EECS, University of Ottawa

ELG5374 –Fall 2021

Computer Communication Network

Circuit & Packet Switching

Note: some material in the slides has been taken from various other sources

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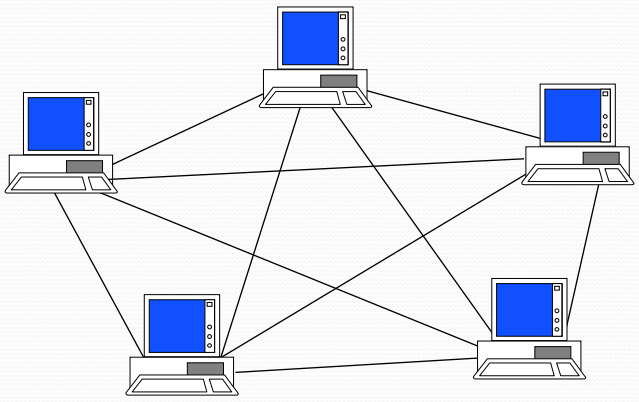
Computer Networks: Why?

Computing & communication devices need to exchange information

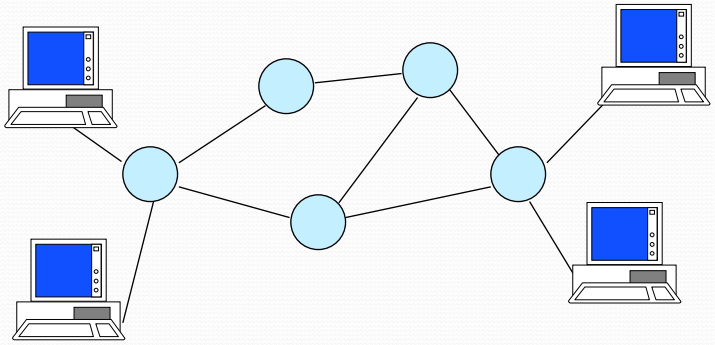


# of links required:
unidirectional links:
n (n-1)
bidirectional links:
n (n-1)/2
n: # of devices

2

Computer Networks

We need switching nodes.



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Switching Technologies

- Circuit Switching
- Packet Switching
  - Datagram
  - Virtual Circuit

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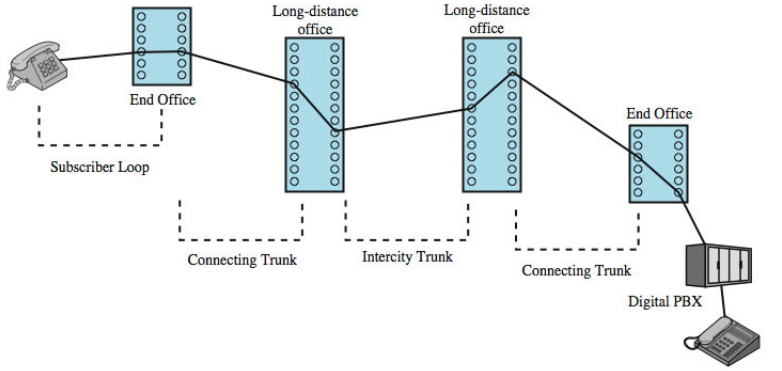
Circuit Switching Network

Example: Public Service Telephone Network (PSTN)



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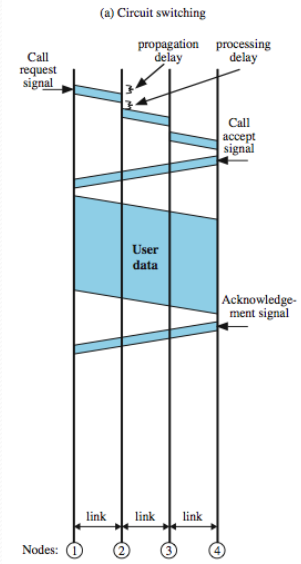
Event Timing for Circuit Switching



