网络与通信

交换与网络
Switching

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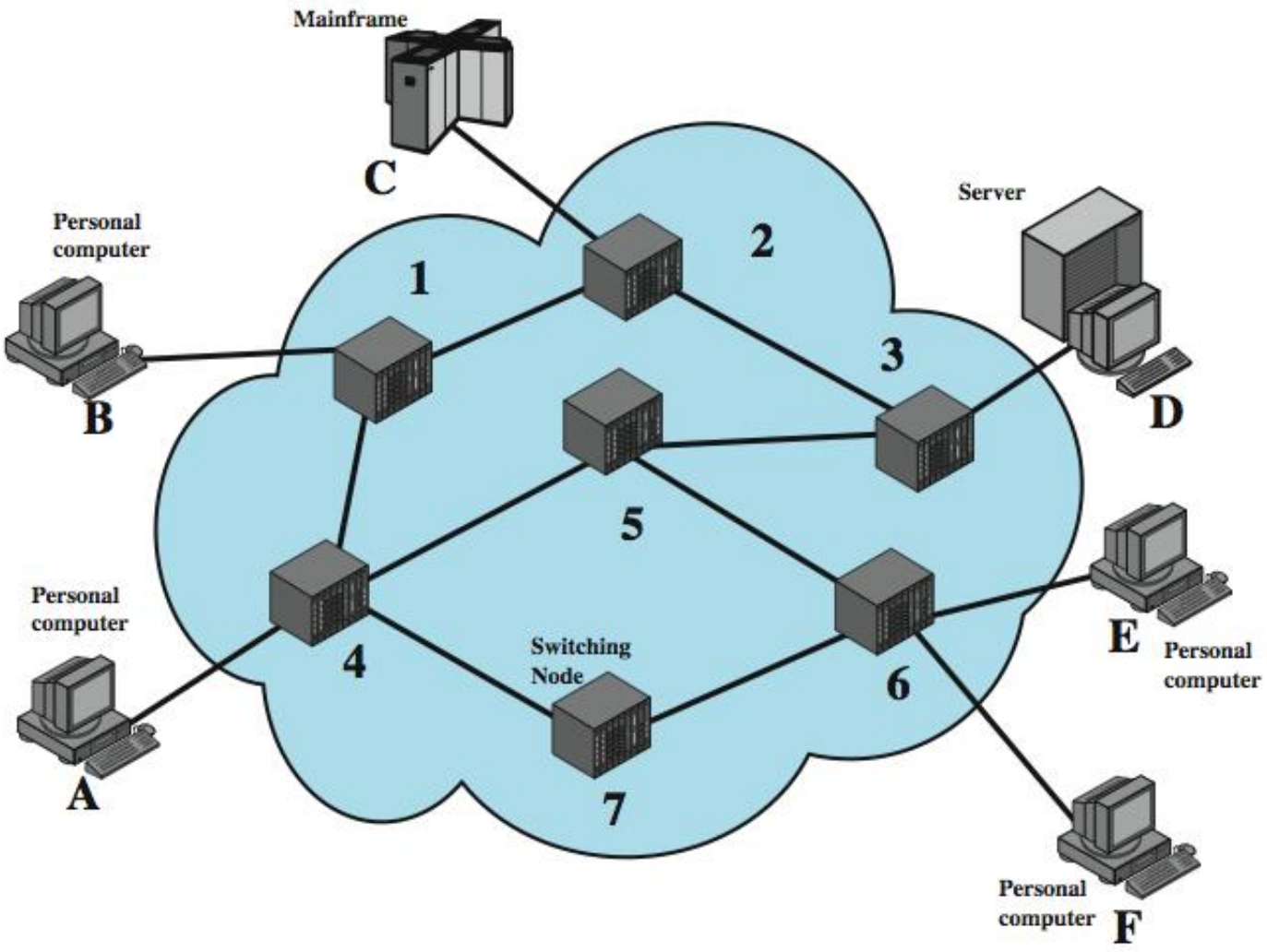
Switching

1. **Switched Communication Networks**
2. Circuit-Switching Networks and PSTN
   - Soft-switch Architecture
3. Packet-Switching Principles
4. Connection-oriented network and Service Quality

