Seminar on Current Issues and Technologies for the Internet

Part A: Early Scenario and ATM

By

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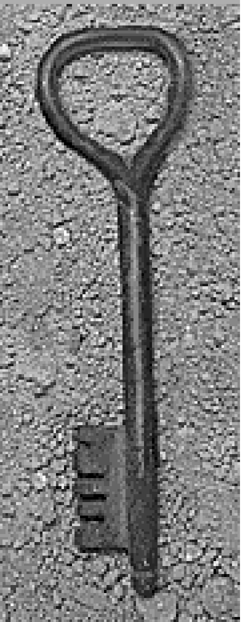
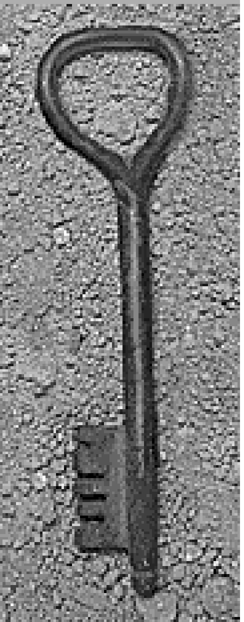


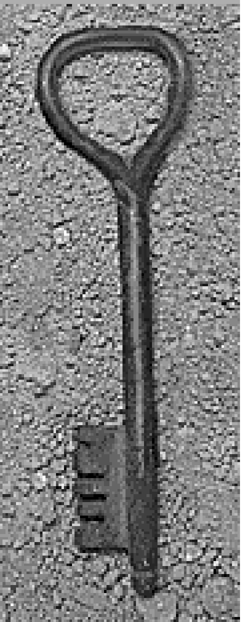
Overview of Presentation

- The Evolution of Internet
- The Types of Traffic on the Internet
- Performance Issues in Packet Switching
- The World Wide Web
- Changing Traffic on the Internet
- The **Birth** of **ATM!!**
- **ATM’s Service Classes and Layers**
- **ATM’s Demise(??)**



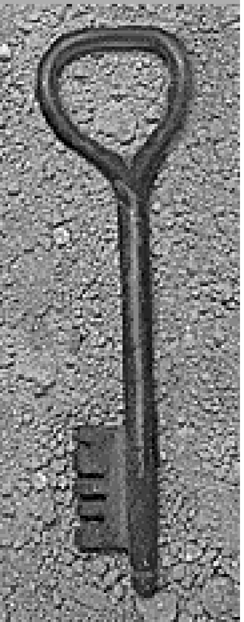
Seminar References

- Computer Networking: A Top Down Approach Featuring the Internet by Kurose and Ross, Addison Wesley 2001
- ATM With X-Cell, XYLAN Course 701, XYLAN Inc.
- Computer Networks: A Systems Approach Peterson and Davie, Morgan Kaufmann 2000
- Computer Networks Andrew Tanenbaum Prentice Hall 1996



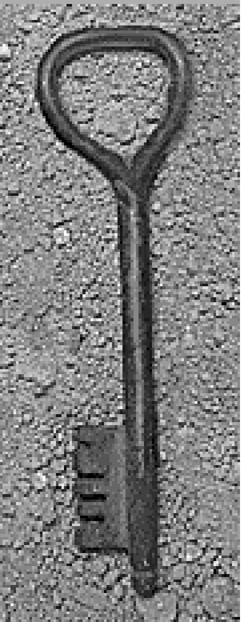
The Evolution of Internet

- DARPA (Defense Advanced Projects Research Agency) funded the development of the Internet. The first working network was ARPAnet that was started in 1969 between four nodes
- The emphasis was on developing a robust network that would continue to function even if its parts were wiped out by bombing
- Therefore, the datagram model was selected because datagrams take any open route



The Evolution of Internet

- The Internet was primarily used for connecting academic campuses together until the mid 80's
- Academicians used the Internet for sharing ideas and research results via email and ftp

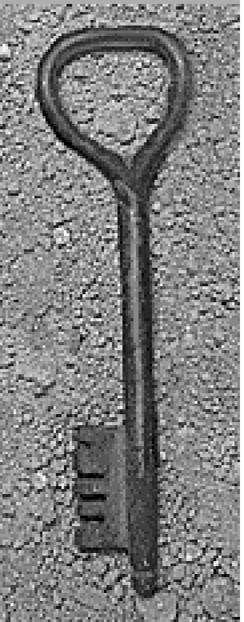


The Evolution of Internet

- Internet was primarily used for **email**, **usenet**, **file transfer** and **remote usage** of machines
- With email, users were able to keep in touch
- With usenet, users could discuss topics of interest in focussed newsgroups
- With file transfer, users downloaded and uploaded articles, programs and images
- With telnet, a user could login to his or her UNIX account from anywhere

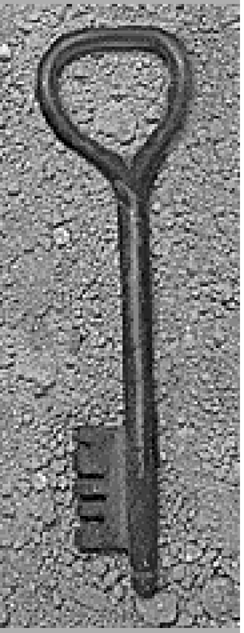
Types of Traffic on the Internet

- Email, usenet, ftp and telnet were applications that generated almost similar type of traffic stream on the Internet
- This traffic required “reliability”.
- The protocols were expected to deliver all the data no matter how long it took
- With high error rate, the elapsed time simply increased but the transmissions were completed

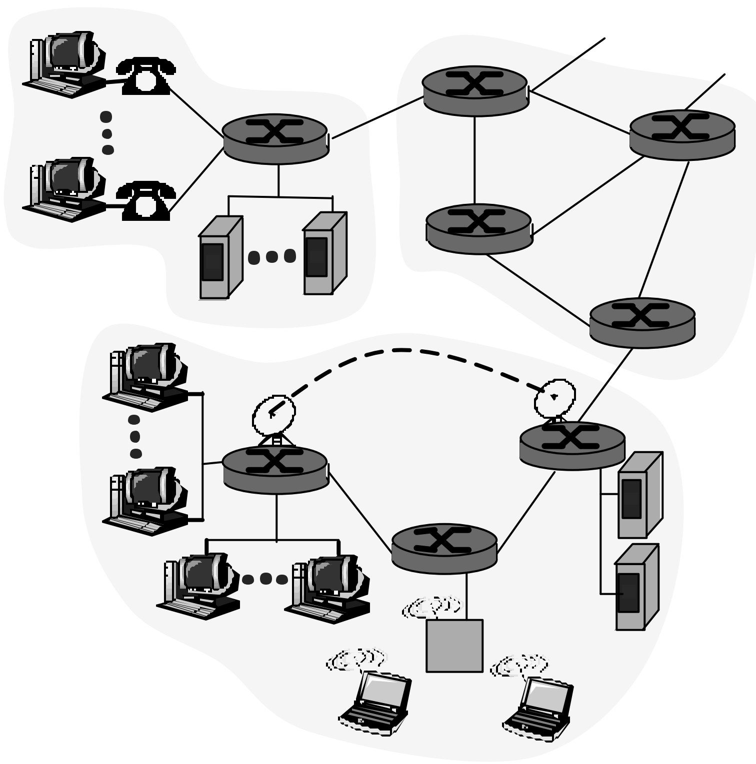


Performance Issues in Packet Switching

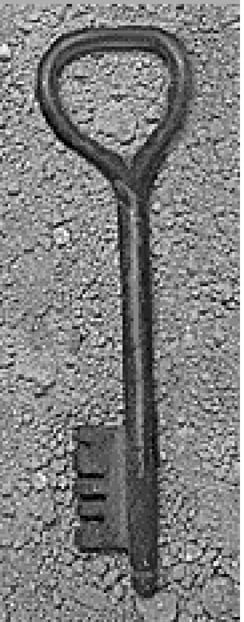
- For transmission on the Internet, the TCP/IP suite of protocols breaks the data into datagrams or packets and routes each packet through an independently selected path
- Packets may arrive at the destination out of sequence but due to buffering and re-ordering, the actual data can be recovered easily



Performance Issues in Packet Switching

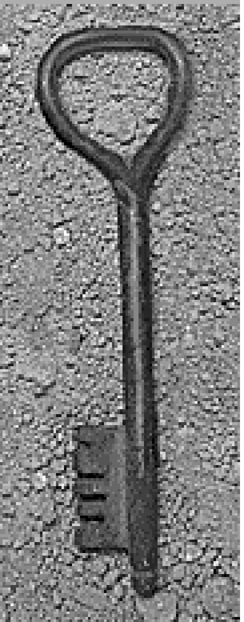


- Selecting a path is called routing and the intermediate nodes from source to destination are called routers
- Each router builds up a routing table to keep track of reachable destinations
- If more than one path is open to destination, the router may select the "best" path



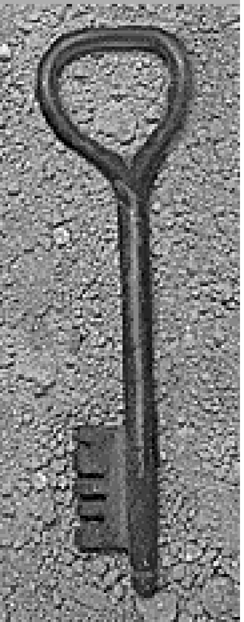
Performance Issues in Packet Switching

- Path selection criterion is usually shortest path first
- If the shortest path is congested or unreliable, the router can choose another path
- All routers decide independently and it is a distributed environment
- Traditional TCP/IP based traffic is bursty and it can increase or decrease abruptly



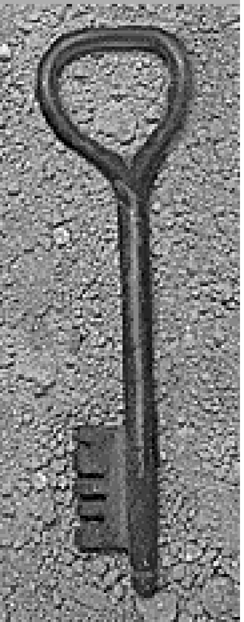
Performance Issues in Packet Switching

- Given this scenario, a router may find itself overwhelmed with a lot more packets than it can handle
- Routers have limited buffering space in which a queue of packets is managed
- Usually routers would use simple FIFO scheme to select the next packet to be transmitted



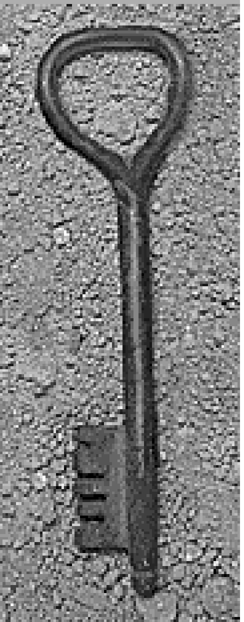
Performance Issues in Packet Switching

- If the queue is full, the newly arrived packets must be dropped (or discarded)
- Thus increase in traffic may increase time-outs, retransmissions and decrease in efficiency
- Usually, congestion in the network results in four types of penalties



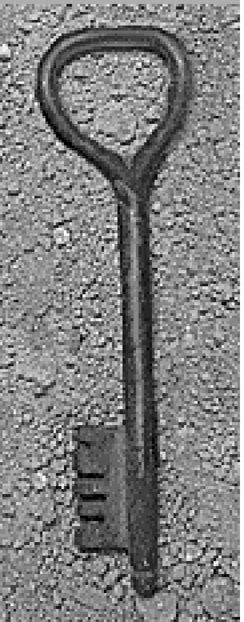
Penalties of Congestion

- Variable delays are introduced due to queuing at intermediate nodes
- The delays may be so excessive that the upper layer (TCP) may time out and a packet may be retransmitted. Thus the network carries two copies of a packet
- Packet loss causes additional delays
- If the last node before destination drops a packet, all the effort done by upstream routers gets wasted



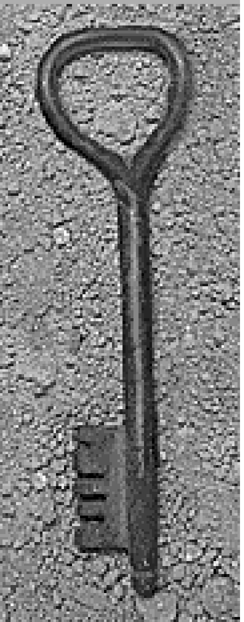
Reasons for Congestion

- Bursty users deliver bursty traffic
- No active resource allocation strategy
- Users can play around TCP congestion control by modifying its source code or opening multiple parallel TCP connections
- Using UDP, users can inject packets without any congestion control



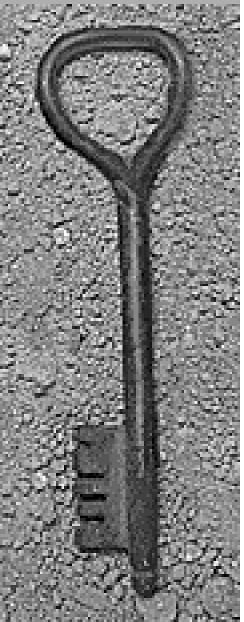
Performance Issues in Packet Switching

- The packet switching network makes its best effort to deliver the data however it makes no guarantees or promises to the user about the network performance
- Thus, traditional TCP/IP network based on packet switching is a “best effort” network



The World Wide Web

- Up around 1990, Internet had expanded a lot and it contained a lot of information on hosts spread around the globe
- Users had to use command-line tools to search and get the information
- Usenet, public ftp sites and some search tools were used to extract the information from the Internet