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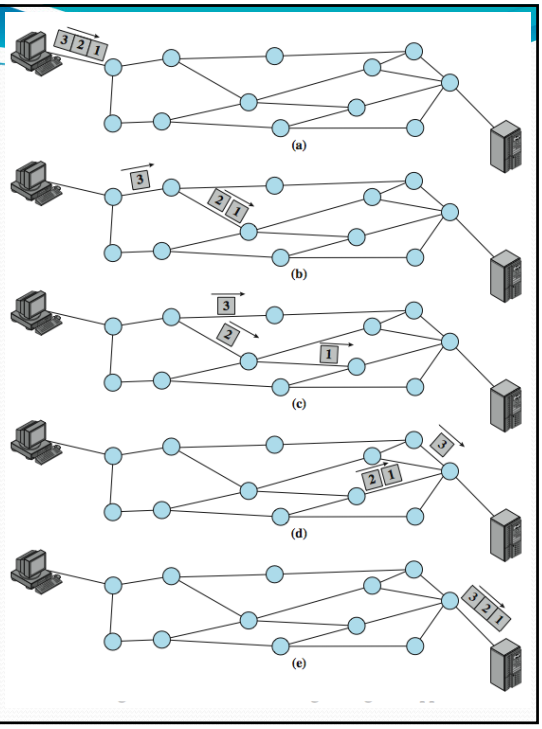
Datagram Packet Switching

- No path establishment
- Packets can follow different paths



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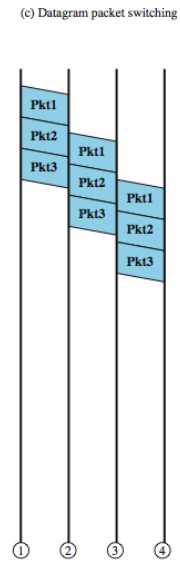
Event Timing for Datagram



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Circuit Switching

- Uses a dedicated path between two stations
- Process consists of three phases
  - establish
  - transfer
  - disconnect
- Bandwidth inefficient
  - channel capacity dedicated for duration of connection
  - if no data, capacity wasted
- Set up (connection) takes time
- Once connected, transfer is transparent
- Can provide deterministic performance guarantees

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Packet Switching

- Source breaks long message into "information transporting segments" (packets).
- Packets are sent one at a time to the network.
- Packets contain user data and control/signaling information.
  - user data may be part of a larger message
  - control information includes routing/addressing information
- Packets are received, stored "briefly" (buffered) and are passed onto the next node.

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Characteristics

- Line efficiency
  - single link shared by many packets over time
  - packets queued and transmitted as fast as possible
- Data rate conversion
  - stations connect to local nodes at their own speed
  - nodes buffer data if required to equalize rates
- Packets are accepted even when the "line" is busy
- Priorities can be used to support users' needs, instead of dedicating resources regardless if they are used or not (becoming wasted if they are not)

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Virtual Circuits versus Datagram

- Virtual circuits
  - network can provide sequencing
  - traffic engineering can be applied, enabling more practical provision of quality of service (QoS) support
  - less reliable in cases of switching node failures
- Datagram
  - no call setup phase
  - more flexible
  - more reliable in cases of switching node failures
  - difficult to control network's state and provide quality of service (QoS)

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Circuit versus Packet Switching: Comparison

- **Circuit Switching**
  - Dedicated channels/resources
  - Constant delay
  - Blocking
  - Continuous flow
  - Point-to-Point
- **Packet Switching**
  - Shared channels
  - Variable delay
  - Store-and-forward point-to-point & multipoint

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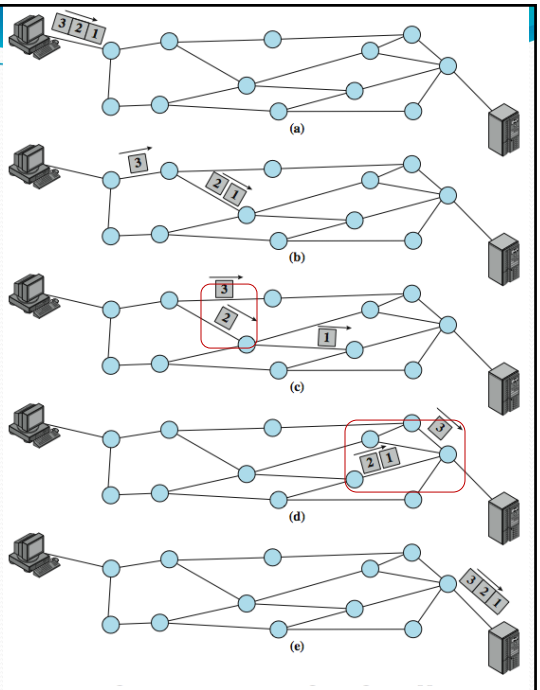
Datagram Diagram