Switched Communications Networks

- switching nodes provide a switching facility that move data between nodes
- **stations** – devices attached to the network
- **nodes** – switching devices that provide communication
  - connected by transmission links
  - dedicated point-to-point
  - usually multiplexed using either FDM or TDM

Switched Network



On Fully Connected Networks

- Costs of links is too high
  - n nodes: links = n(n-1)/2
  - 5 nodes: 10 links
  - 100 nodes: 495 links
- Time spent for generating and examining topologies
  - 5 nodes: 10 links,
  - 4 possible cases:
    - high, middle and low speed; and faults
  - number of total topologies = 4^{10}=1,048,576
  - processing time 100ms per topology
  - Total time = 104,857.6s, i.e. 29 hours

Communication Networks

communications network – a collection of nodes

in addition to switching functions, some nodes also deliver data to attached stations

network is not fully connected so there is not a direct link between every possible pair of nodes

redundant connections increase network reliability

switching technologies:

- circuit switching
- packet switching

Switching

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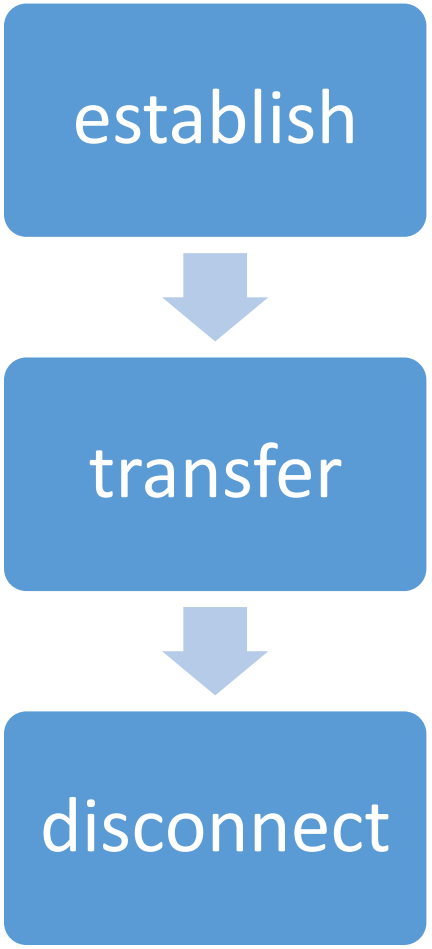
Circuit Switching

- 电路交换
  - 用于公众电话网 PSTN
  - 建立租用线专用网的基础，用于租用方内部电路交换
  - 为处理话音通信量（voice traffic）而开发，但也能处理数字数据
- 使用电路交换的通信
  - 在两个站点之间建立固定通路
  - 通信期间在网络内部保留交换与传输资源
  - 一旦电路建立，网络连接是透明的

