Overview of High Speed Network Technologies

PASI (Pan-American Advanced Studies Institute)

Grid Computing and Advanced Networking Technologies for e-Science

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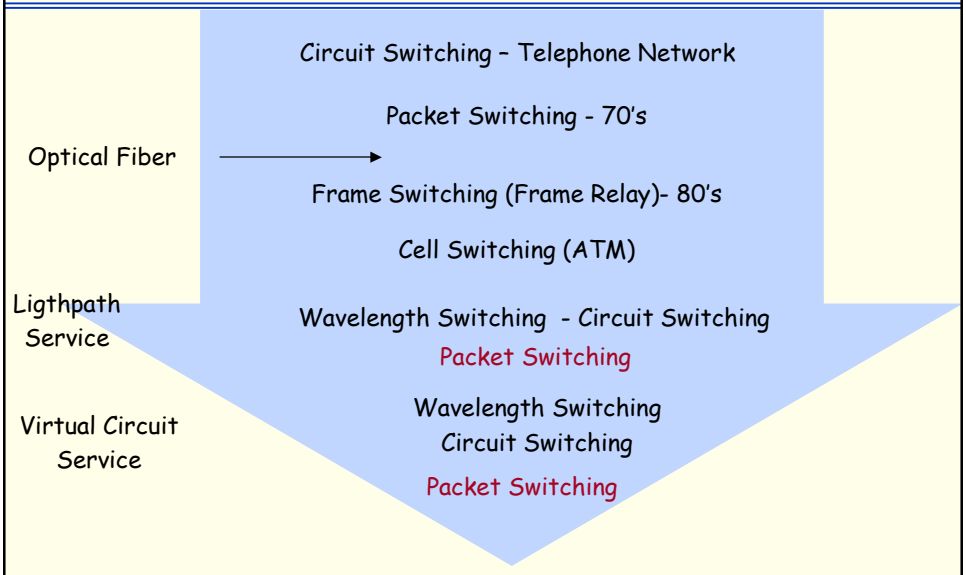
Agenda

- Why High-Speed Networks?
- Switching Techniques
  - Circuit Switching.
  - Packet Switching.
  - Cell Switching
- High-Speed Network Technologies.
  - ATM
  - MPLS
  - IP Networks.
- Final Considerations

Why High-Speed Networks?

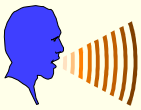
- Optical Network Development
- Multimedia Application.

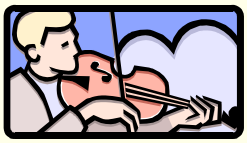
Network Evolution



Multimedia Applications

- Simultaneous and integrated usage of data, sound and video, aiming to get more efficient and interactive interface.



Types of Multimedia Applications

- The main types of multimedia applications are:
  - **Conversational services.**
  - **Retrieval services.**
  - **Messaging services.**
  - **Distribution services**.

Conversational Services

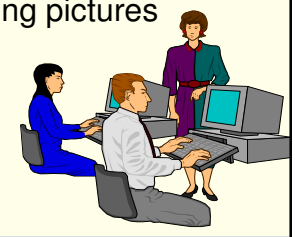
- Allow the mutual exchange of data, whole documents, pictures and sound in real-time:
  - **Videotelepony.**
  - **Videoconference.**
  - **Real-time transmission of multimedia objects** (medical images, remote games, among others).
  - **Virtual reality systems.**

Retrieval Services

- These services are used, for instance, to obtain video films at any time or to acess remote software library.
  - **Electronic library.**
  - **Video On-demand:**
    - **For entertainment purposes.**
    - **Remote education and training.**
    - **Medical image communications.**
    - **Professional image communications.**

Messaging Services

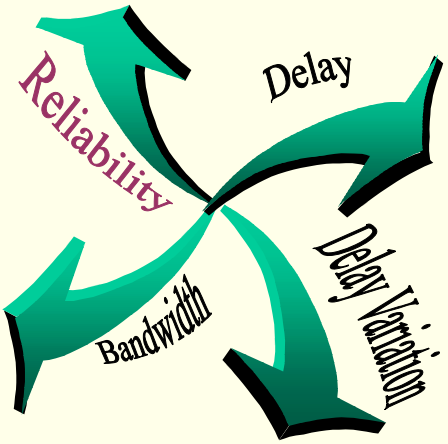
- Include mailboxes services for the transfer of sound, pictures and/or documents.
- No real-time applications.
  - **Video mail services** (transfer of moving pictures and accompanying sound).
  - **Multimedia mail services** (tranfer of mixed documents containing text, graphics, still and moving pictures information as well voice annotations).



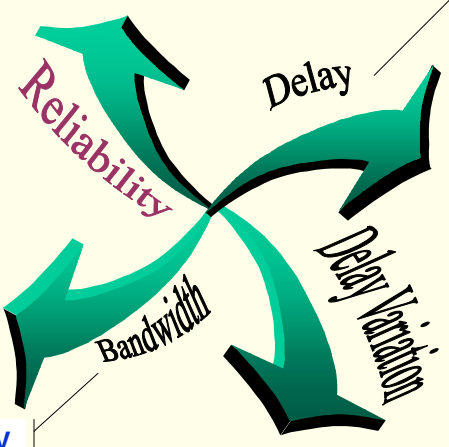
Distribution Services

- These services are classified as:
  - **Services without user presentation control**:
    - Distribution of video/audio signals.
    - Electronic publishing such as electronic newspaper..
    - TV program distribution.
  - **Services without user presentation control**:
    - Remote education and training.
    - Tele-advertising.