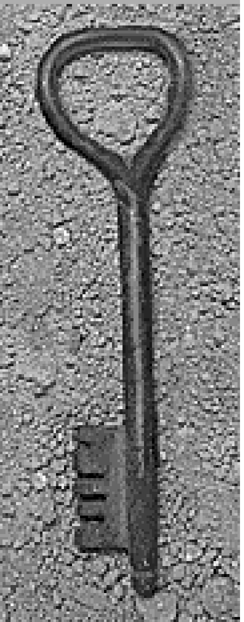


The World Wide Web

- Users had to work really hard in order to find the information they were looking for
- With the introduction of GUI desktop, the users were introduced to the convenience of click and launch for applications
- In a similar way, users were able to browse the help files and informative CD ROMS (such as encyclopaedias) easily with GUI

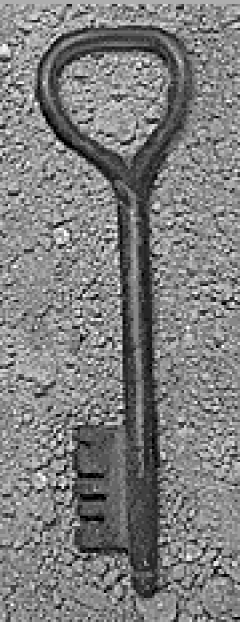
The World Wide Web

- The introduction of hypertext marking language (HTML) in early 1990 revolutionized the Internet
- HTML and its associated protocol HTTP have transformed the Internet into a user-oriented information repository
- HTML has also made it very easy to "publish" information online even for users with very little computer expertise



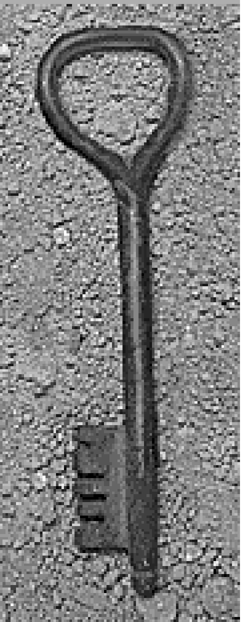
The World Wide Web

- The open ended HTTP has resulted in supporting the linking of various types of data into the web published documents
- HTTP makes it possible for web sites to offer binary files, images, and multimedia documents to the users with the click of a button
- HTTP has also resulted in making the Internet very popular. Internet continues to expand in number of websites and the number of users



The World Wide Web

- Web deployment is flexible and easy
- Due to the web technologies, the Internet has been put to use in almost all areas of human knowledge
- For example, water distribution monitoring, real-time traffic maps of big cities, free long distance calling, distance learning with lecture videos, buying and selling shares, online shopping etc., the list appears endless



The Changing Traffic on the Internet

- Due to the web enabled applications on the Internet, there has been a tremendous change in the types of traffic
- Now we have to deal with a significant amount of traffic that is time-sensitive
- For example, consider the case of an audio based application that needs to transmit the data across the Internet

The Changing Traffic on the Internet

Figure 6.20 An audio application.

The Changing Traffic on the Internet

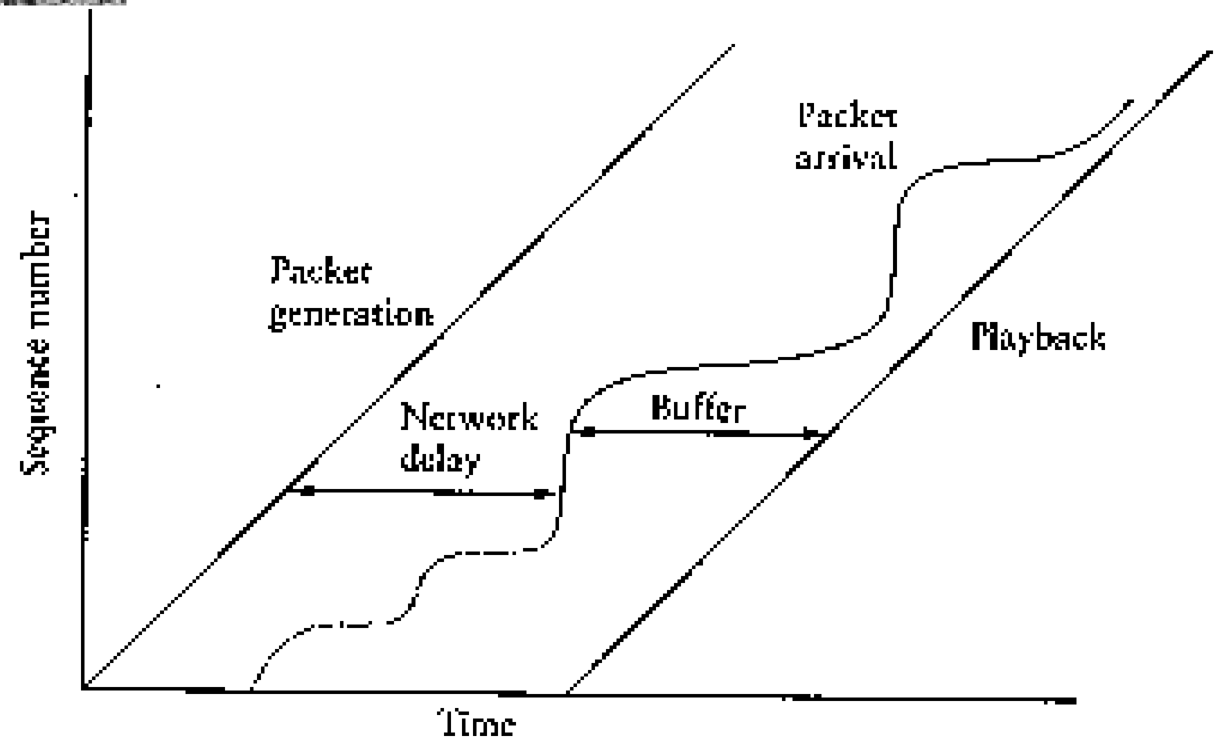
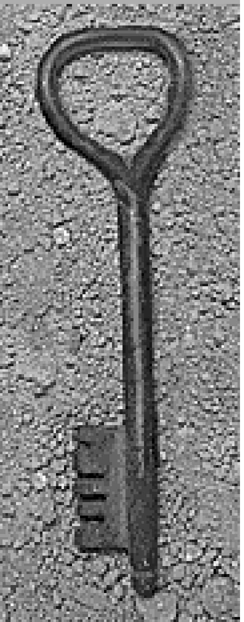
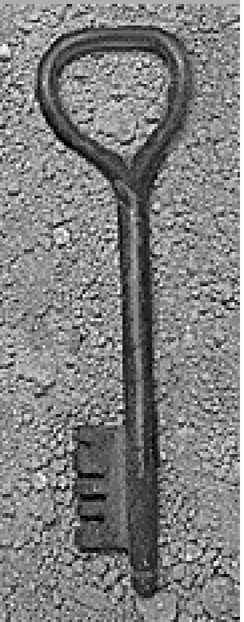


Figure 6.21 A playback buffer.



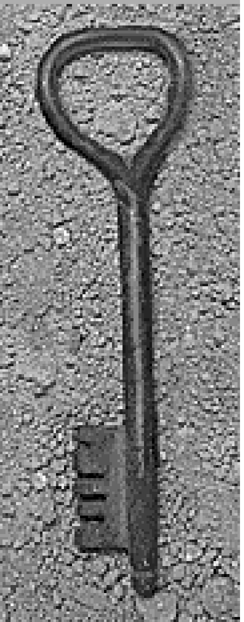
The Birth of ATM!!

- As the users started to use the web for time-sensitive applications, they did not get what they wanted--- *a consistent acceptable performance*
- On some occasions, the network would give the best performance and on other occasions, it would be horrible in terms of delays and lost packets



The Birth of ATM!!

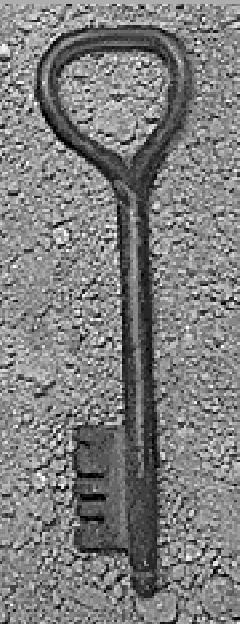
- In this scenario, ATM offered a great promise to the users
- ATM (Asynchronous Transfer Mode) is a cell-switching technology that was targeted to become the B-ISDN (Broad ISDN) network of the future
- ATM standards started taking shape in mid-1980’s as telcos pushed for integrating voice, video and data networks
- ATM was developed with the right targets and in mid-1990’s, it offered the much awaited *performance assurance*



What is ATM?

ATM:

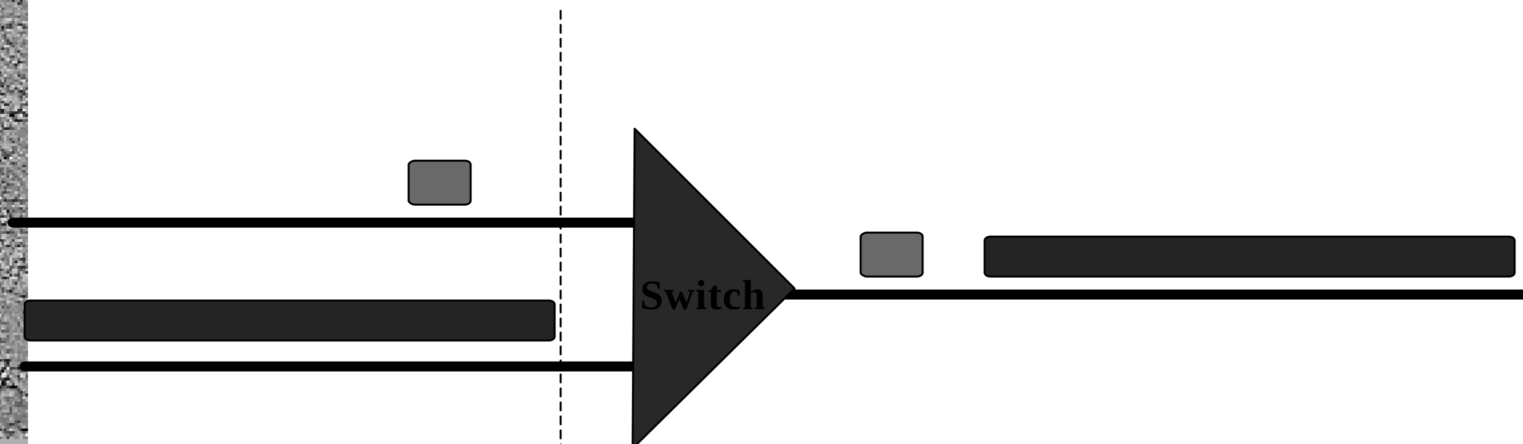
- **Is a cell-switching and multiplexing technology that combines the benefits of *Circuit Switching* (consistent transmission delay and guaranteed bandwidth) with those of *Packet Switching* (flexibility and efficiency for intermittent traffic).**



Why ATM?

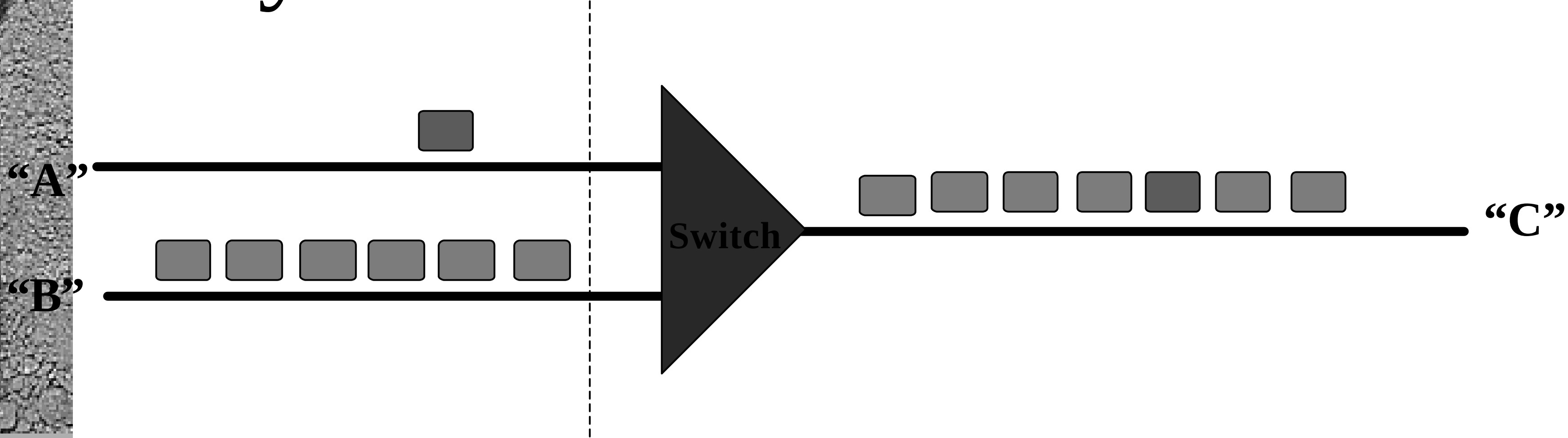
- High Bandwidth requirements
- Need to support Voice, Video, Data
- Connection Oriented to support QoS
- Quality of Service based on:
  - Data rate (CBR, VBR, UBR, ABR,..)
  - Acceptable Latency
  - Delay variations
- Scalable

Why is ATM needed?