Circuit Switching

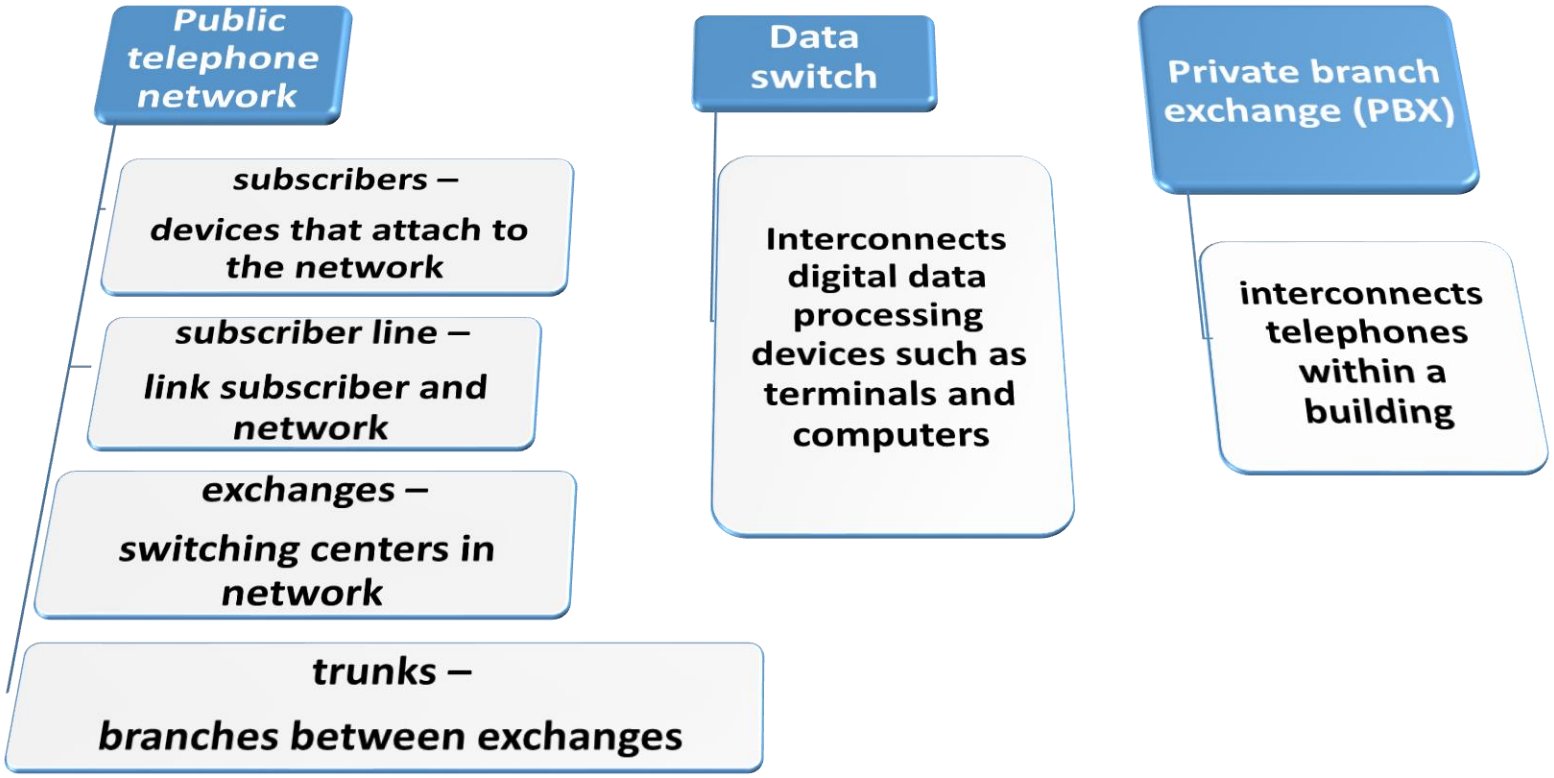
- uses a dedicated path between two stations
- can be inefficient
  - channel capacity dedicated for duration of connection
  - if no data, capacity wasted
- set up (connection) takes time
- once connected, transfer is transparent