Multimedia Application Requirements



Multimedia Application Requirements



Voice
Delay = 400ms
Eco <= 100ms
Reproduction
125 µs

Compressed HDTV from 20 Mbps

Quality of Service for Multimedia Applications

- Different multimedia applications work properly on different QoS parameters.

Application Requirements	Data	Graphic Data	Voice	Interactive Voice	Video	Real-Time Video
Bandwidth	L	H	H	H	VH	VH
Delay	L	L	H	VH	H	VH
Delay Variation	L	L	H	VH	H	VH
Error Rate	H	VH	L	L	L/H	VH/

L: Low; H: High; VH: Very High.

Normally, the high-speed networks support multimedia applications guaranteeing the Quality of Service parameter compliance.

Quality of Service in High-Speed Networks

• Delay	• Data prioritization according to the channel type. • rt-VBR > nrt-VBR
• Delay Variation	• Synchronization Mechanisms • Ex: time stamp.
• Bandwidth	• Bandwidth reservation via signaling.
• Reliability	• Error detection and recovery

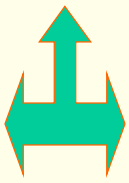
QoS and Network Tecnologies

- Network technologies that already supported application integration and convergence: Frame Relay.
- Network technologies that support natively QoS: ATM.
- IP Technology with:
  - Control mechanisms of quality:
    - Standards: H.323, RSVP, RTP, RTCP.
    - MPLS/Diffserv
    - Standards: IEEE 802.1 Q/p
  - IP over high-speed networks:
    - IP over SDH/SONET
    - IP over DWDM
    - IP over Fiber

Switching Techniques

Switching Techniques

Network = Resource Sharing



Physical Media (Multiplexing Mechanisms)

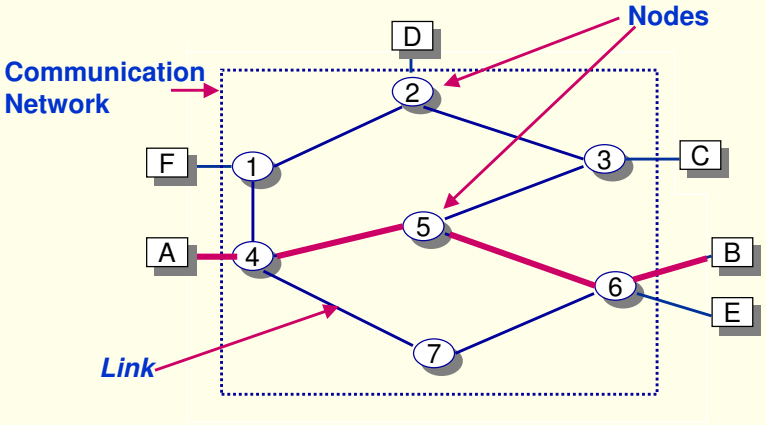
- Frequency.
- Time.

Equipment Infrastructure (Switching Mechanisms)

- Circuits
- Packets
- Cells

The different network technologies combine these techniques, providing different results of Quality of Service.

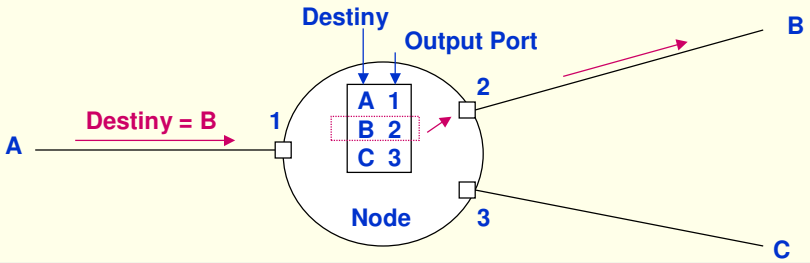
Communication Networks



Communication network is a system composed of nodes connected through transmission links that provide a path between any two nodes of the network.

Switching

- ***In a network, the information is sent from one node to another until reaching its destiny.***
  - In each node, the incoming information that arrives at an input port is transferred to an output port that is more proper to reach its destiny.
  - The output port is defined taking as basis the information of the switching tables.
- **The information transfer from one input port to an output port is called switching.**

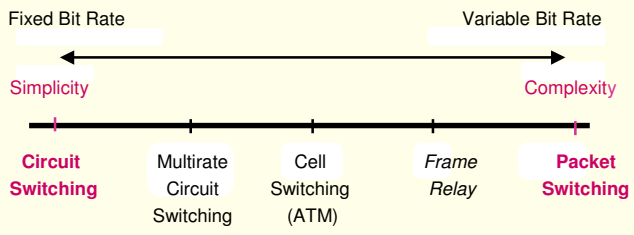


Switching Techniques

- There are different types of switching techniques.
- The two most known switching techniques are:
  - **Circuit Switching does** keep the resources reserved through the whole communication path before transmitting the information.
  - **Packet Switching does not** keep the resources reserved through the whole communication path before transmitting the information.