➢No path establishment
➢Packets can follow different paths
➢**Packets may arrive out of order**



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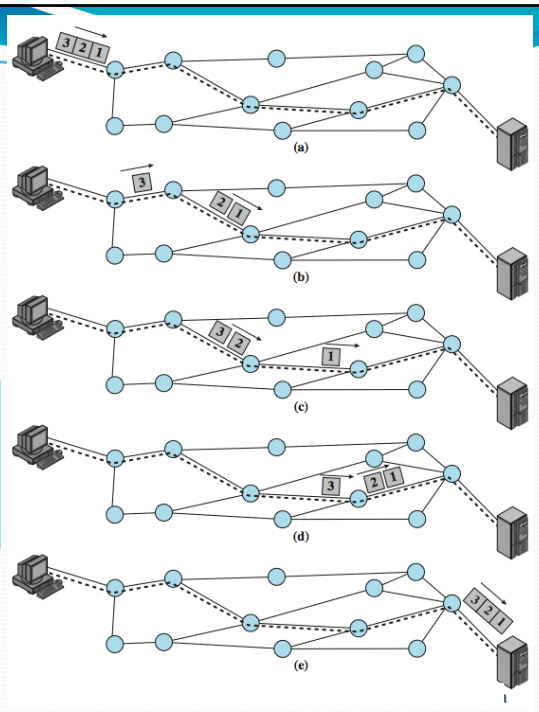
Virtual Circuit Packet Switching

- Path establishment is required
- All packets follow the path
- All packets arrive in order



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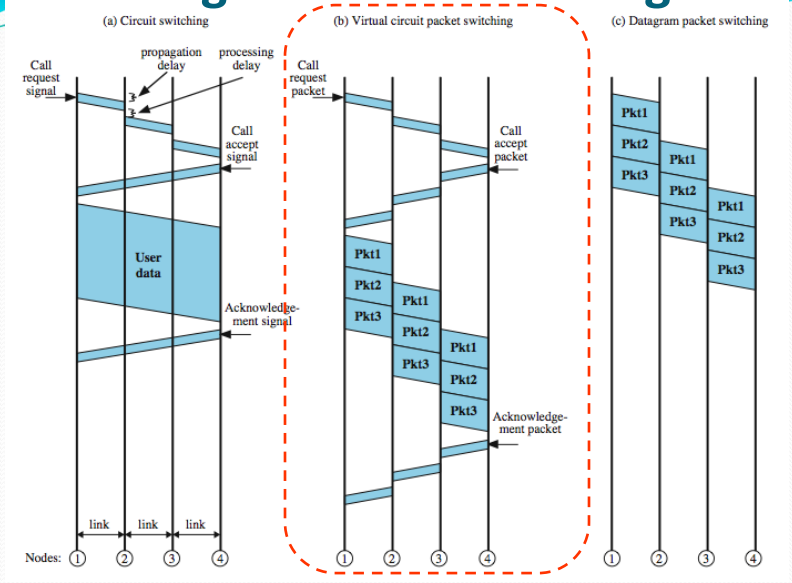
Event Timing for the 3 switching methods



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Virtual Packet Switching Networks

- Integrated Services Digital Network (ISDN)
- Narrowband ISDN: X25 & Frame Relay
- X-25:
  - ITU-T standard for interface between host and packet switched network.
  - almost universal on packet switched networks and packet switching in ISDN.
- Frame Relay
  - designed to eliminate most X.25 overhead, improves efficiency
  - requires high level of network reliability.
- Broadband ISDN: Asynchronous Transfer Mode (ATM)
  - based on the use of fixed size packets (53 bytes, called ATM cells).
  - first Broadband ISDN (B-ISDN) .
  - offered quality of service (QoS) choices.

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What is ATM?

- ATM was born out of B-ISDN in mid 1980s.
- It was a new multiplexing and switching technique.
- First broadband, QoS capable switching technology.
- It is based on fixed-length packets, called “cells”.
- Cell structure facilitated silicon implementation of switch fabric for fast packet switching.
- Supports high performance cell switching or “cell relay”.

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Why all the Interest in ATM?