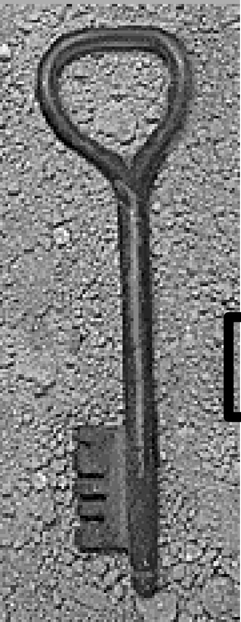


- Need to mix data, voice, and video traffic.
- Packet switching devices are insensitive to real time traffic. First come first serve.
- Small packet must wait for large packet, non deterministic delay occurs
- We cannot just throw more bandwidth at the problem

Why is ATM needed?



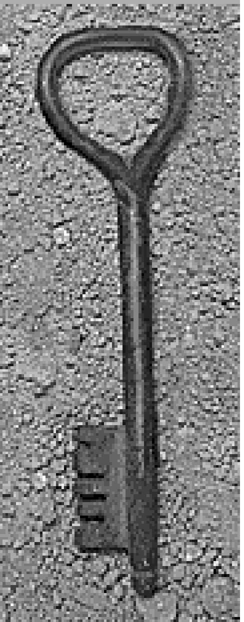
- All data packets are fragmented into fixed size cells
- Segmentation & re-assembly only occurs at end stations
- Time critical traffic on segment "A" only has to wait for the current cell of "B"s data packet to be sent before it can get the wire and be transmitted
- The ability to interleave cells from different messages is instrumental to the operation of ATMs QoS.



ATM Cell

Header	Payload
5 bytes	**48 bytes**

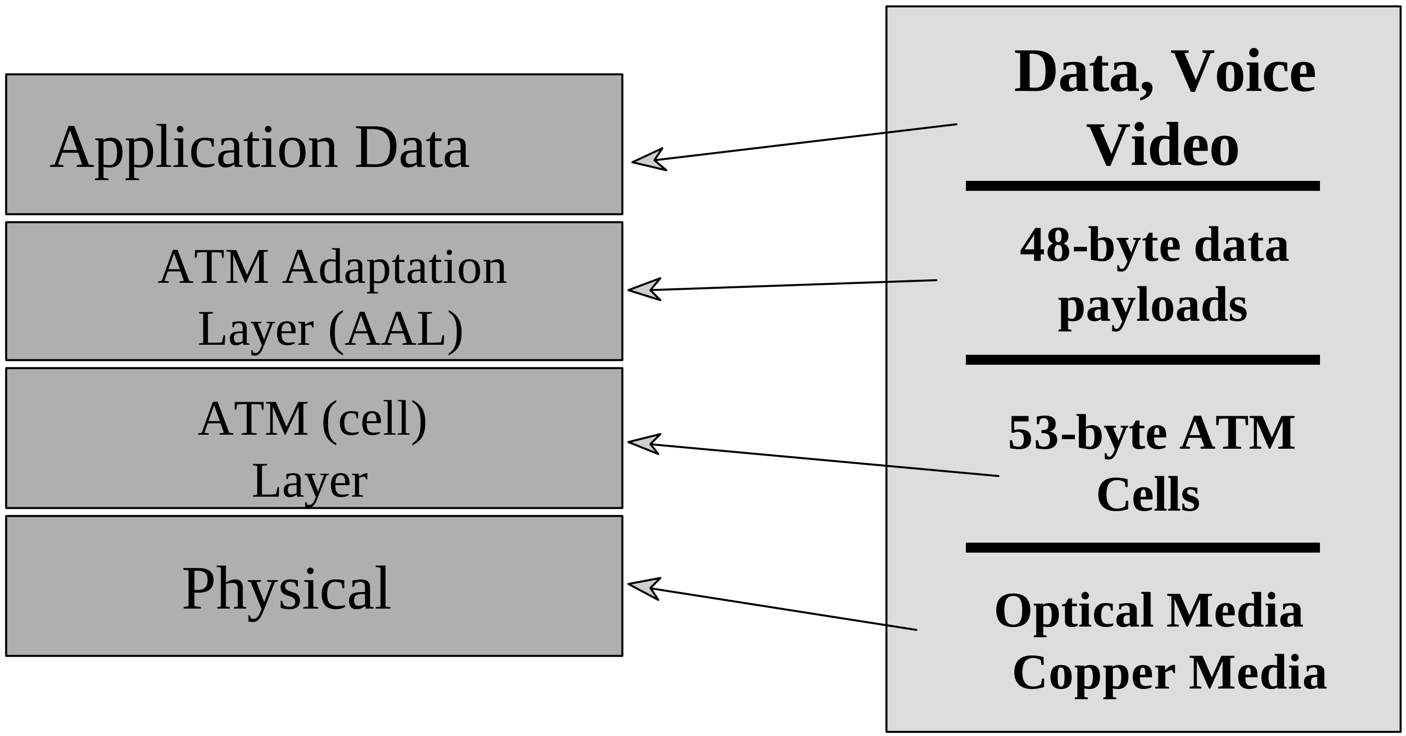
- Small Cells - 53 bytes long
  - 5 byte header
  - 48 byte payload
- Fixed Length = Fast Switching
- Fixed Length = Contracts can be established and QoS maintained

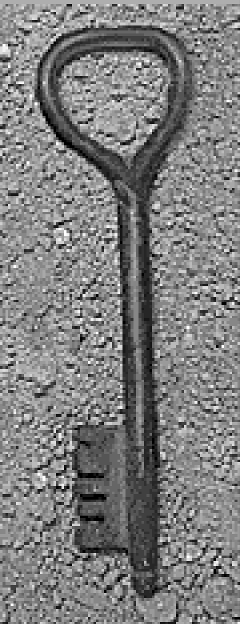


ATM Header Fields

- Header contains
  - VCI (Virtual Channel Identifier) it indicates the channel to which this cell belongs. It must be changed at each switch in order to avoid substantial signaling among all switches to agree on a specific VCI
  - PT (Payload type) data or control cell
  - CLP (Cell Loss Priority) to discard or not in case of congestion
  - HEC (Header Error Checksum)

ATM Layers

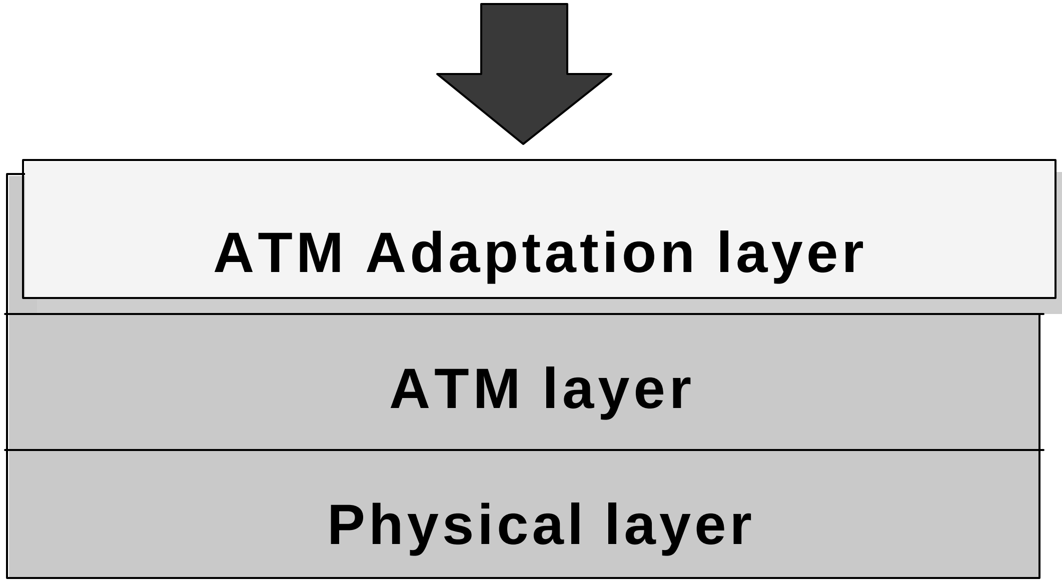

Application Data
ATM Adaptation Layer (AAL)
ATM (cell) Layer
Physical
Data, Voice Video
48-byte data payloads
53-byte ATM Cells
Optical Media Copper Media



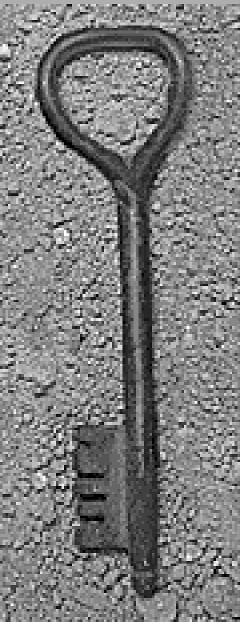
ATM Layers: ATM Adaptation Layer

- AAL allows existing protocols to run on top of ATM
- It is only present at the endpoints of an ATM network
- AAL has two sub-layers as defined below:
- Convergence Sublayer (CS)
  - CS would encapsulate the IP datagram into a CPCS data unit and pass it on to SAR
- Segmentation and Reassembly (SAR) Sublayer
  - Handles all issues related to the formation of the 48 byte payload of an ATM cell

AAL Types

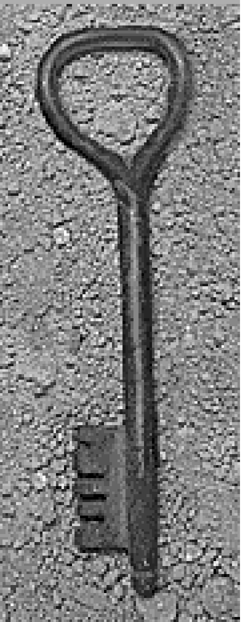


- AAL1 is for circuit emulation
  - Class A - constant bit rate and time sensitive traffic
- AAL5 is for compressed video and data (used in IP over ATM)
  - Class B - variable bit rate and time sensitive traffic
  - Class C - variable bit rate (e.g., Frame Relay)
  - Class D - variable bit rate, connectionless



ATM Layers

- ATM Layer (OSI Layer 2 and 3)
- Cell multiplex/demultiplex
  - Multiplexes cells over same physical link, distinguish at destination by header fields
- Cell VPI/VCI translation
  - Translate incoming VPI/VCI to proper output VPI/VCI pair
- Cell header generation/extraction
  - Interprets header, passes payload to layers

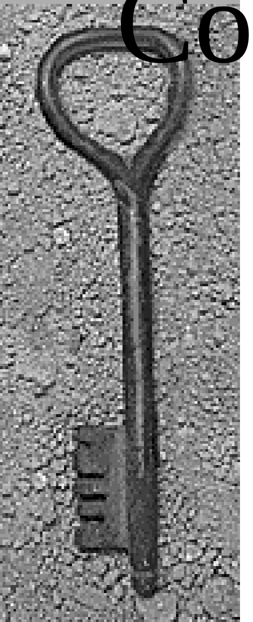


Traffic Contract

- Established at call setup
- Specifies requirements for both sides of the agreement
- Traffic contract includes:
  - Service Category (CBR, VBR, ABR,..)
  - Traffic Descriptors (PCR, SCR, BT, MBS,..)
  - Traffic Conformance (CDV, GCRA,..)
  - QoS Parameters (CLR, CTD, CDV,..)

Service Categories

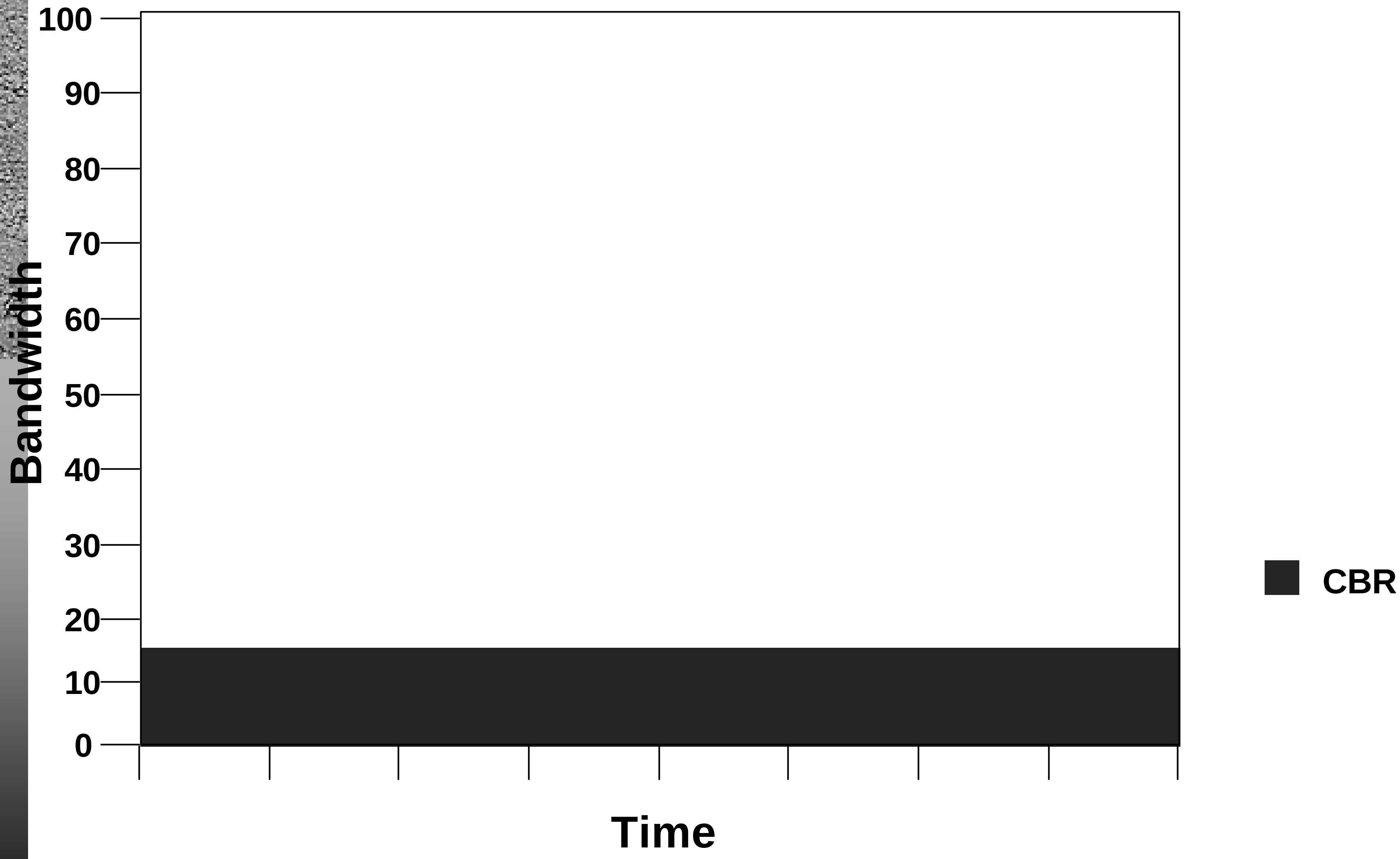
- Categories are based on type of traffic and type of service
  - CBR Constant Bit Rate -Voice
  - rt-VBR Real-Time Variable Bit Rate -Video
  - nrt-VBR Non-Real Time Variable Bit Rate -Frame Relay
  - ABR Available Bit Rate -Data
  - UBR Unspecified Bit Rate -Data