Evolution of the Switching Techniques

- One one side, the circuit switching technique requires lower processing complexity of its nodes and supports constant bit rate (CBR - Constant Bit Rate).
- On other hand, the packet switching technique requires higher processing complexity of its nodes and provides greater flexibility, supporting also bursty traffic and variable bit rate (VBR - Variable Bit Rate).



Switching Techniques

Circuit Switching

- Examples of networks based on circuit switching technique:
  - ***PSTN – Public Switched Telephone Network***
  - ***ISDN - Integrated Services Digital Network***
  - ***Cell Phone Network***

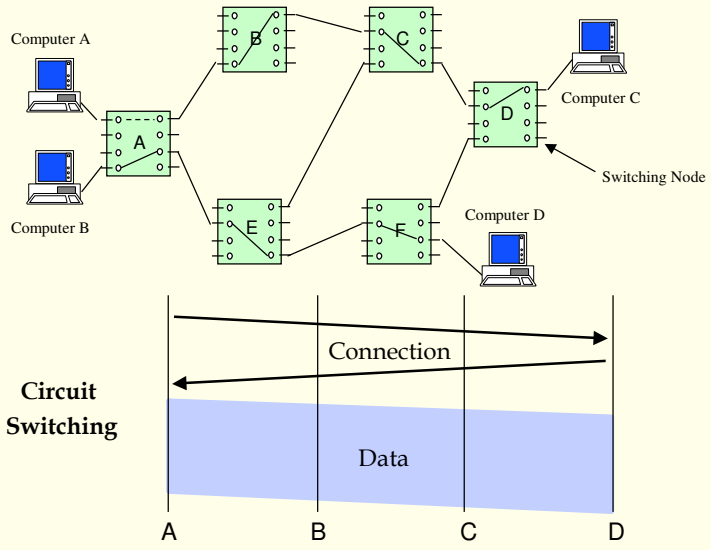
Circuit Switching

- The communication in a switched circuit network is performed in three phases:
  - ***Circuit Establishment***

    In a telephone network, the resources are allocated when we call the destiny number.
  - ***Data Transfer***

    Conversation period.
  - ***Circuit Release***

    Telephone disconnection.
- The circuit establishment and release are performed through a signaling mechanism between the nodes and imply some delay.

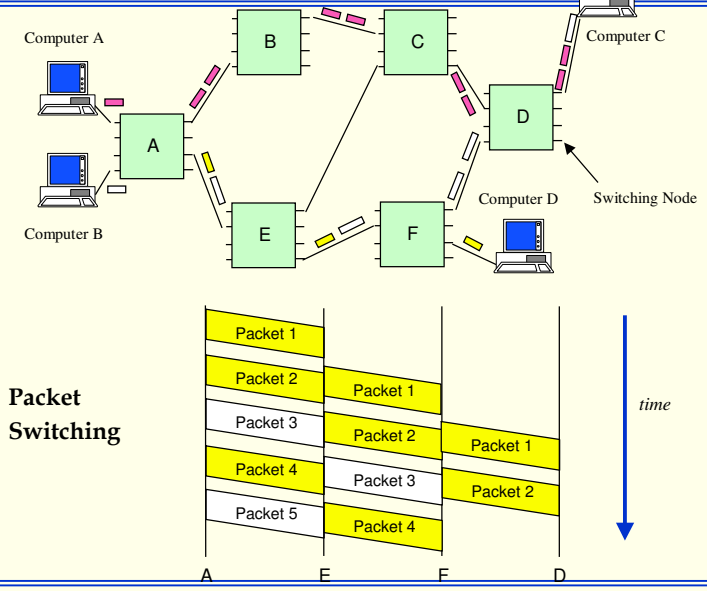


Circuit Switching Characteristics

- **The connection resources are kept allocated, even when there is no data being transferred.**
- If there is no enough resources for a connection establishment, the connection request is blocked or denied.
- The **delay in each node is not meaningful**.
- It is **not well-suited for bursty traffic**.
- It is proper for transmission of isochronous signals, such as voice and video.
  - ***Isochronous traffic*** - the received data has to be reproduced at the same rate of its generation.

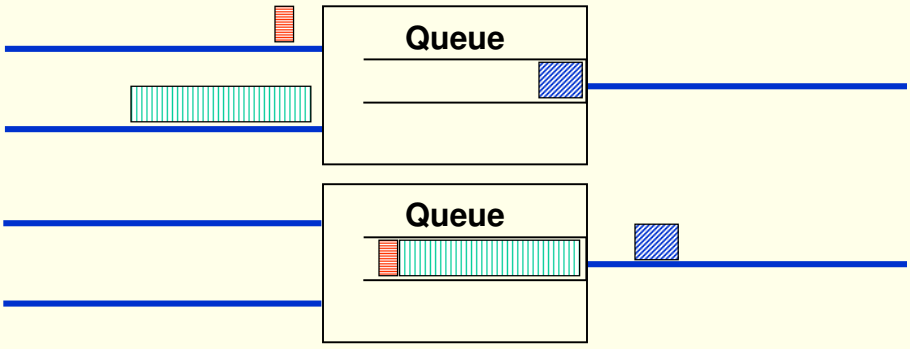
Packet Switching

- ***In packet switching networks, the resources are not previously reserved.***
  - The resources are allocated on-demand for the packets.
  - So, the packets have to wait in a queue if the required resource were not available.
- **The main network resource is the link**.
  - If the output link is already being used, the packet will be kept in a waiting queue and as consequence it will suffer a delay.
  - If the waiting queue is full, the incoming packets will be discarded.
- ***Why packets?***
  - Long messages monopolize the switch queues.