- has three phases

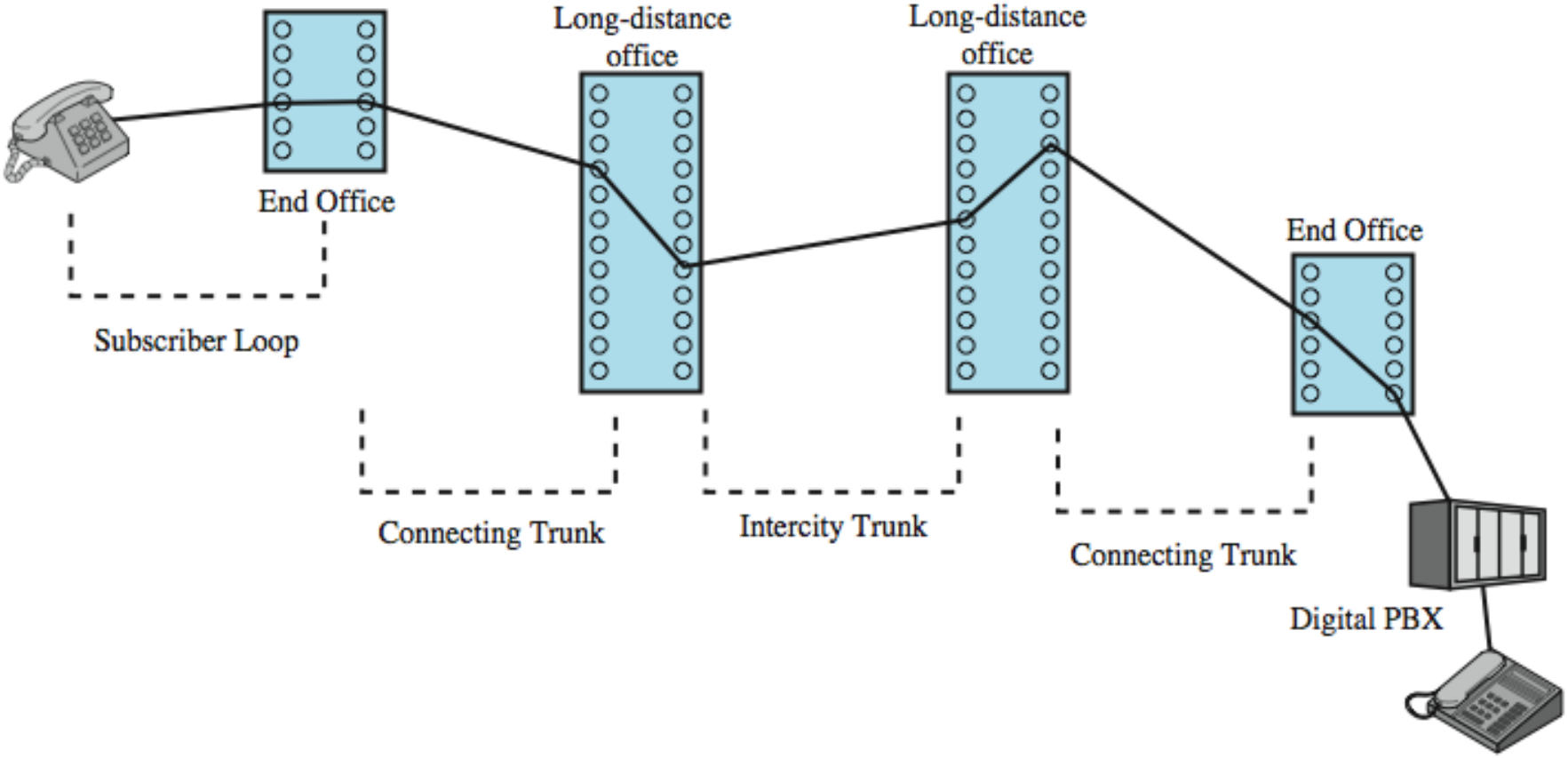


Public Telecommunications Networks

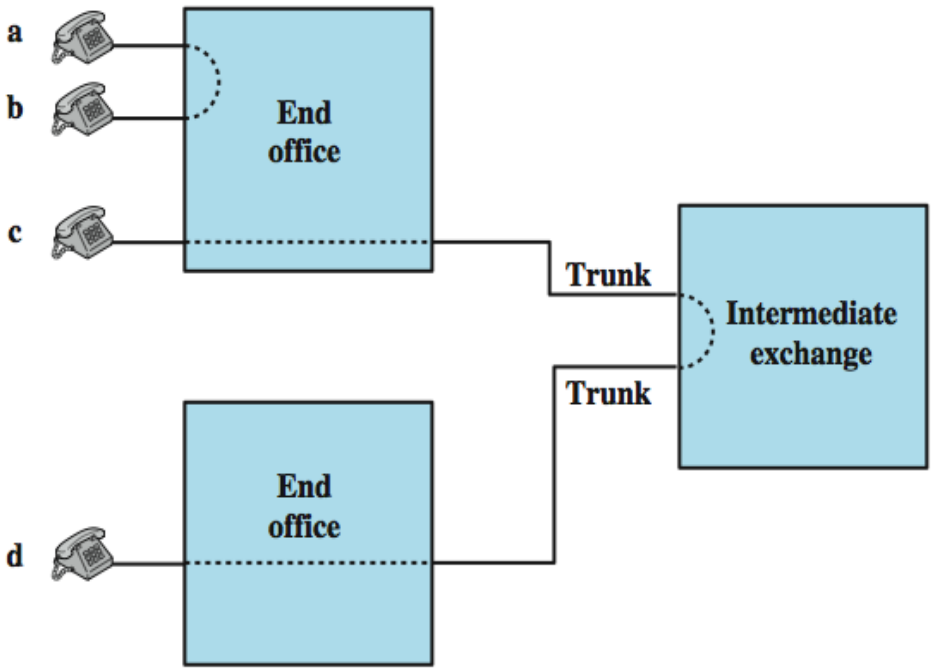
- Examples of circuit switching network:



Public Circuit Switched Networks



Circuit Establishment



- 保留容量
  - 在通话持续期间保留电路容量
  - 在每个交换机保留
  - 在每条中继线上保留
- 保留电路容量以保证吞吐率
  - 获得的吞吐量决不会小于保留的容量
  - 网络不会出现拥塞这样的情况
- 保留电路容量是昂贵的
  - 无论是否利用都要付费
  - 适合话音，因为会话是相当平稳的
  - 不太适合数据，因为大多数数据是突发的

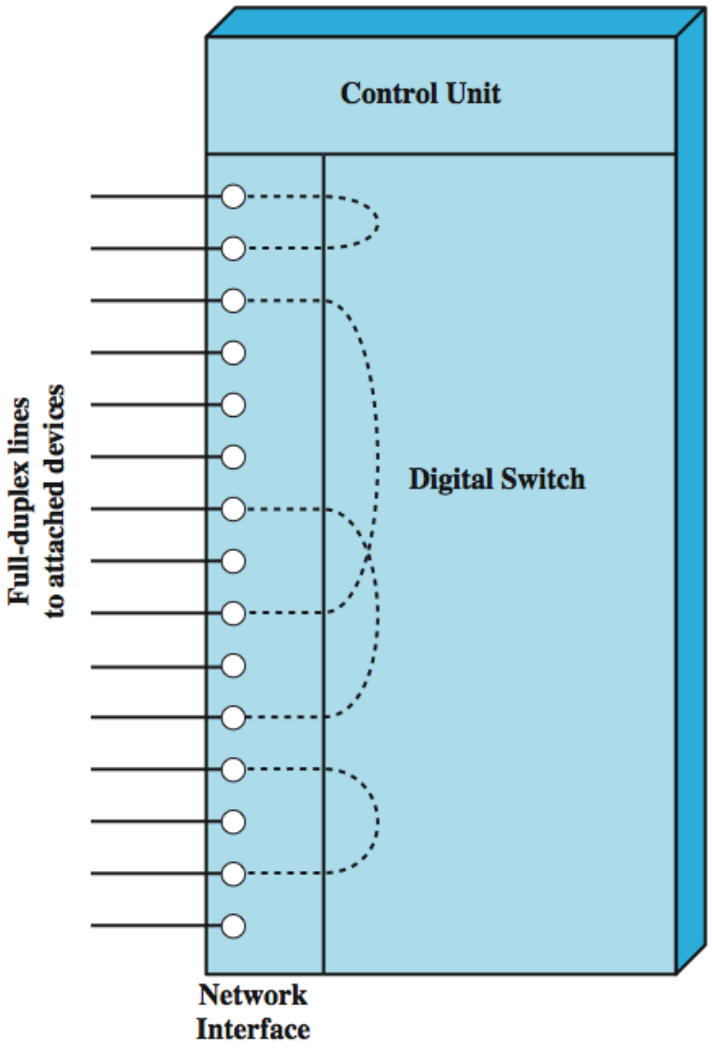
Circuit Switching Technology

- Driven by applications that handle voice traffic
  - Key requirement is no transmission delay and no variation in delay
- Efficient for analog transmission of voice signals
- Inefficient for digital transmission
- Transparent
  - once a circuit is established it appears as a direct connection; no special logic is needed