- Need for world-wide standard to allow interoperability of information.
- Historically there were separate methods used to transmit information among the following users:
  - Local Area Networks
  - Wide Area Networks
- It was thought that ATM will provide a network for efficient traffic integration and a solution for application to both; LAN and WAN environments.
- ATM allowed to consolidate networks; instead of using separate networks for different applications (e.g. integrate voice, video, data).
- ATM can support communications at all speeds; from Megabits to Terabits.

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Basic Principles of ATM

- ATM is based on fixed length cells
  - information field
  - header used for addressing
  - cell sequence integrity is preserved
- ATM is connection oriented
  - Header values are assigned to each section of a connection.
  - Signaling and user information are carried on separate virtual channels.
- The information field is carried transparently through the network
  - no processing like error control is performed by the network.
  - ATM does not guarantee that cells arrive.
  - for efficient operation, a highly reliable physical layer is required (bit error rates in the order of 10^{-9} to 10^{-12}).
- All services (voice, video, even connectionless data) can be supported via ATM.
  - to accommodate various services, an adaptation function is provided.

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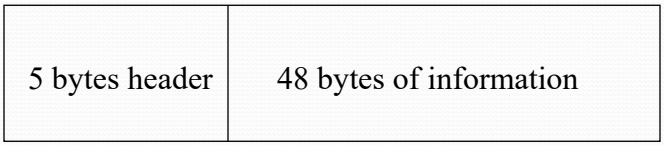
ATM Cell Format



- 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

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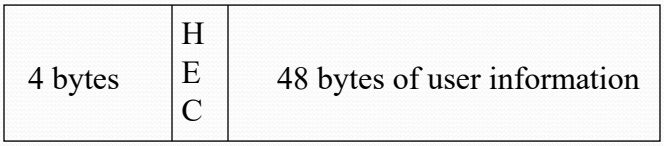
ATM Cell Header

- 5 bytes in length
- Contains a Header Error Check (HEC) to find cell boundaries
- Receiver locks on 5 bytes that satisfy the HEC algorithm (on first 4 bytes)



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ATM UNI Cell

UNI - User Network Interface

1	GFC	VPI	
2	VPI	VCI	
3	VCI		
4	VCI	PT	CLP
5	HEC		
6-53	User Information		

GFC - Generic Flow Control

VPI - Virtual Path Identifier

VCI - Virtual Channel Identifier

PT - Payload Type

CLP - Cell Loss Priority

HEC - Header Error Check

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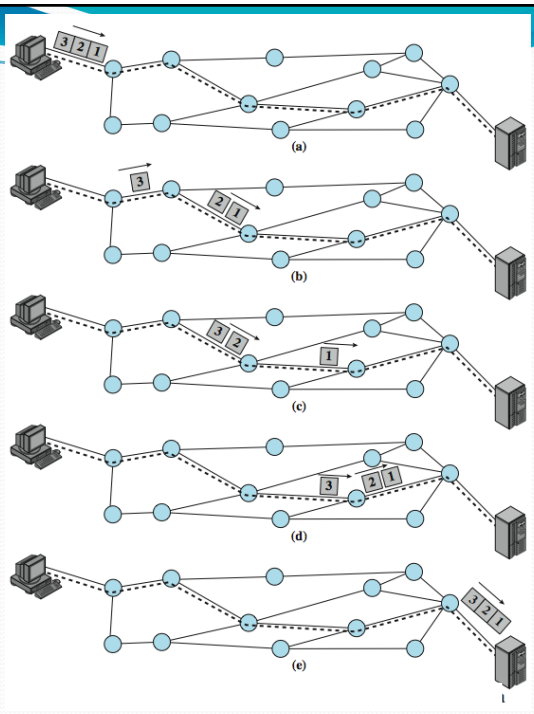
Virtual Circuit Packet Switching

- Path establishment is required
- All packets follow the path
- All packets arrive in order