Packet Switching

- ***The packets are kept in a waiting queue if the resource is already being used.***
  - Long messages monopolize the switch queues.



Packet Switching

- ***The packet switching networks normally work with a packet maximum size:***
  - For this reason, the sender has to segment the too long messages in packets before they are sent to the network.

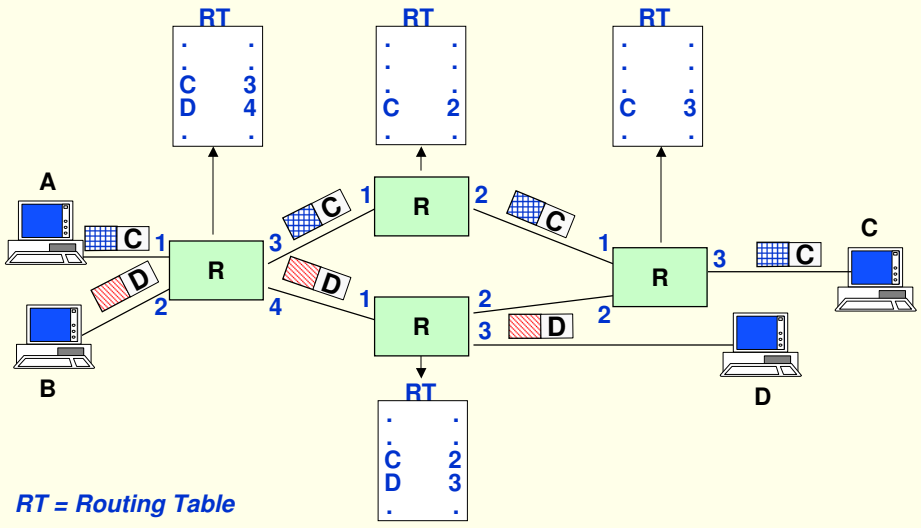
Characteristics of Packet Switching

- The link capacity is **shared** among several simultaneous communications.
- The **delay in each node is meaningful** due to the waiting time of the packets in the queues.
- It is not **well-suited for isochronous transmission**.
- It is very proper for **bursty traffic** as that one generated by data computer networks.
- In a packet switching network, the nodes accept the packets even when there is a high workload:
  - The packets are kept stored in queues until the necessary resources are available.
  - It implies that the delay can increase. The **delay is variable** and depends on the queue size.

Classes of Packet Switching

- There are two classes of packet switching:
  - ***Packet switching oriented to datagram.***
  - ***Packet switching oriented to virtual circuit.***

Packet Switching oriented to datagram

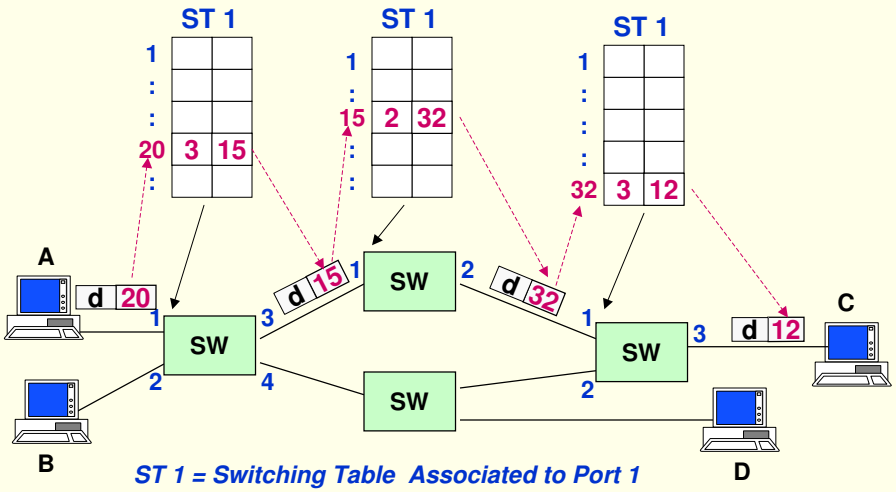


Packet Switching oriented to virtual circuit

- There are two types of ***virtual circuits***:
  - ***SVC (Switched Virtual Circuit)*** is a virtual circuit created and released on demand through a signaling protocol.
    - A special packet, called **signaling message,** is sent by the sender.
    - This message (Packet) passes from one switch to the next one until the destiny, establishing the path (virtual circuit).
  - ***PVC (Permanet Virtual Circuit)*** is a pre-configured virtual circuit.
    - The switching tables are manually configured.
    - Management systems can be deployed to remotely configure this table.