Circuit-Switching Concepts

- 了解电路交换技术的最好方法是考察单个交换节点的操作过程
- 围绕单个电路交换节点建立的网络由一组连接到该中央交换单元的站点构成
- 中央交换单元在希望相互通信的任意两个站点间建立一条固定容量的专用通路

Circuit-Switching Elements



digital switch

- provides a transparent signal path
- must allow full-duplex transmission

network interface

- functions and hardware needed to connect digital devices

control unit

- establishes, maintains, and tears down the connection

Blocking or Non-Blocking

Blocking network

- may be unable to connect stations because all paths are in use
- used on voice systems because it is expected for phone calls to be of short duration and that only a fraction of the phones will be engaged at any one time

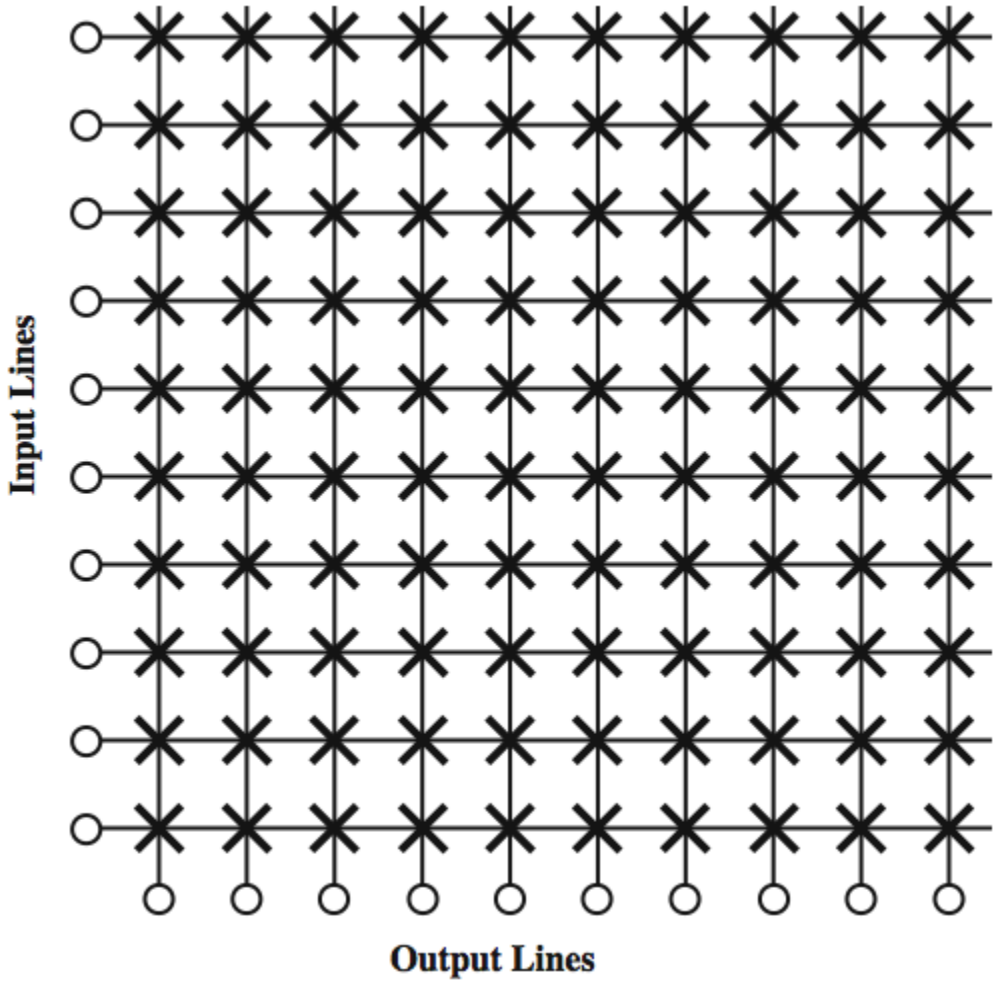
Non-blocking network

- permits all stations to connect at once
- grants all possible connection requests as long as the called party is free
- when using data connections terminals can be continuously connected for long periods of time so nonblocking configurations are required