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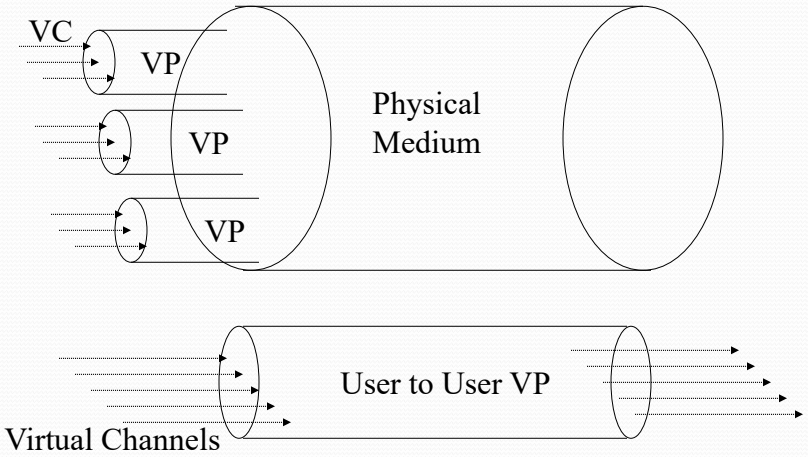
Virtual Path and Channel



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Virtual Connections

- VPI - Virtual Path Identifier
  - 8 bits ==> 256 paths (UNI)
  - 12 bits ==> 4096 paths (NNI)
- VCI - Virtual Path Identifier
  - 16 bits ==> 65,536 channels
- Each VPI holds a bundle of circuits.
- These are per physical medium, regardless of speed or bandwidth.

1-26

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Payload Type Identifier

- Used to identify the following cells:
- Network generated cells
  - used for maintenance & control of network
  - used for call set-up, loopbacks and keep alives
- Customer generated cells
  - user information

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Cell Loss Priority

- CLP in the header
  - CLP = 0: High priority, last likely to be discarded
  - CLP =1: Low priority, maybe discarded during congested intervals
- CLP can be set:
  - by the terminal
  - by the ATM switch
- CLP determines the class of service or service contract

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Virtual Connections

- Permanent Virtual Circuits (PVC)
  - network operator connects endpoints
- Switched Virtual Circuits (SVC)
  - can be switched like PSTN
  - Call set-up routine

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Service Categories (1)

- Quality of Service (QoS) are parameters that are set for end-to-end network performance
  - Cell Transfer Delay (CTD): delay between start & finish of cell
  - Peak to Peak Cell Delay Variation (CDV): difference between maximum CTD and minimum CTD
  - Cell Loss Ratio (CLR): % of cells lost
  - Sustained Cell Rate (SCR): average rate of transmitted cells
  - Bust Tolerance (BT): maximum burst size at PCR
  - Maximum Burst Size (MBS): maximum No. of cells sent at PCR
  - Minimum Cell Rate (MCR)

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Service Categories (2)

- ATM is divided into (5 + 1=) 6 service categories
  - Constant Bit Rate (CBR).
    - CTD & CDV are tightly constrained, low CLR
  - Real - Time Variable Bit Rate (rt - VBR)
    - CTD & CDV are tightly constrained
  - Non-Real - Time Variable Bit Rate (nrt - VBR)
    - CTV is tightly constrained
  - Available Bit Rate (ABR)
    - Minimize CTD, CDV and CLR
  - Unspecified Bit Rate (UBR)
    - No CTD, CVD or CLR constraints
  - Guaranteed Frame Rate (guarantees delivery of "x"% of frames to user)

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Available Bit Rate (ABR)

- It guarantees to the sources a minimum rate. It is based on adaptation of the source rate to use resources when available and reduce transmission rate when resource are scarce, in order to avoid congestion.
- Its primary use was to carry Internet traffic
- Two main categories
  - Rate Based Control
  - Credit Based Control

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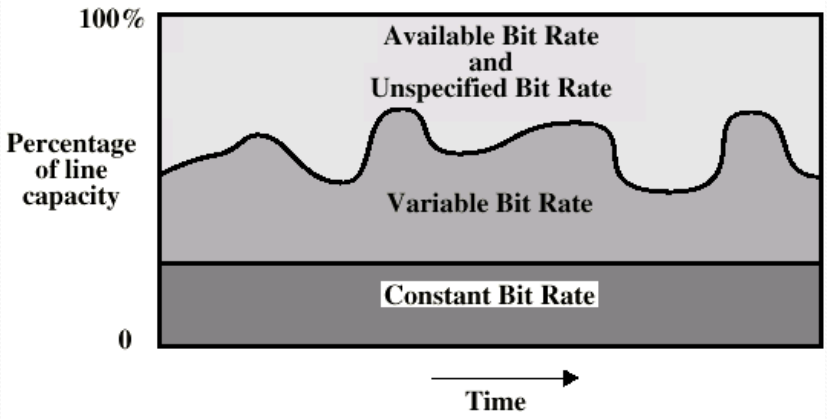
ATM Bit Rate Services



