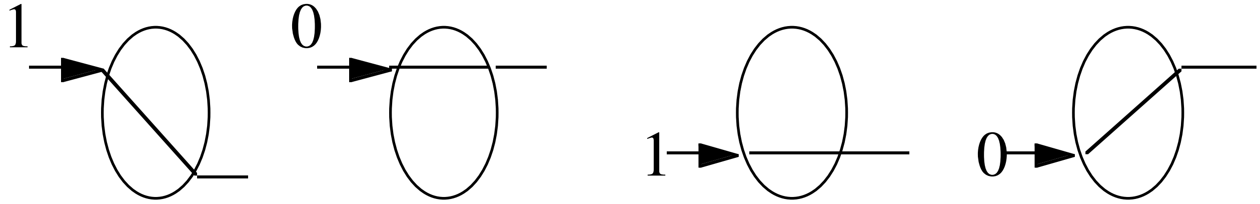
- General purpose computers
- Special purpose processors
- Custom hardware
  - Crossbar swicthes
  - Self routing switches

Self Routing Switches

Basic Element

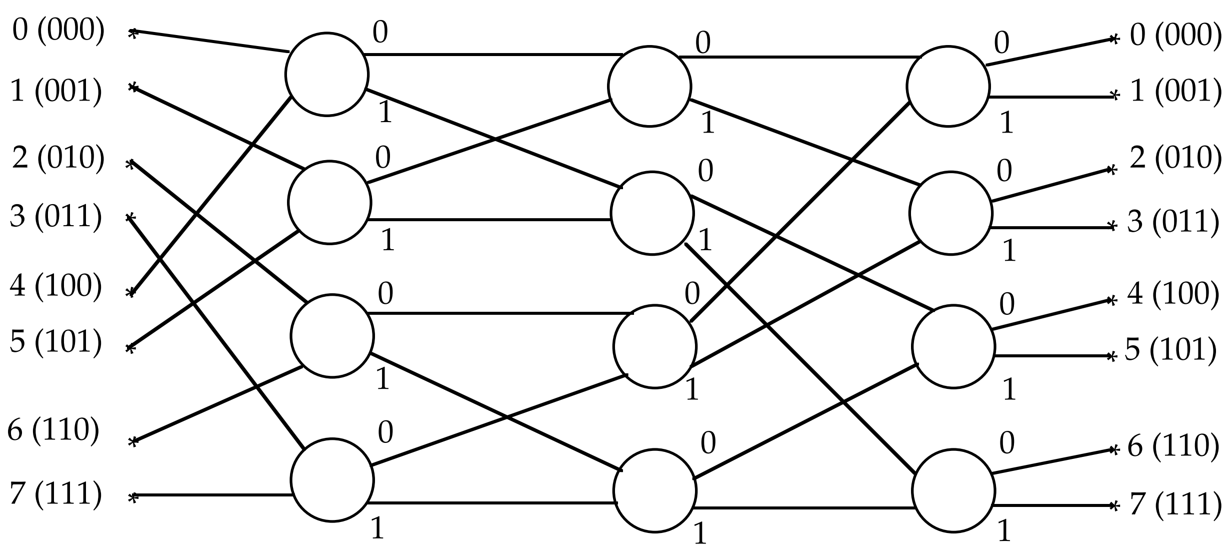


Each input packet contain routingbits.
The 2-by-2 switch routs based on a specific routing bit.



Self Routing Switches

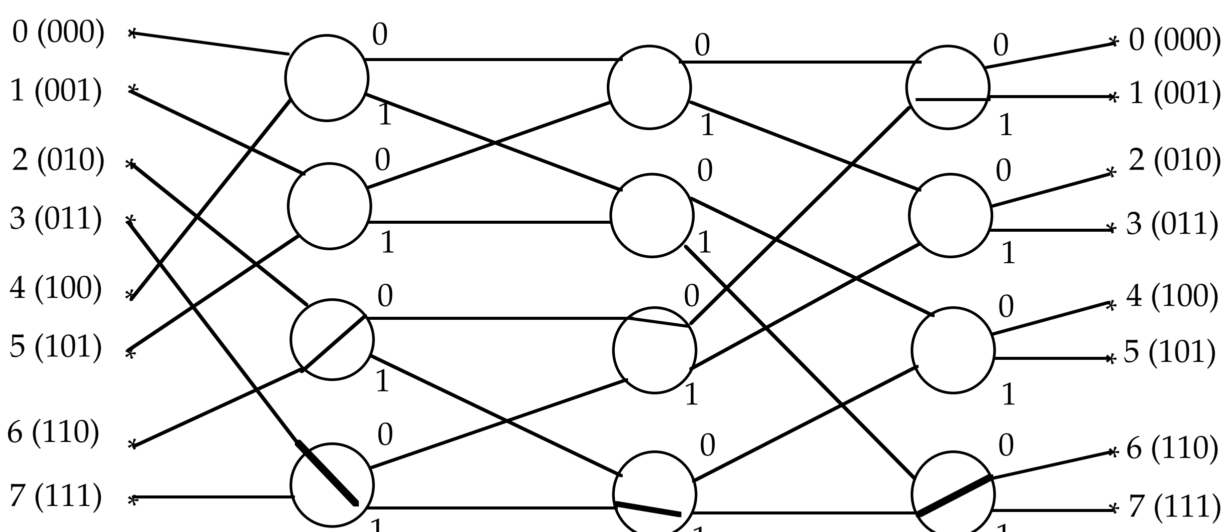
- Simplest network , i.e., fewest number of elentents, constructed from these elements is called a Banyan Network