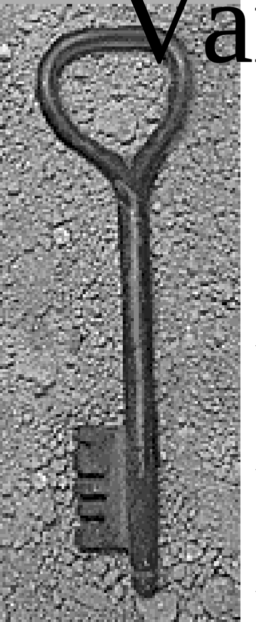
Constant Bit Rate (CBR)

- For traffic with stable date rate requirements
- Typically used for AAL 1 traffic
- Timing Relationship Between Source and Destination
- Very little variation in cell delay,
- Examples:
  - Circuit Emulation, & Fixed Rate Video.

Constant Bit Rate

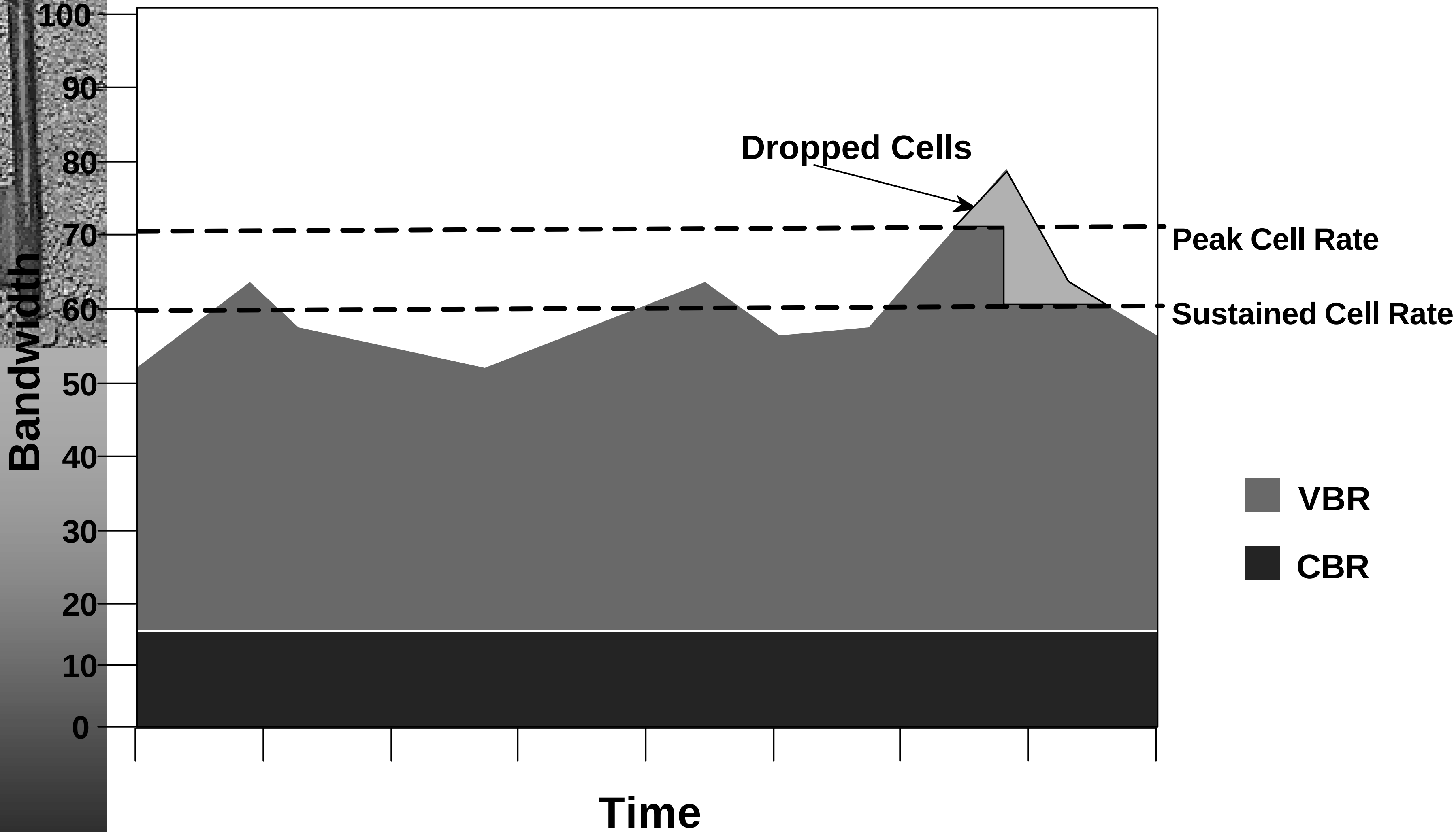


Variable Bit Rate (VBR)

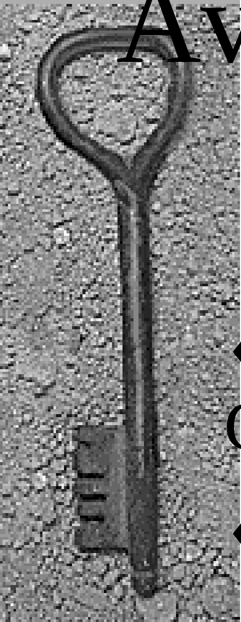


- For Traffic with wide variations in bit rates
- Typically used for AAL5
- Real-Time (rt-VBR)
  - CDV is specified
  - Example: Interactive compressed video
- Non Real-Time (nrt-VBR)
  - CDV not specified
  - Example: Frame Relay

Variable Bit Rate(VBR)

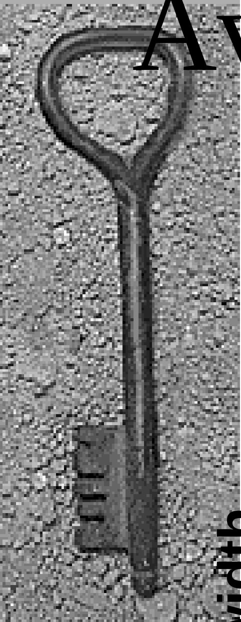


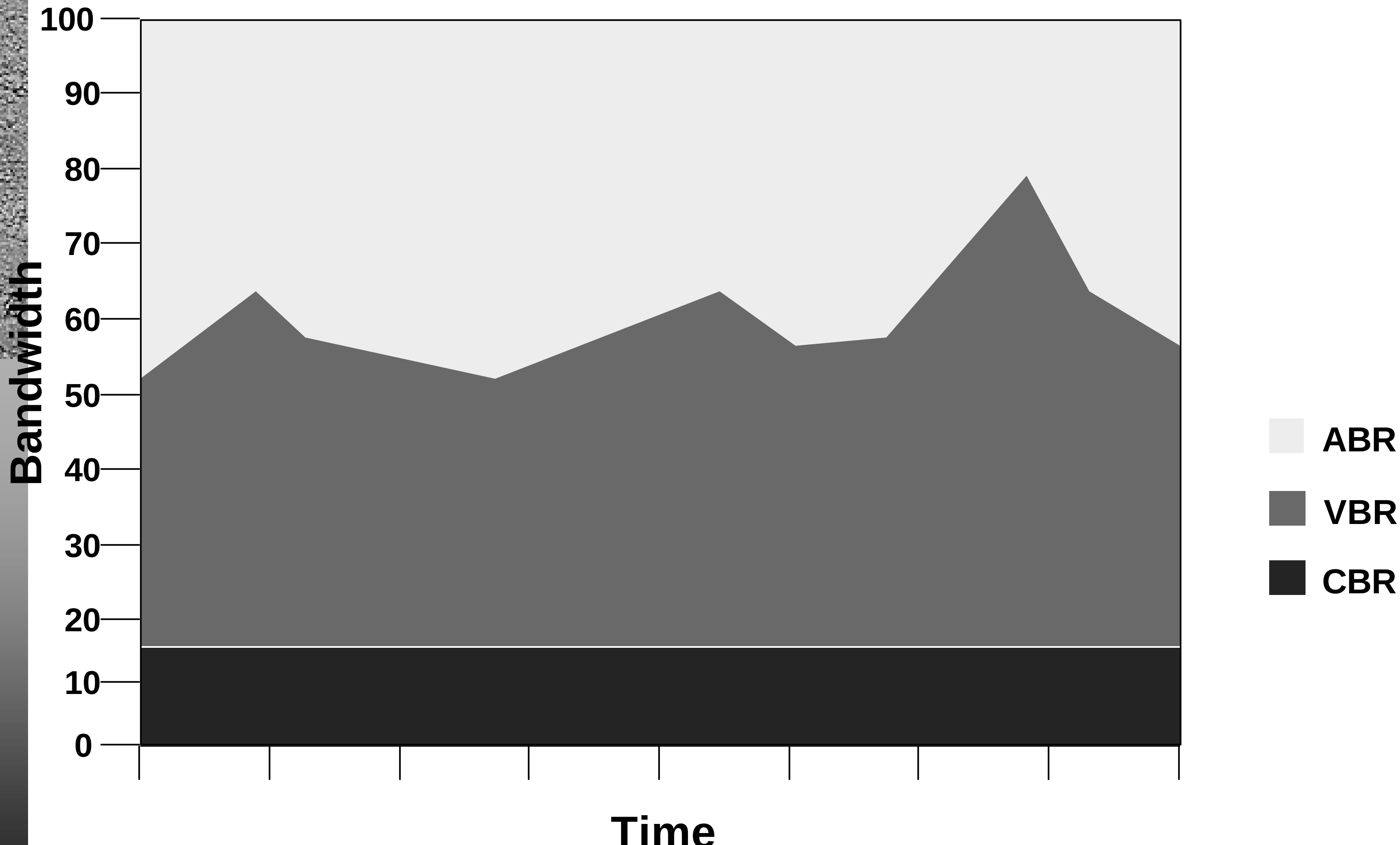
Available Bit Rate (ABR)



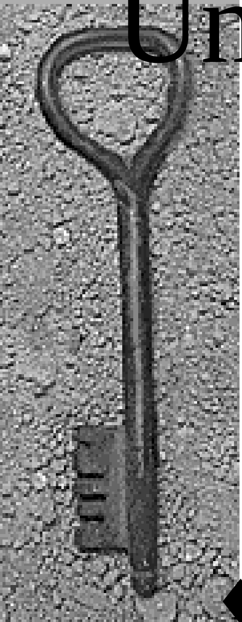
- Offered as a Fair Share of the Available Bandwidth once CBR and VBR services are accounted for.
- Typically used for AAL-5 traffic
- No QoS guarantees, designed to support data
- Minimum Cell Rate (MCR) Specified by the User
  - The MCR is guaranteed by the network,
  - MCR=0 is allowed.
  - Uses rate-based congestion control (flow control)

Available Bit Rate(ABR)