Packet Switching oriented to virtual circuit

- *Example*



Datagram x virtual circuit

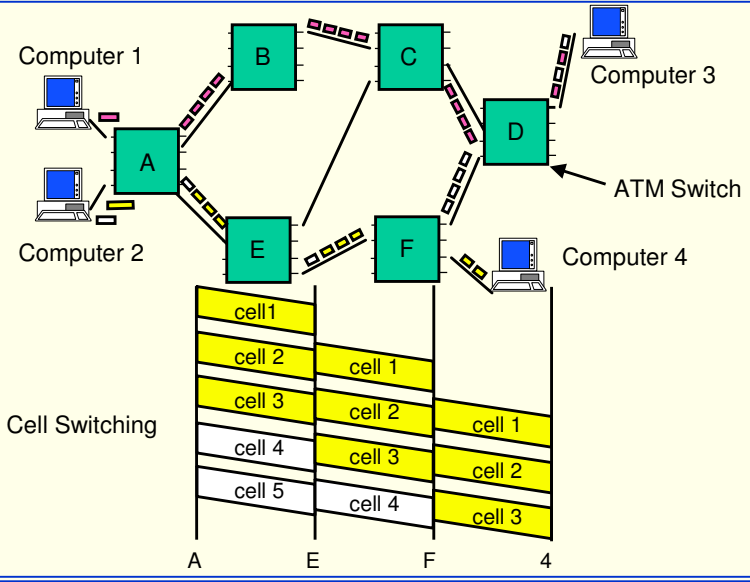
Datagram	Virtual Circuit
All packets carry the complete address.	The packets carry an identifier
Slow Switching: The routing is performed on demand.	Fast Switching: The routing is pre-performed.
The datagrams can be discarded during congestion periods.	It is possible to avoid congestion during the virtual circuit establishment.
Examples: **IP**, IPX, Ethernet, Token Ring	Examples: X.25, Frame Relay, **ATM**, **MPLS**

Routing and Switching Tables

- **Routing Table** is a table that associates destiny addresses to output ports (*links*).
  - It informs the output port to reach the specified destiny address.
- **Switching Table** is a table that associates a VCI of an input port to a VCI of an output port.
  - It indicates to which output port the packets that arrive at some input port should be sent.
  - It is built up during the virtual circuit establishment.
  - The output port is determined from the routing table.

Cell Switching

- **Characteristics:**
  - Evolution of Frame Relay
    - based on the **very low BER** of the current physical media
  - **Fixed length cells**
    - processing overhead is reduced
  - **Dynamic bandwidth allocation**
  - End-to-end error and flow control are NOT implemented
  - Supports constant or variable bit rate services
    - **Data, voice and video** over a single network
    - **The number of networks needed is reduced**



Cell Switching

- **Advantages:**
  - Supports **data (static and dynamic images), voice and video**.
  - Allows the combined transfer of different types of information.
  - Make possible the **integration of different types of networks and communication systems**.
- **Disadvantages:**
  - Does **not** operate in an **optimized way** for any type of network.
  - Requires an **infrastructure with low error rate and high transmission rate**.

Summaring...

Switching
- Low Jitter
- No Congestion
- Fixed Capacity
- Waste of Bandwidth
- Lower average availability
- Lower "overhead"

Packet/Frame Switching
- Jitter
- Supports burst traffic
- Statistics aggregated traffic
- Dynamic resource allocation
- Packet loss
- Alternative routes (traffic engineering)

Cell Switching
- Low processing "overhead"
- High header "overhead"
- Dynamic bandwidth allocation
- Support of different types of services

High-Speed Network Technologies

High-Speed Network Technologies

- As examples of high-speed networks:
  - Cell Switching
    - ATM (Asynchronous Transfer Mode).
  - Packet Switching
    - Gigabit Ethernet (Local and Metropolitan Networks).
    - MPLS over IP
    - IP
      - IP over SONET ou SDH.
      - IP over WDM ou DWDM.
      - IP over fiber.

ATM

Asynchronous Transfer Mode

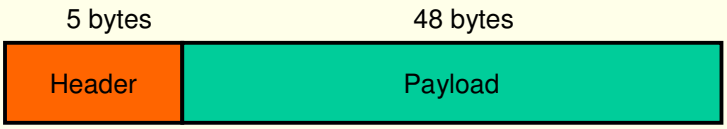
these slides are based on USP ATM slides from Tereza Carvalho

ATM Basics

- ITU-T approved standard for Broadband ISDN
- packet switching technique with fixed length packets (53 bytes):
  - cell switching
- support for multimedia applications (data, voice and video)
  - transmission media ⇨ high-speed data links
- ATM service model includes support to
  - constant bit rate ⇨ CBR
  - variable bit rate ⇨ VBR
  - available bit rate ⇨ ABR