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Traffic Shaping(1)

- Traffic shaping is forcing your traffic to conform to certain specified behaviour
- Each service has a contract
- If the contract is violated, the network has the right to discard the cells
- The ATM switch monitors the traffic flow
- The shaping and policing is based on the Generic Cell Rate Algorithm (Leaky Bucket)

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Traffic Shaping(2)

- Traffic parameters
  - Mean Cell Rate (Sustained Rate)
  - Peak Cell Rate
  - Burst Frequency
  - Burst Length
  - Cell-loss Priority
  - Cell-loss Rate

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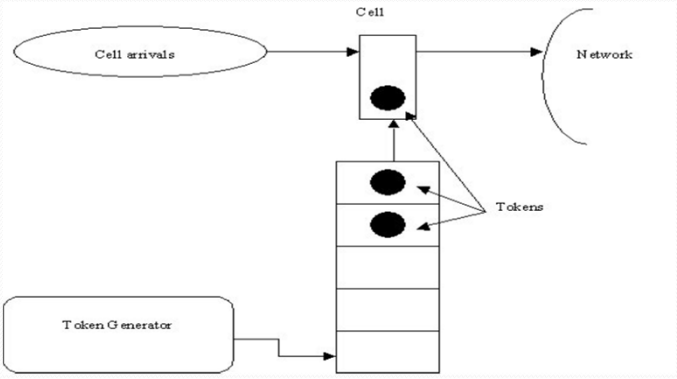
Leaky Bucket



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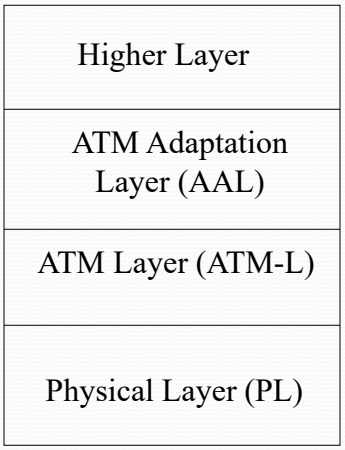
ATM Layers



AAL adapts from other protocols to ATM.

ATM-L is responsible for routing and switching the cells.

PL is responsible for sending and receiving bits on the medium.

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ATM Layers (2)

- ATM Layer
  - Generic Flow Control (applied to UNI to alleviate short term overload)
  - Cell header generation/extraction
  - Cell Virtual Path Identifier(VPI)/Virtual Circuit Identifier (VCI) translation
  - Cell multiplexing/demultiplexing.

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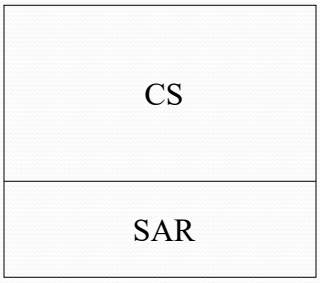
ATM Layers (3)

- ATM Adaptation Layer is subdivided into:
  - Segmentation And Reassembly (SAR)
  - Convergence Service Specific (CS)



CS - interfaces with the upper layer protocol information - provides padding and CRC checking.

SAR - generates the ATM payload.

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ATM Adaptation Layers

- Standardized ATM Adaptation Layers
  - AAL1 - provides connection oriented Constant Bit Rate services that have timing and delay requirements
  - AAL2 - provides connection oriented Variable Bit Rate services that have timing and delay requirements
  - AAL3/4 - provides connection-oriented Variable Bit Rate services with no timing requirements (e.g., frame relay)
  - AAL5 - provides connectionless Variable Bit Rate services with no timing requirements

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ATM Interfaces

- User to Network Interface (UNI)
  - specifies how cells come to a public network
- Broadband Inter-Carrier Interface (B-ICI)
  - specifies how two carriers interact their services
  - defines the traffic contract between two carriers
- ATM Data Exchange Interface (DXI)
  - protocol between router and CSU/DSU
- Network to Network Interface (NNI)
  - connection between switches

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END

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