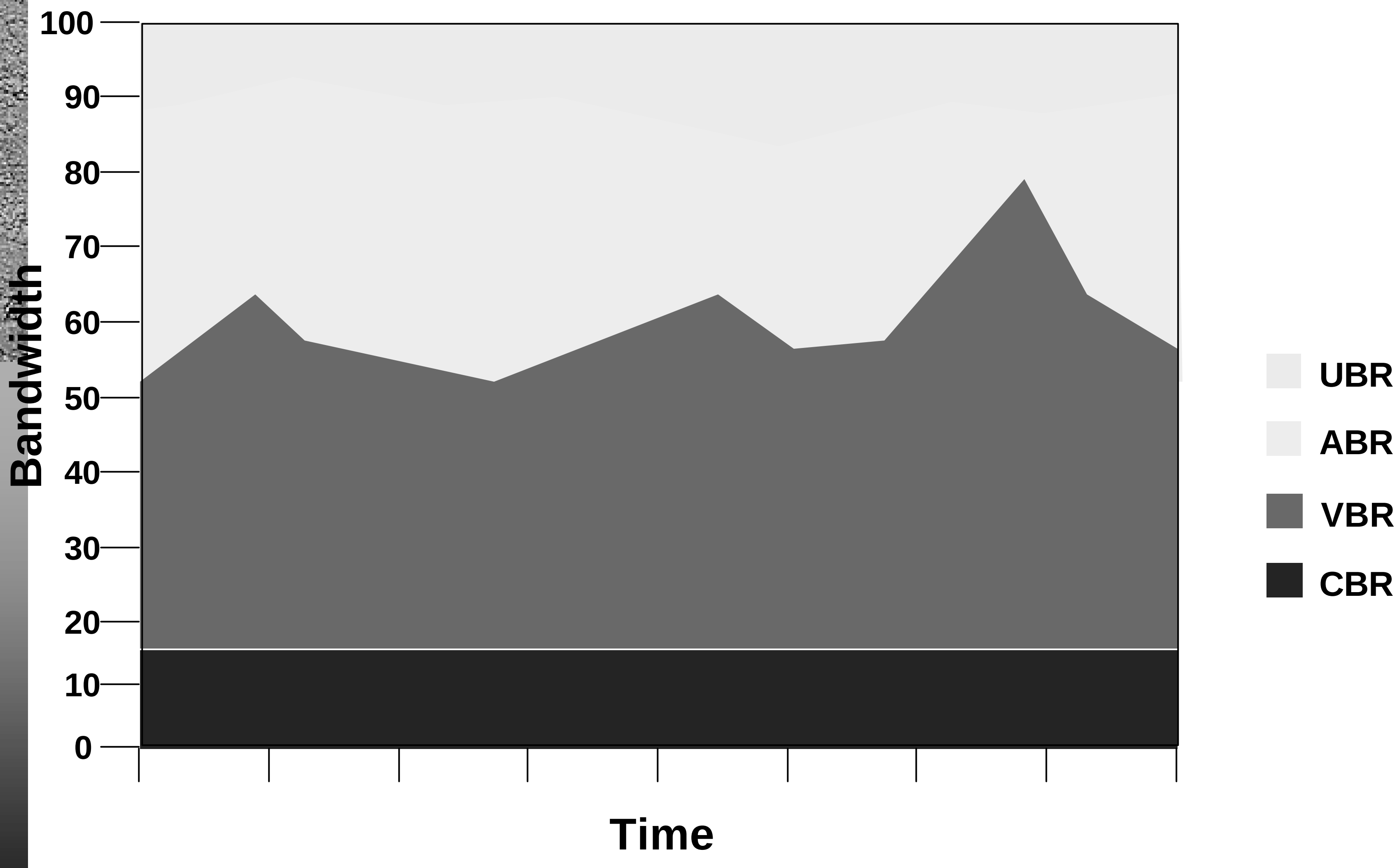


Unspecified Bit Rate (UBR)



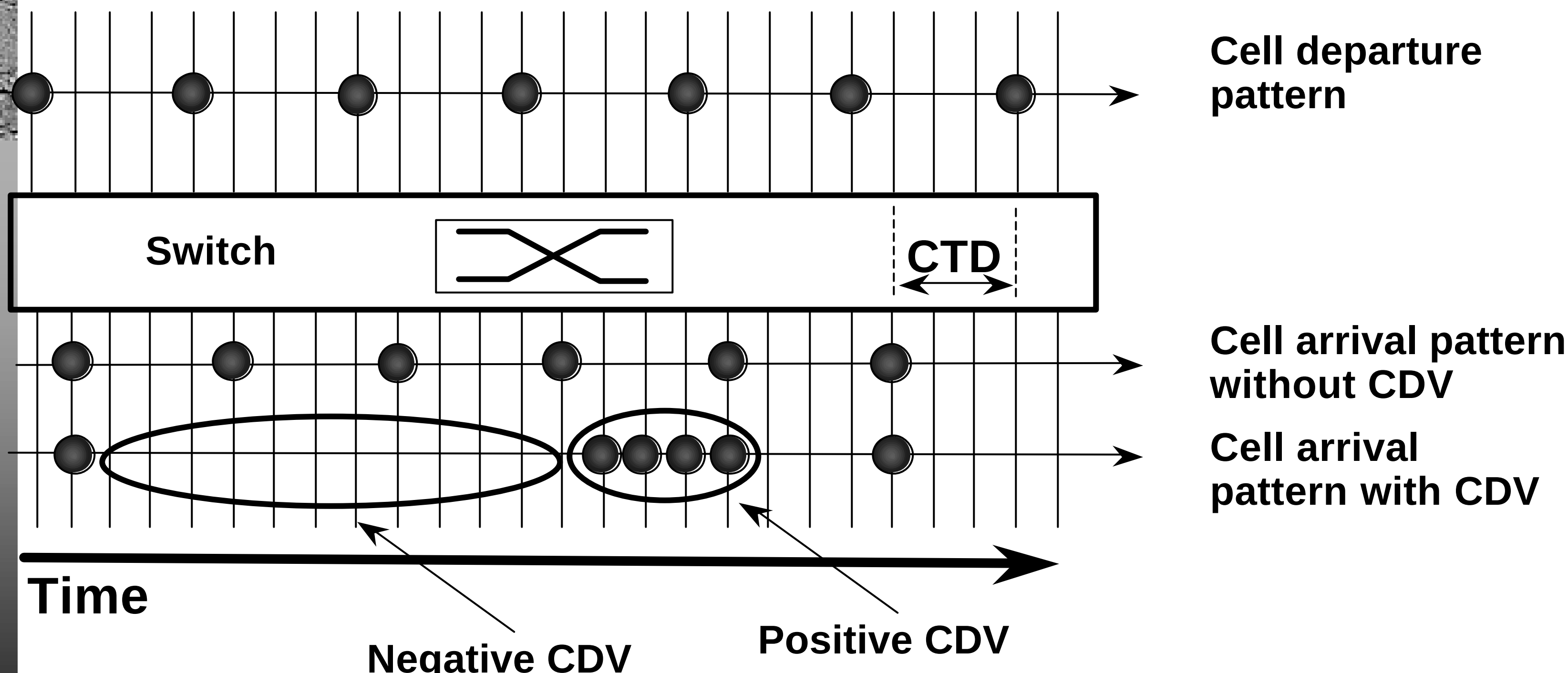
- Used for data traffic (AAL-5)
- Only offers a best effort delivery
- No Connection Admission control refusal
- No Flow Control (not required)

Unspecified Bit Rate



Quality of Service

- Cell Transfer Delay (CTD)
- Cell Delay Variation (CDV)



Quality of Service (QoS) Parameters

- *Cell Transfer Delay (CTD):* The delay experienced by a cell between network entry and exit points (propagation, queuing, service times, etc.).
- *Cell Delay Variation (CDV):* Variations in the CTD.
- *Cell Loss Ratio (CLR):* The percentage of cells that are lost in the network because of error, congestion or mis-delivering. (lost cells/total cells)
- *Minimum Cell Rate (MCR):* The minimum rate desired by a user.

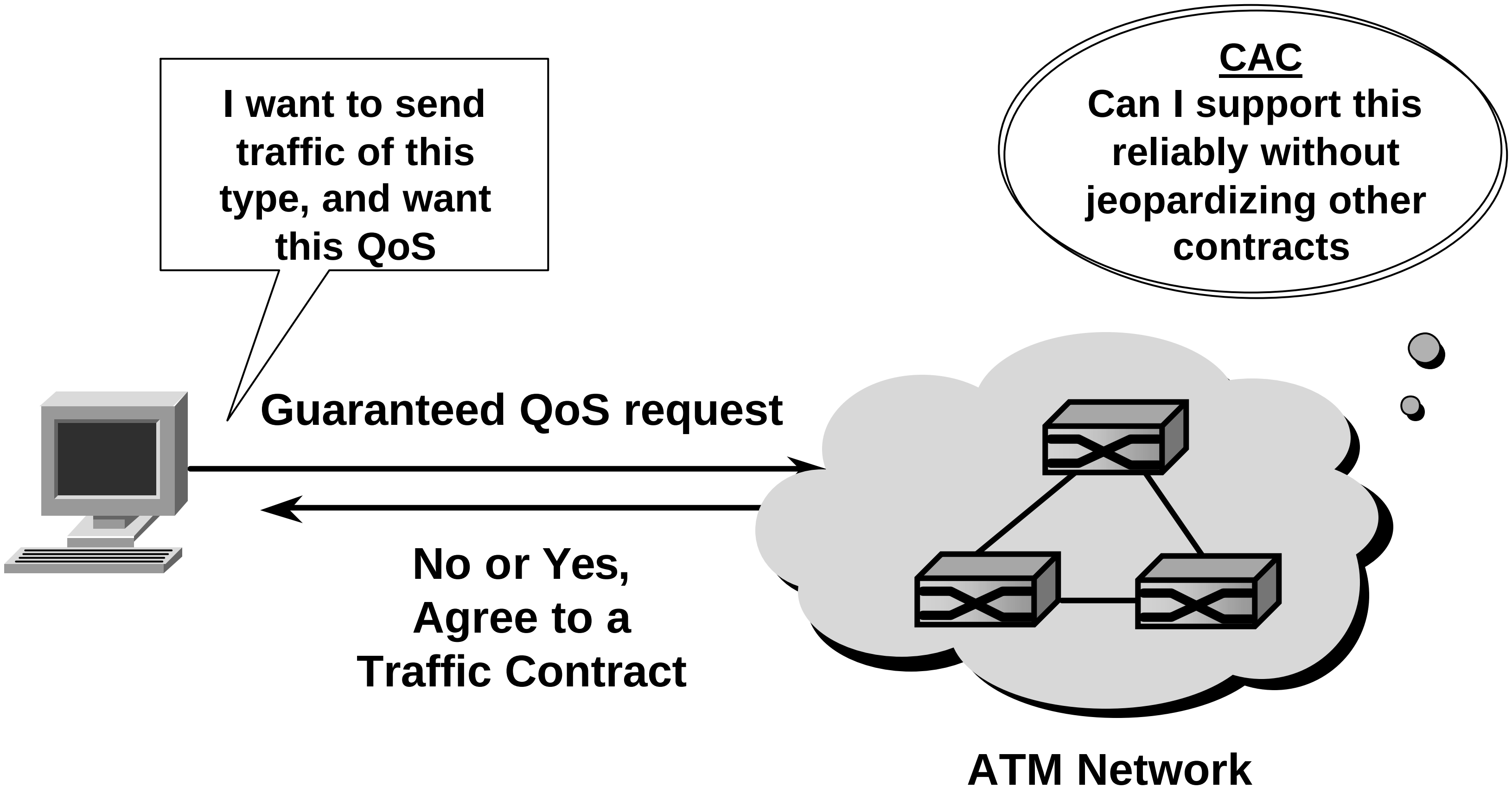
Traffic Descriptors

- Source Traffic Descriptors
  - *Peak Cell Rate (PCR)* - The Maximum instantaneous rate at which the user will transmit.
  - *Maximum Burst Size (MBS)* - The maximum number of back-to-back cells that can be sent at the peak cell rate
  - *Sustained Cell Rate (SCR)* - The average rate of an ATM connection measured over a time interval.
  - *Minimum Cell Rate (MCR)* - The minimum cell rate desired by a user.

Traffic Management Mechanisms

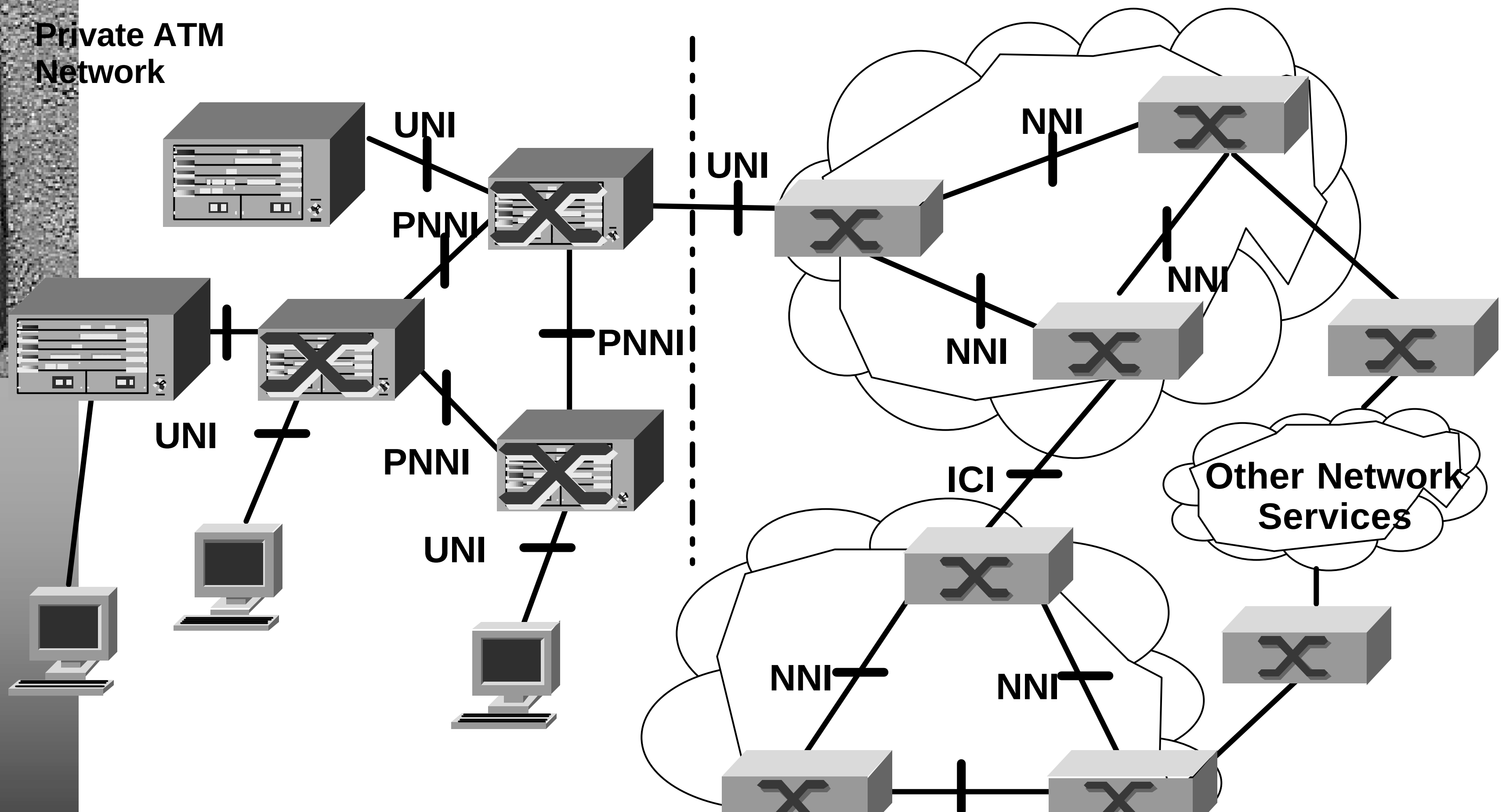
- Connection Admission Control (CAC)
  - **Can the new call be supported**
- Usage Parameter Control (UPC)
  - **Usage Parameter Control (UPC): Once connection is granted this function monitors and regulates traffic at the UNI.**
  - **Cell Loss Priority Control (CLP): Mechanism for tagging non-conforming cells**
- ABR Flow Control
  - **Mechanism for adjusting end station transmission depending on available network bandwidth**