Self Routing Switches

Example:

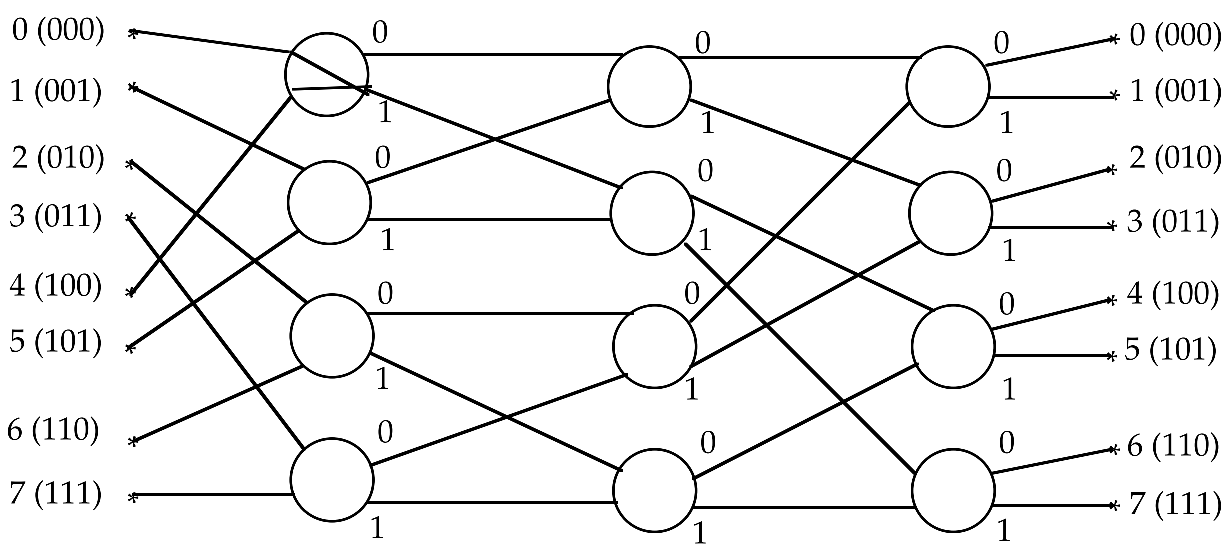
In-Port	Out-port
3	6
6	1



Self Routing Switches

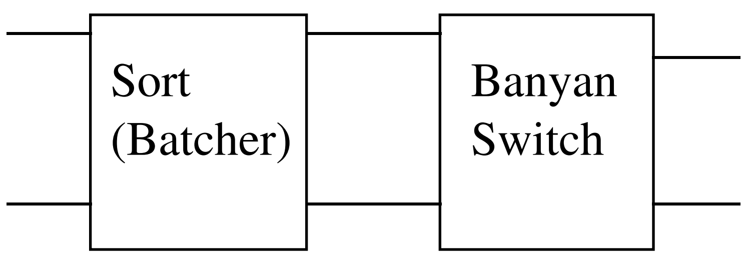
Example:

In-Port	Out-port	Collision in the first element
0	7	
4	6	



Self Routing Switches

- Avoid collisions
  - Buffers in the switch fabric
  - Higher speed switching
  - Sort the input elements



Example: Input to Sort stage by port 6, 5, 0, 7, 3
Input to Banyan by port 0, 3, 5, 6, 7

Without sort there will be blocking in Banyan Switch.
With the sort there will be no blocking