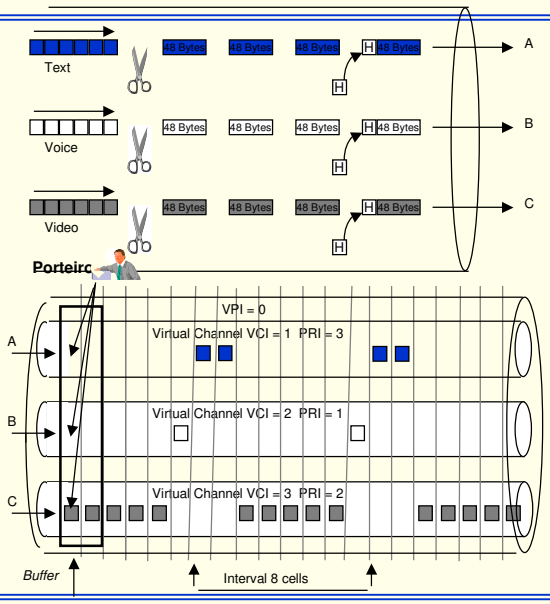
ATM cells

- ATM works with cells
  - packets with fixed length - 53 bytes
  - 5 bytes for the header + 48 bytes for payload



  - some advantages of using cells include
    - queuing delay for high-priority cells is reduced
    - switching is more efficient

      it is easier to implement switching hardware

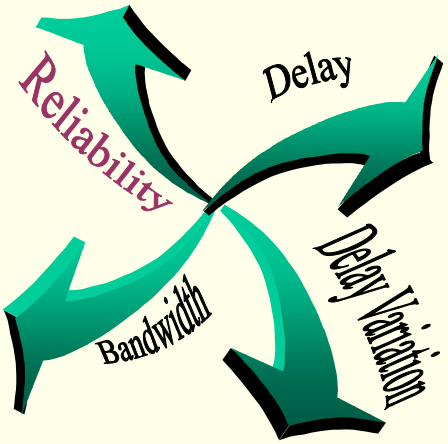


QoS no ATM: Traffic Shaping

ATM Services

- ATM Forum has defined 5 types of services
  - CBR ⇨ Constant Bit Rate
    - e.g. uncompressed audio & video
  - RT-VBR ⇨ Real Time Variable Bit Rate
    - e.g. real time video conferencing
  - NRT-VBR ⇨ Non-Real Time Variable Bit Rate
    - e.g. banking transactions, airline reservation
  - ABR ⇨ Available Bit Rate
    - e.g. burst applications (browsing)
  - UBR ⇨ Unspecified Bit Rate
    - e.g. data transfer

Multimedia Application Requirements



ATM – Quality of Service

- **Delay and Delay Variation**
  - Prioritization of different service types:
    - CBR, rt-VBR, nrt-VBR, ABR, UBR
  - Time Stamp: AAL1 e AAL2.
- **Bandwidth**
  - Bandwidth reservation.
- **Reliability**
  - Congestion control.
  - Header error detection and recovery.
  - Adaptation Layer.

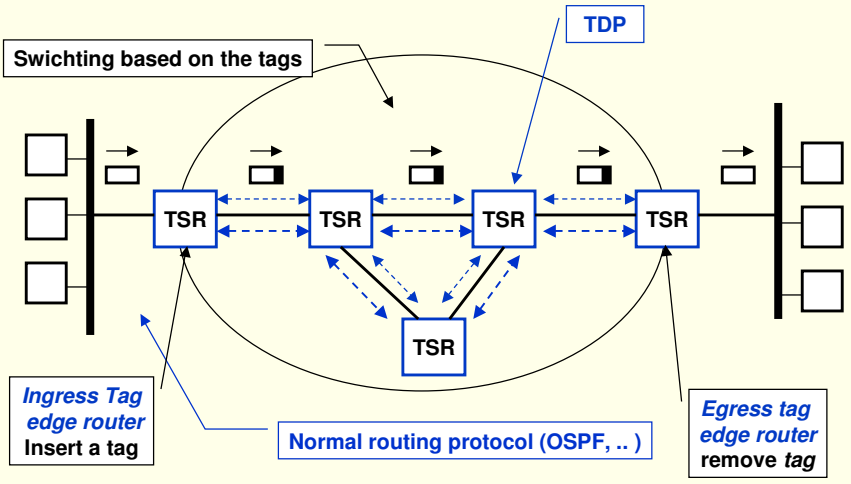
MPLS

MultiProtocol over Label Switching

MPLS (MultiProtocol Label Switching)

- Corresponds to IETF standard for **tag switching**.
- The routing is performed deploying the **traditional routing protocols** such as RIP, OSPF ou BGP. It is possible to use also static routes.
- The switching is performed deploying **labels** (or tags wit local meaning).
- This technique can be used jointly with ATM networks, associating labels to VPI/VCI.

Tag Switching



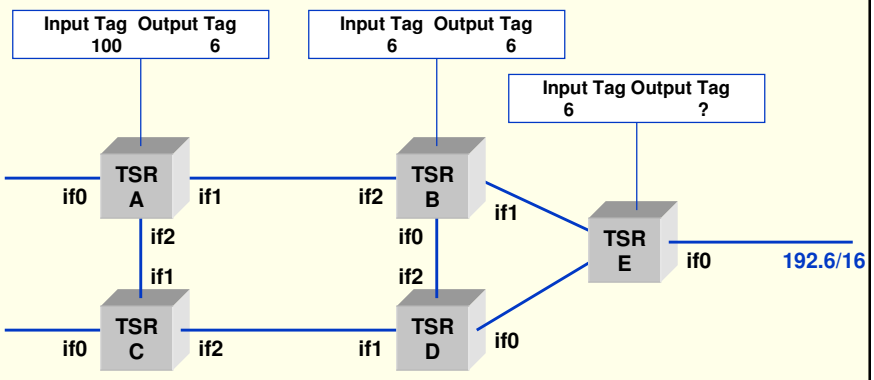
Tag Switching

- Example of transmission in a network with *tag switching*

	Input tag	*output tag*	*next step*	*output interface*
at TSR A	100	6	TSR B	if1
at TSR B	6	6	TSR E	if1
at TSR C	17	5	TSR D	if2
at TSR D	5	6	TSR E	if0
at TSR E	6	?	TSR E	if0