CAC



- **If CAC passes, network and user agree on a traffic contract**

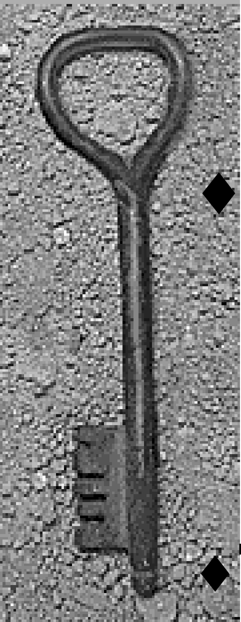
ATM Networks



NNI: Network Node Interface
UNI: User Network Interface
ICI: Inter-Carrier Interface
PNNI: Private Network to Network Interface

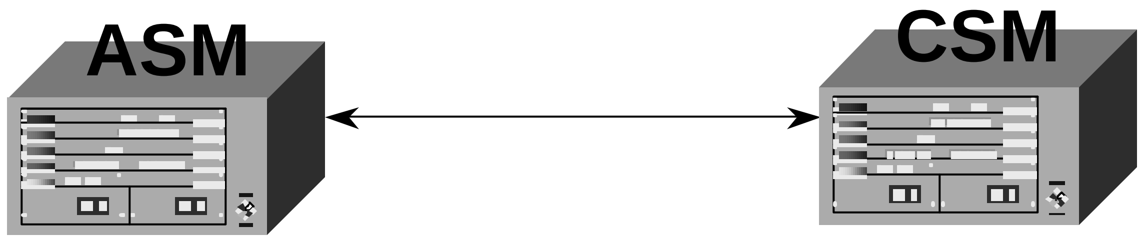
ATM Signaling

- ATM, a connection oriented service, requires an end to end link be established prior to data transfer. This link is established via the UNI & NNI specifications.
- Two Types of signaling are used
  - UNI- User to Network Interface, end device to first switch.
  - NNI- Network to Network Interface, switch to switch interface.



ATM cells

- UNI cells

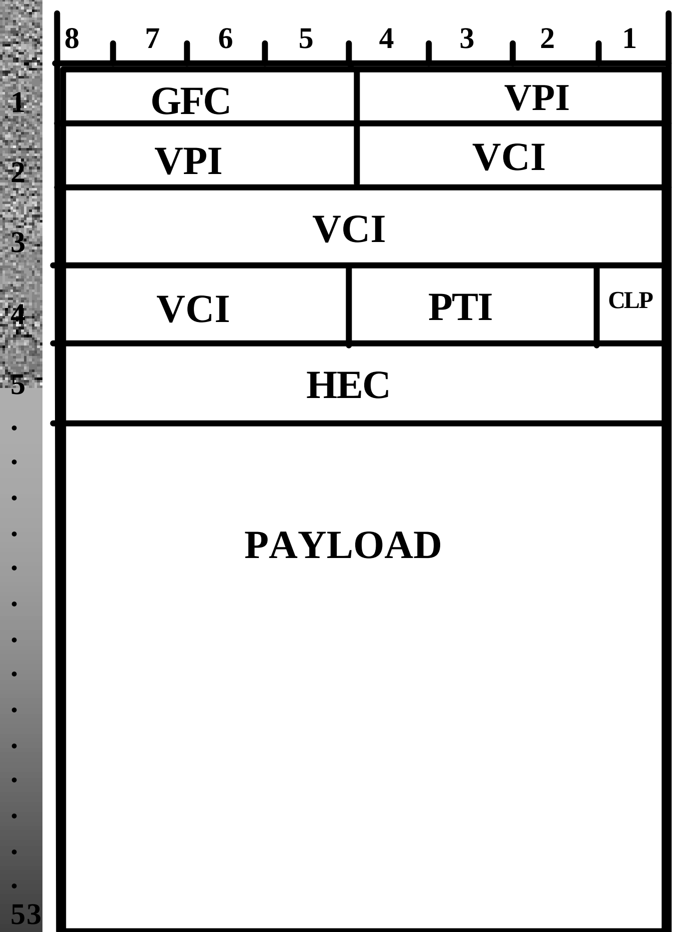


- Travel between Edge Device and switch

- NNI cells

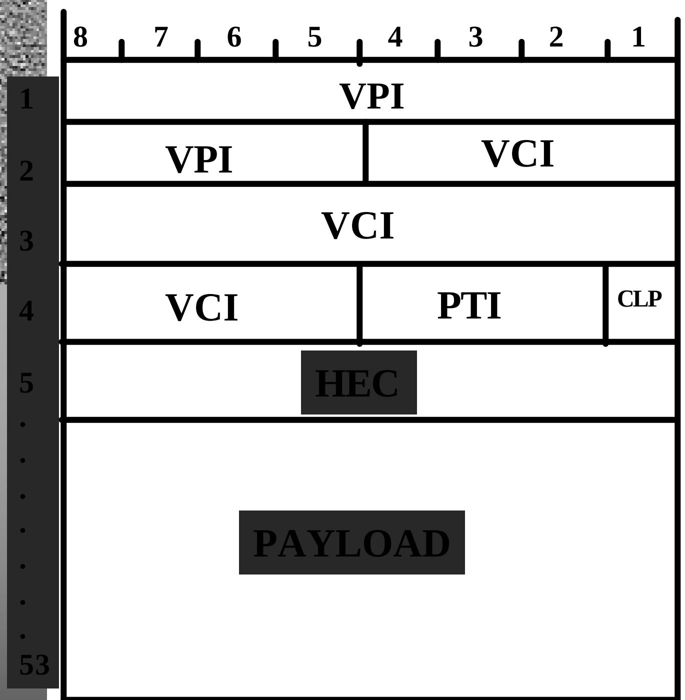
- Travel from switch and switch

UNI Cell Format



- GFC- Generic Flow Control
- VPI - Virtual Path Identifier
- VCI - Virtual Channel Identifier
- PTI - Payload Type Identifier
- CLP - Cell Loss Priority
- HEC - Header Error Check
- Payload - User Information

NNI Cell Format



- VPI - Virtual Path Identifier
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- PTI - Payload Type Identifier
- CLP - Cell Loss Priority
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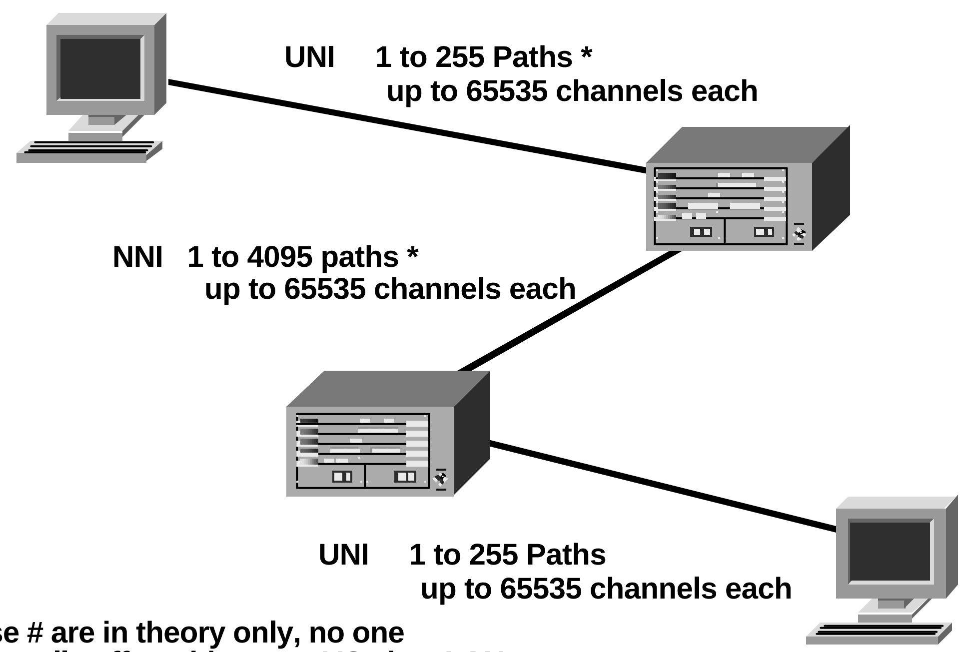
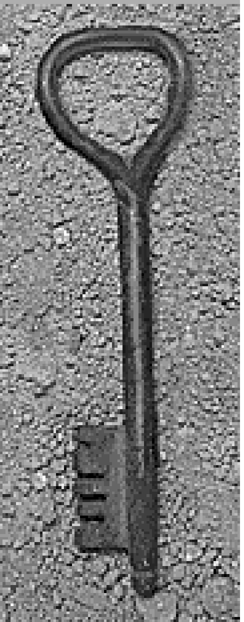
Virtual Circuits



* These # are in theory only, no one
one really offers this many VCs in a LAN

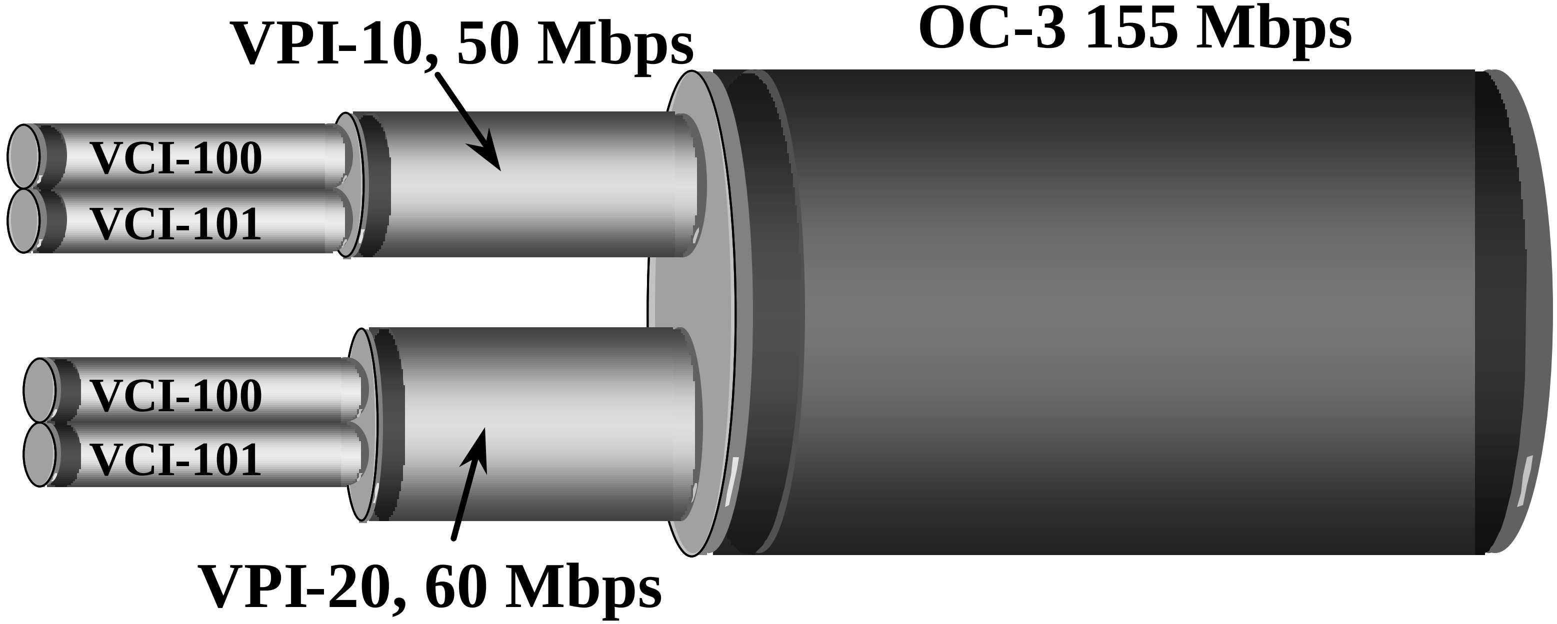


Virtual Circuits

- Permanent Virtual Circuits (PVCs)
  - Pre-configured connections (‘nailed-up’ pipes)
    - VPI/VCI translations pre-defined
    - QoS, Delay, Peak rates, etc.
  - No signaling infrastructure required
- Switched Virtual Circuits (SVCs)
  - A collection of procedures used to dynamically establish, maintain, and terminate connections
- Soft PVCs
  - PVCs at UNI with signaling in the network for setup

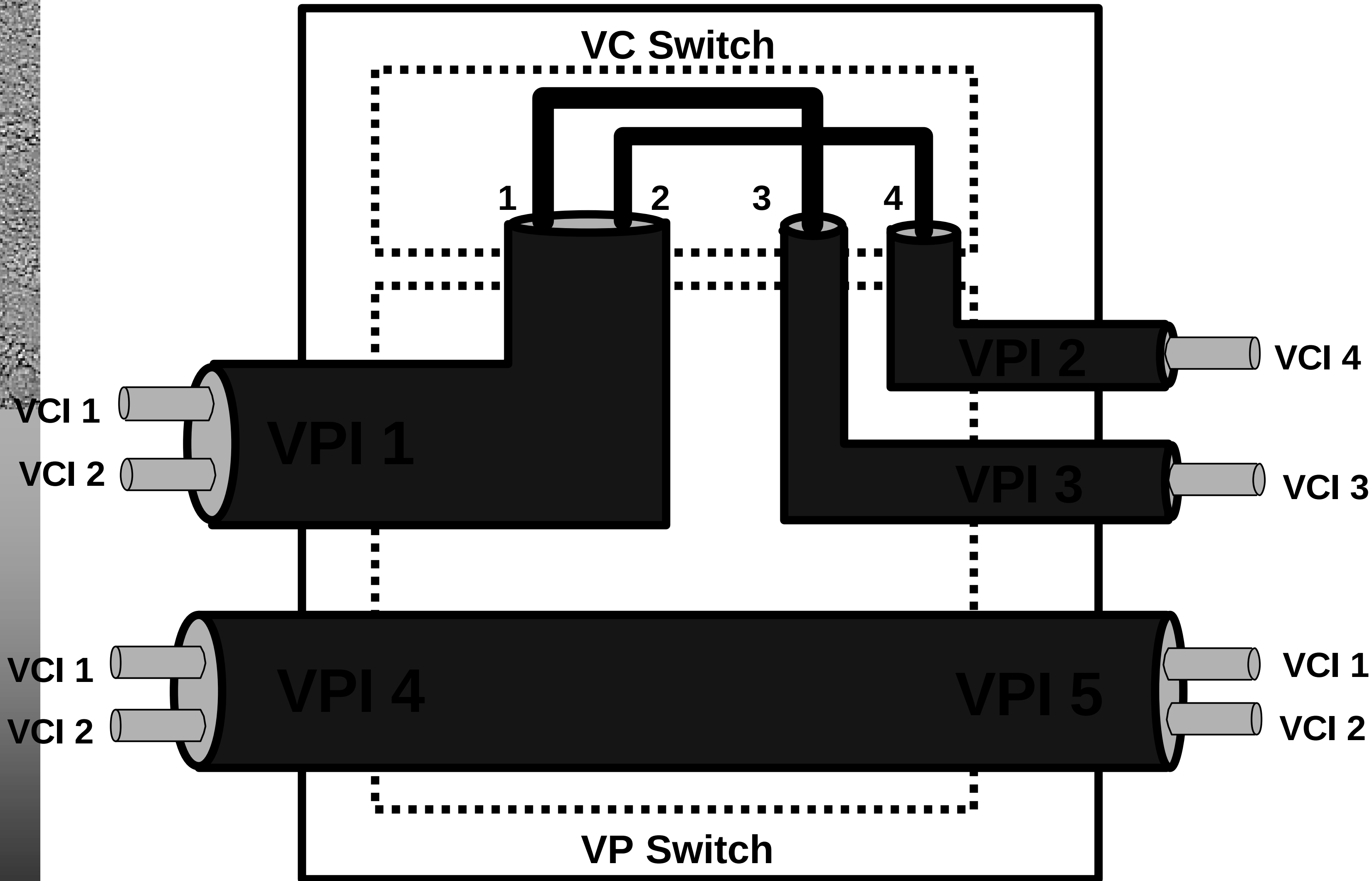
VPIs and VCIs

- Virtual Path Identifier (VPI)
- Virtual Circuit Identifier (VCI)

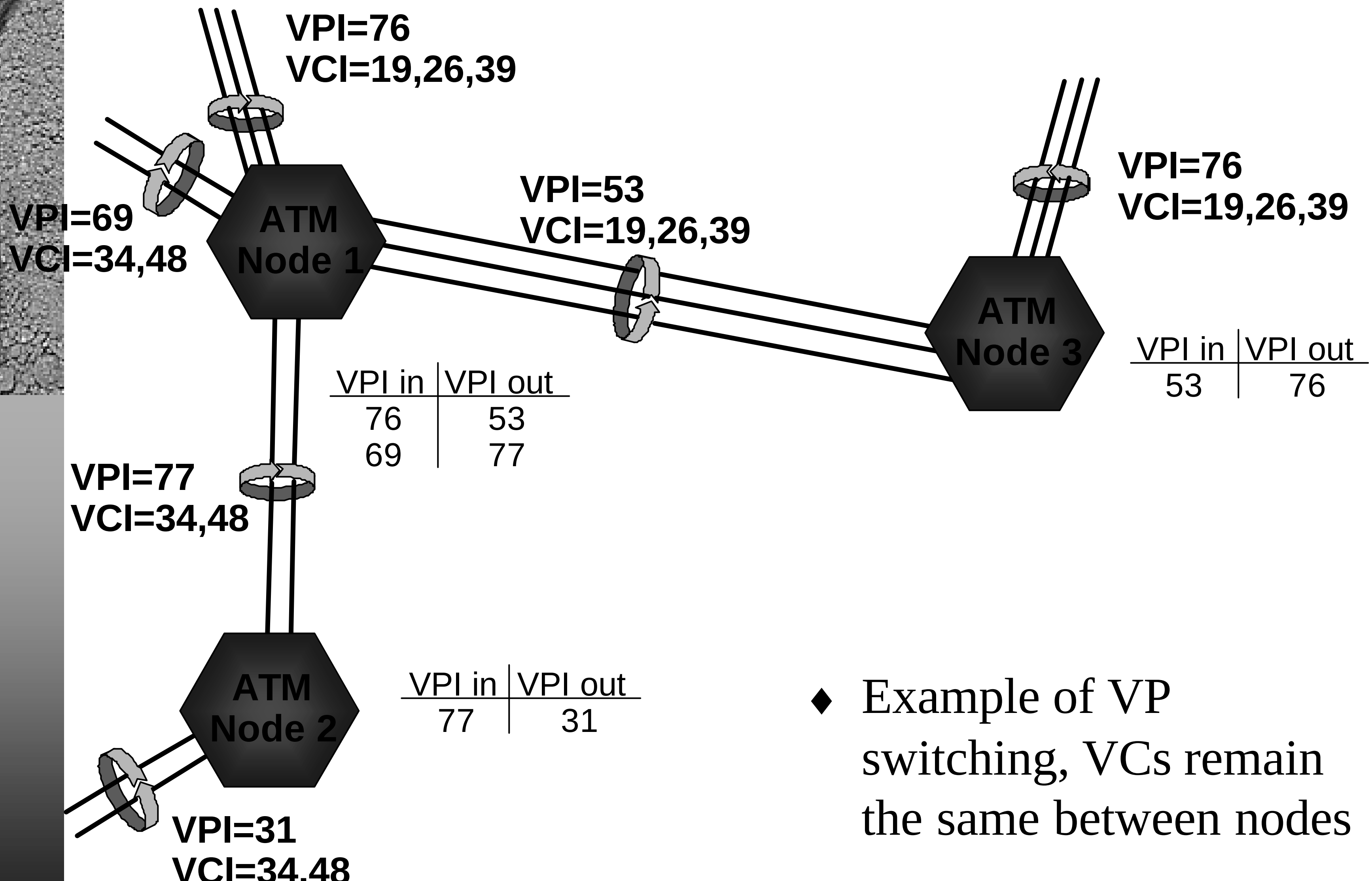


Remaining 45 Mbps is in VPI-0

VP and VC Switching

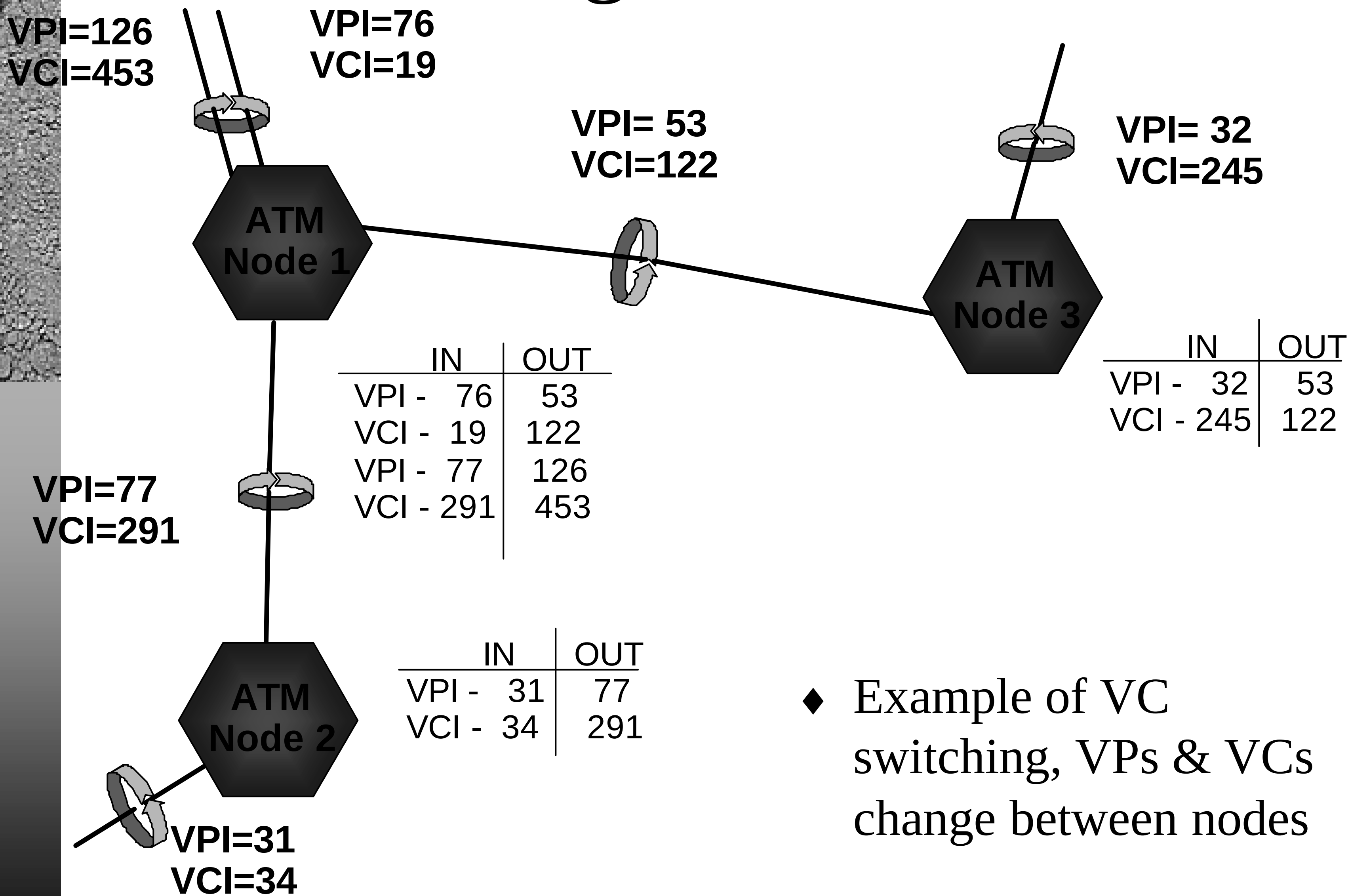


VP Switching



- Example of VP switching, VCs remain the same between nodes

VC Switching

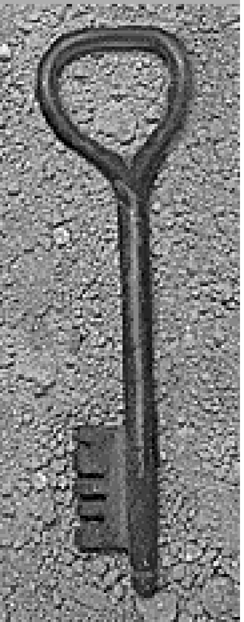


	IN	OUT
VPI -	76	53
VCI -	19	122
VPI -	77	126
VCI -	291	453

	IN	OUT
VPI -	32	53
VCI -	245	122

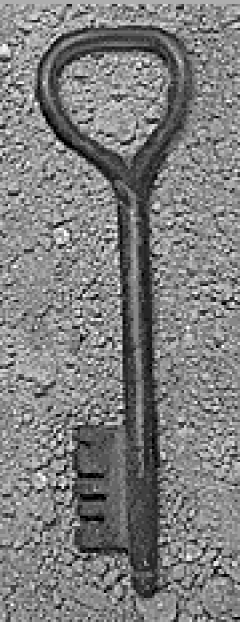
	IN	OUT
VPI -	31	77
VCI -	34	291

- Example of VC switching, VPs & VCs change between nodes



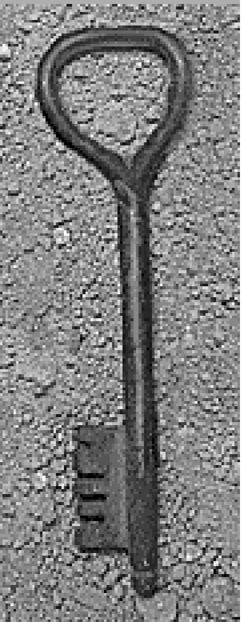
ATM-ETHERNET Networks

- ATM has to support traditional LANs including the dominant Ethernet
- ATM offers LAN Emulation services called LANE
- LANE can emulate Token Ring or Ethernet LANs