Tag Switching

- Example of transmission in a network with *tag switching*



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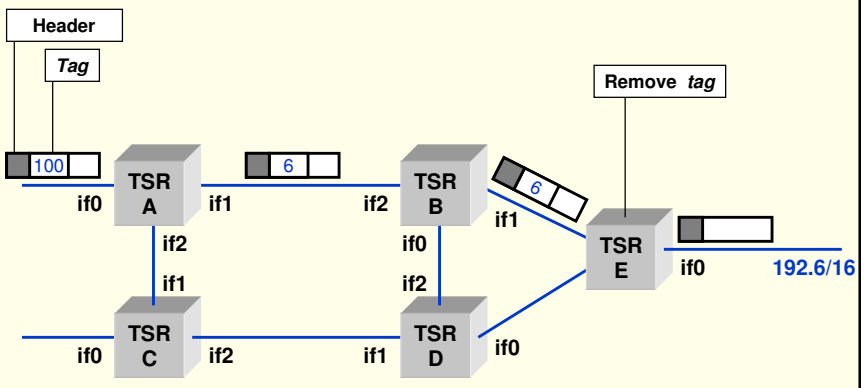
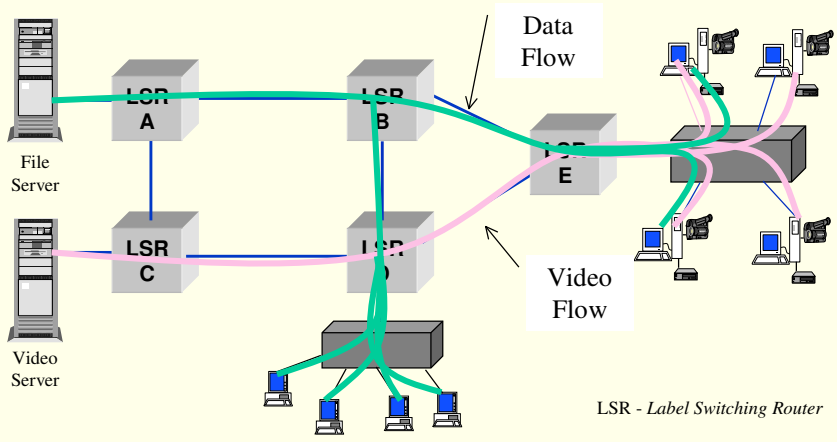


MPLS (MultiProtocol Label Switching)

- Uses the **tag switching** technique.
- Uses **prioritization mechanisms**.
- The **packet priority** is define by the **TOS (Type Of Service)** field containing in the IP packet header.
- 8 different classes of service are defined.
- This field is initiated by the edge switches. In this case, all switches work with different queues with different priorities.
- These switches can also implement **congestion control mechanisms**. In the case of congestion, the network request to its end-nodes to reduce the generated traffic.

MPLS (MultiProtocol Label Switching)

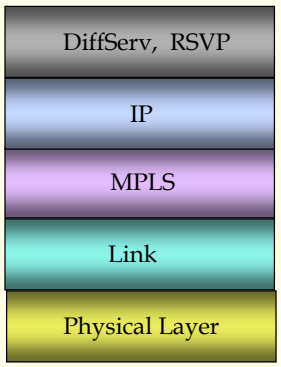
- MPLS allows the creation of different information flows with different service classes.



Diffserv (Differentiated Service)

- It is used to define different service classes that can be associated to different values of the IP packet field -TOS (Type Of Service), or DS (Differentiated Services) as it is called in the case of DiffServ.
- The services classes are:
  - **Premium Service:** for applications with low delay and delay variation. For instance: IP Phone, Videoconference e Virtual Private Lines over VPNs.
  - **Assured Service:**for applications that require nore reliability than the Best Effort Service.
  - **Oympic Service:** provide 3 levels of service with different quality:
    - Gold, Silver e Bronze.