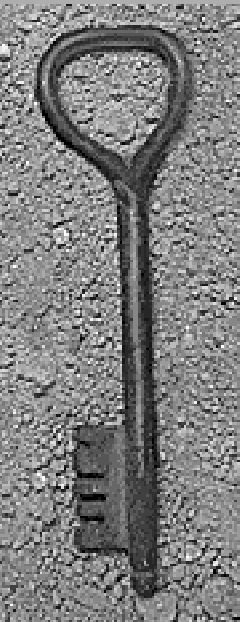
IP Over ATM

- As Most LANs use TCP/IP to Communicate with each other, IP packets have to transit through ATM core before reaching the destination
- New problems arise including cell-frame translation and virtual-circuit management overheads



Problems (IP over ATM)

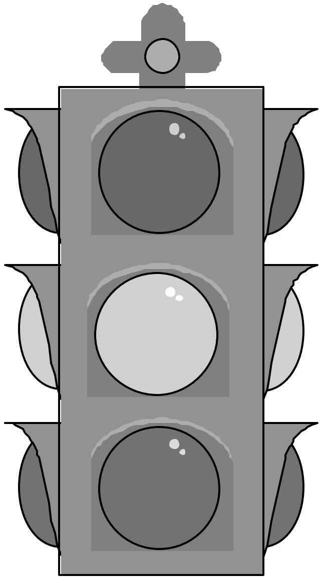
- Some of the problems in sending IP over ATM are
- Providing connectionless service over connection oriented network
- Providing broadcast support over a non-broadcast network
- Performing IP-ATM-MAC address resolutions
- Figuring out an end-to-end Quality of Service measure
- Minimizing overhead in Frame-Cell-Frame translations

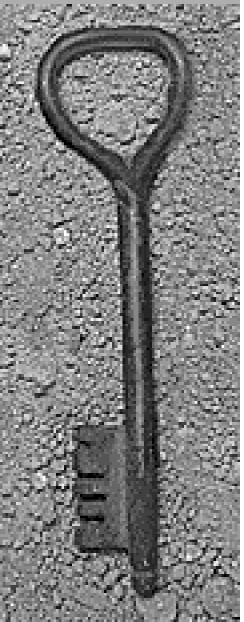


IP Over ATM Scenario

- ATM switches are in the network core
- IP treats ATM as just another link layer network
- ATM switches have PVC’s set up among themselves
- An IP datagram enters a dual-interface router for onward transmission across ATM
- The router determines ATM address of the exit router from its ATM ARP table
- The datagram is handed over to ATM via AAL that first prepares a PDU and then cuts it into cells
- ATM consults a table that maps ATM addresses to VCI’s and then sends it to the destination

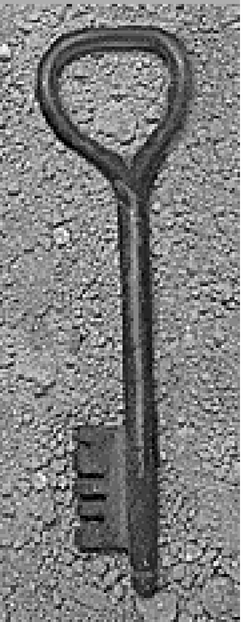
Traffic Management





Traffic Shaping and Policing

- In order to meet the QoS contract obligations, ATM network enforces traffic **shaping** and **policing**
- Shaping involves techniques such as “Leaky Bucket Algorithm” to regulate bursty traffic
- Policing means marking CLP (Cell Loss Priority) on the offending cells that violate the maximum rates agreed



Leaky Bucket Algorithm

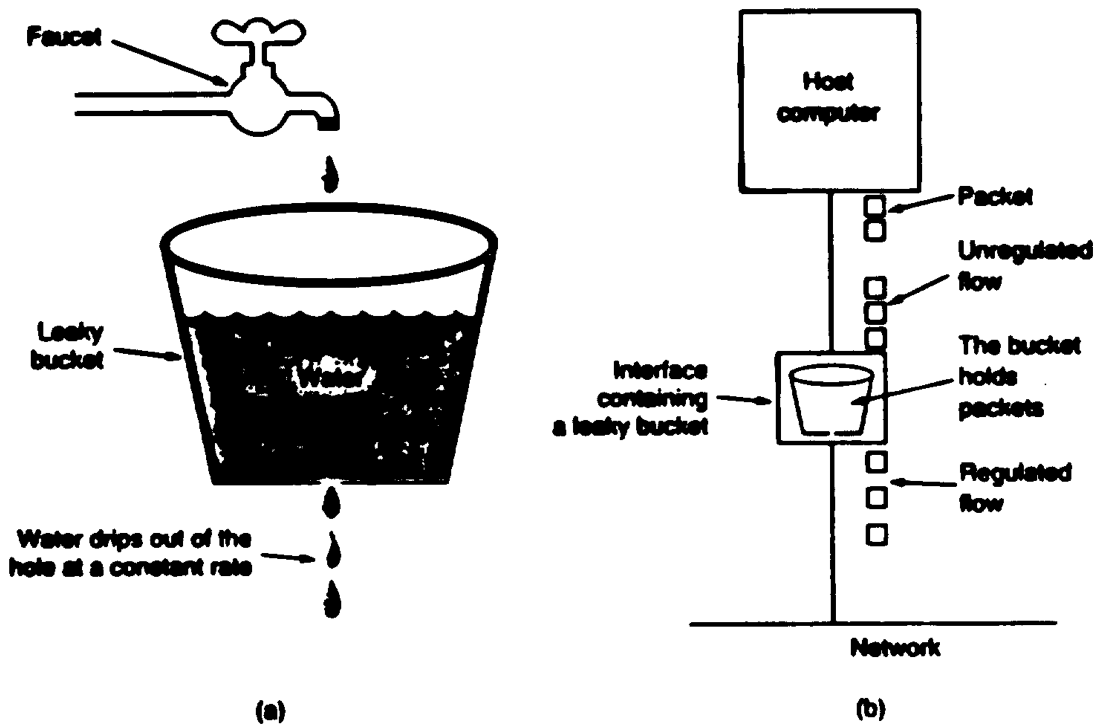
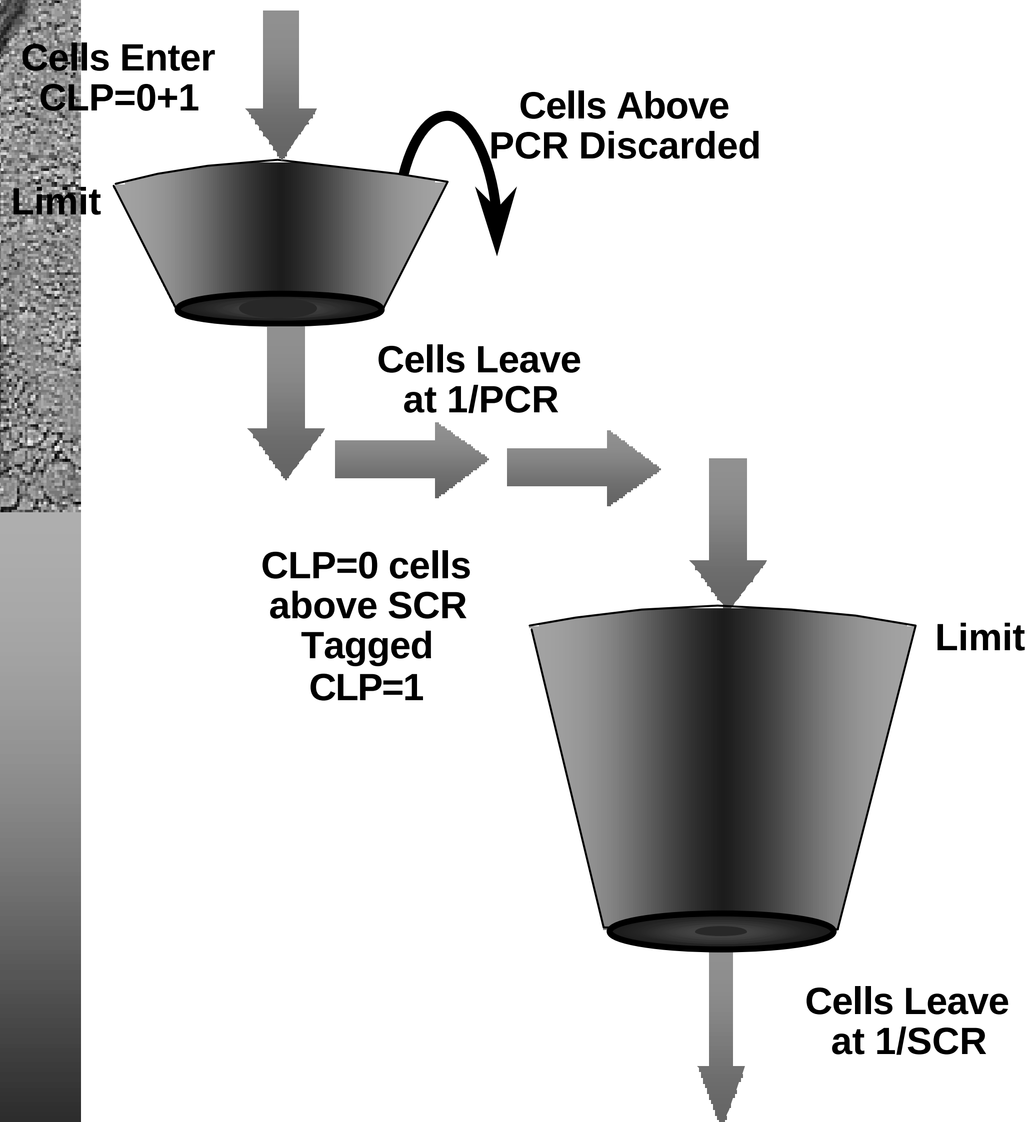
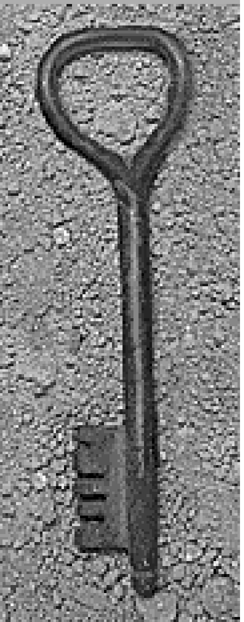


Fig. 5-24. (a) A leaky bucket with water. (b) A leaky bucket with packets.

Dual Leaky Buckets

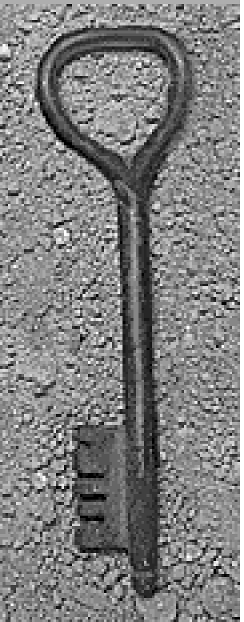


- Cells enter first "bucket" at some rate.
- Cells are "drained" at a rate 1/PCR, cells above PCR are discarded
- Conforming Cells are subjected to a second bucket
- Second "bucket" drains at a rate of 1/SCR
- Cells in excess of SCR may be:
  - Discarded (CLP=0+1)
  - Tagged (CLP=0)



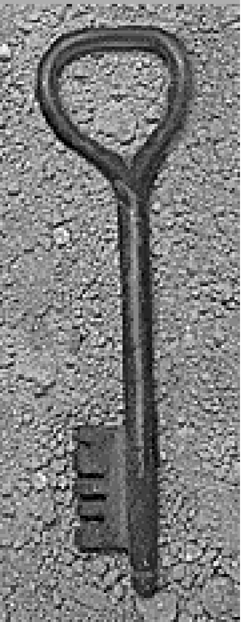
The Death(?) of ATM!!

- ATM came to limelight in mid-1990’s
- By that time, WWW had expanded the Internet to every nook and corner of the world
- The whole Internet and almost all users were using packet switching
- Cell switching was being promoted as very fast as compared to “legacy” networks



The Death(?) of ATM!!

- However, the evolution of shared Ethernet into switched Ethernet at 10Mbps and development of Fast Ethernet at 100Mbps stalled the ATM’s march to the desktop
- ATM was pushed to the backbones of campus networks
- Gigabit Ethernet in the backbone appears to be the last nail in the coffin for ATM



The Death(?) of ATM!!

- ATM failed because of several factors
  - ATM is too complex (From packets to cells to SONET frames, using AAL's, emulating LAN)
  - ATM is expensive
  - Ethernet has evolved into much faster 100Mbps and 1000Mbps services
  - All popular and established network applications are packet based