Diffserv (Differentiated Service)



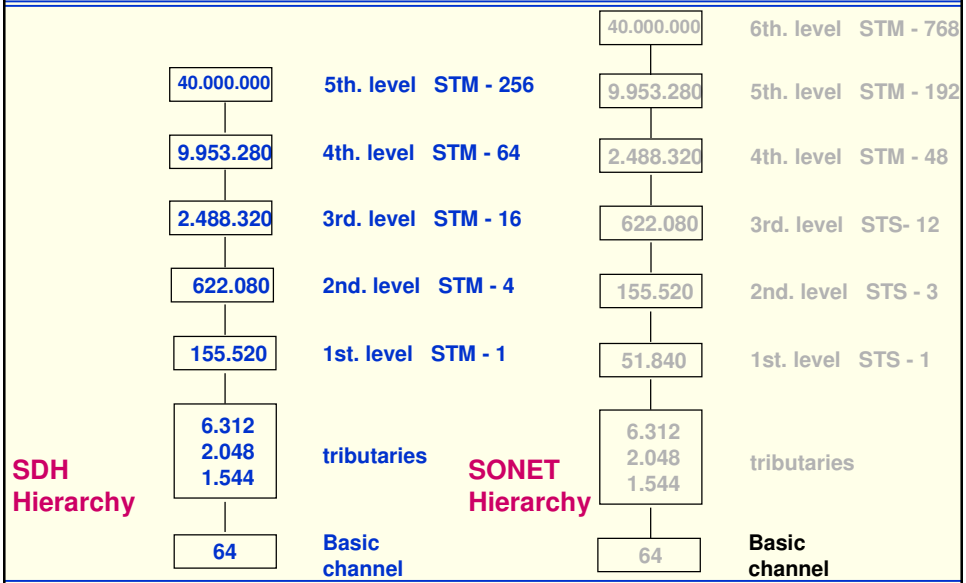
DiffServ Model

- The DiffServ can be used with MPLS.
- The routers provide QOS and traffic control.

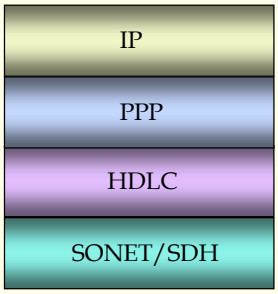
IP

IP over SDH/SONET
IP over DWDM
IP over dark fiber

IP over SONET/SDH



IP over SONET/SDH



IP *over* SONET/SDH Model

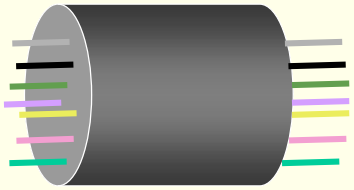
- In this case, the following protocols are deployed:
  - IP – datagram transmission with different service classes and congestion control.
  - PPP – responsible for the link initialization and the packing/unpacking.
  - HDLC – responsible for the frame delimitation and error control.
  - SONET/SDH – physical layer

IP over WDM ou DWDM

- In the case of WDM (Wavelength Division Multiplexing)/ DWDM (Dense WDM) networks, the fiber capacity is multiplexed through the **usage of several wavelengths**.
- The most important motivation for WDM network deployment is the difficulty in converting optical signals to/from electrical signals at a rate greater than Gigabits/second.
- The WDM technique allows to **optimize the usage of the whole fiber capacity**.

IP over WDM ou DWDM

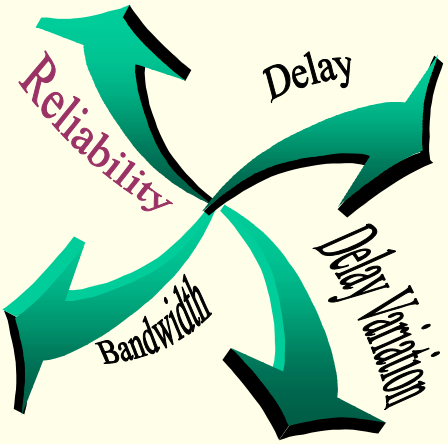
- In the case of DWDM, it is possible to have for instance:
  - **2,5 Gbps Channels:**
    - 16 Channels = 40 Gbps.
    - 24 Channels = 60 Gbps.
    - 40 Channels = 100 Gbps.
    - 80 Channels = 200 Gbps.
  - **10 Gbps Channels:**
    - 4 Channels = 40 Gbps.
    - 16 Channels = 160 Gbps.
    - 128 Channels = 1280 Gbps.



IP over Fiber

- Other option is to deploy IP over dark fiber.
- In this case, the **transmission and the reception of the optical signals** can be performed by the **routers**.
- It can be used in **limited geographical areas** (It is supposed no usage of regenerators).
- There is a very good usage of the fiber transmission capacity.
- It supports bandwidth scalability.

Multimedia Application Requirements



IP and QoS

- **Delay and Delay Variation**
  - Prioritization of different service types.
  - Time Stamp: RTP (Real Time Protocol) and RTCP (Real Time Control Protocol).
- **Transmission Bandwidth**
  - Bandwidth Allocation: RSVP
- **Reliability**
  - Congestion Control.
  - Error Recovery by TCP or any application.

Final Considerations

- The concept of high-speed networks has changed very fast with the technology advances:
  - The **optical fiber** is one of the most important change factor.
  - As consequence, **new types of applications** have become possible.
- The Internet 2 community concentrates research related to:
  - **Optical networks** as Reuna, Giga, Kyatera, Lambda-Rail, Geant-2.
  - **Advanced Applications**:
    - Grid Computing (infra-structure).
    - e-Science.
    - e-Medicine.
    - e-learning.

Acknowledgments

Thanks to:

Prof. Stephan Kovach and Denis Gabus from the Network and Computer Architecture Laboratory (LARC) from the Department of Computer Engineering - Escola Politécnica - Univ. of Sao Paulo (USP) - Brazil