Space Division Switching

- originally developed for analog, space division switching has been carried over into the digital realm
- signal paths are physically separate from one another
- path is dedicated solely to transfer signals
- basic building block of switch is a metallic crosspoint or semiconductor gate

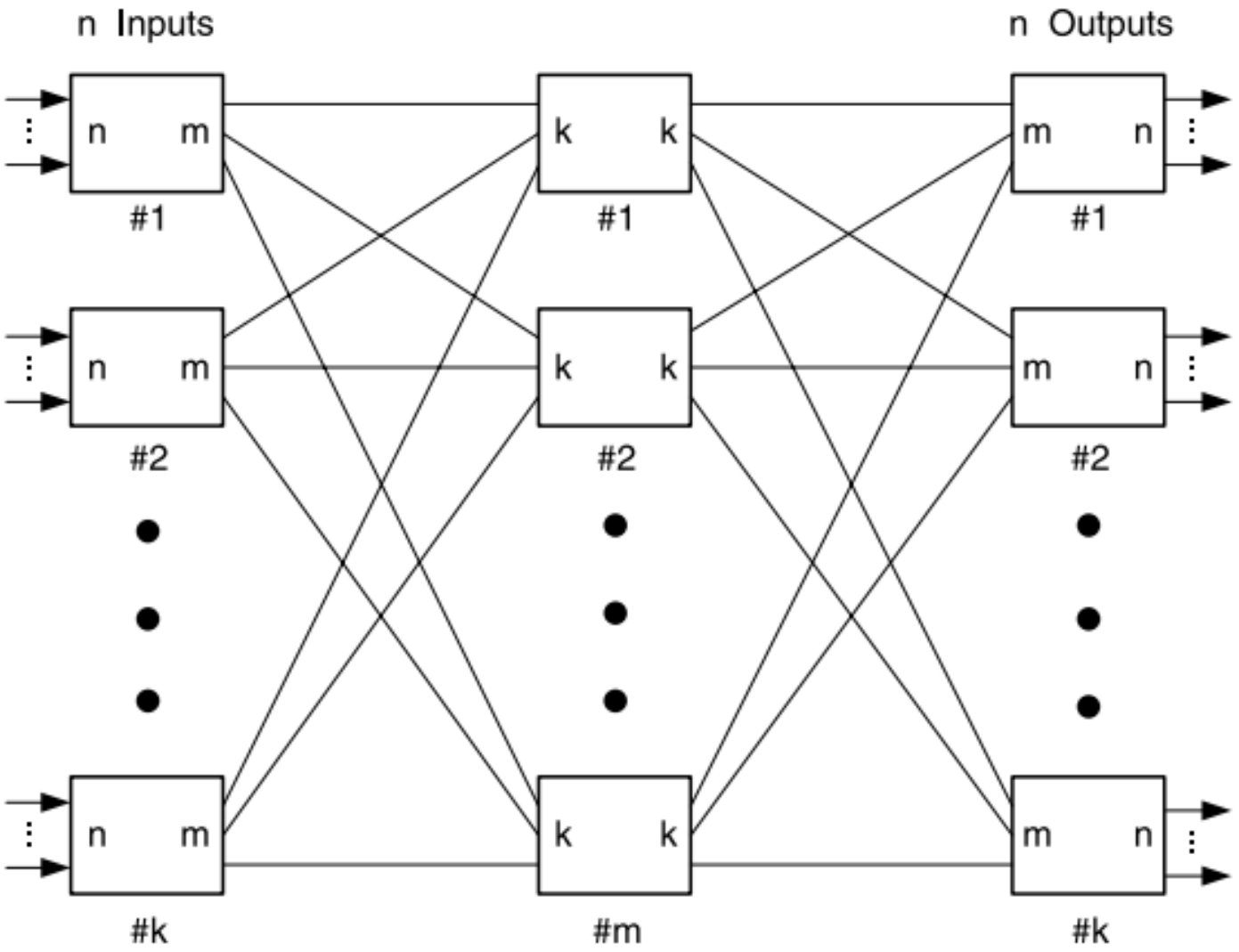
Space Division Switching



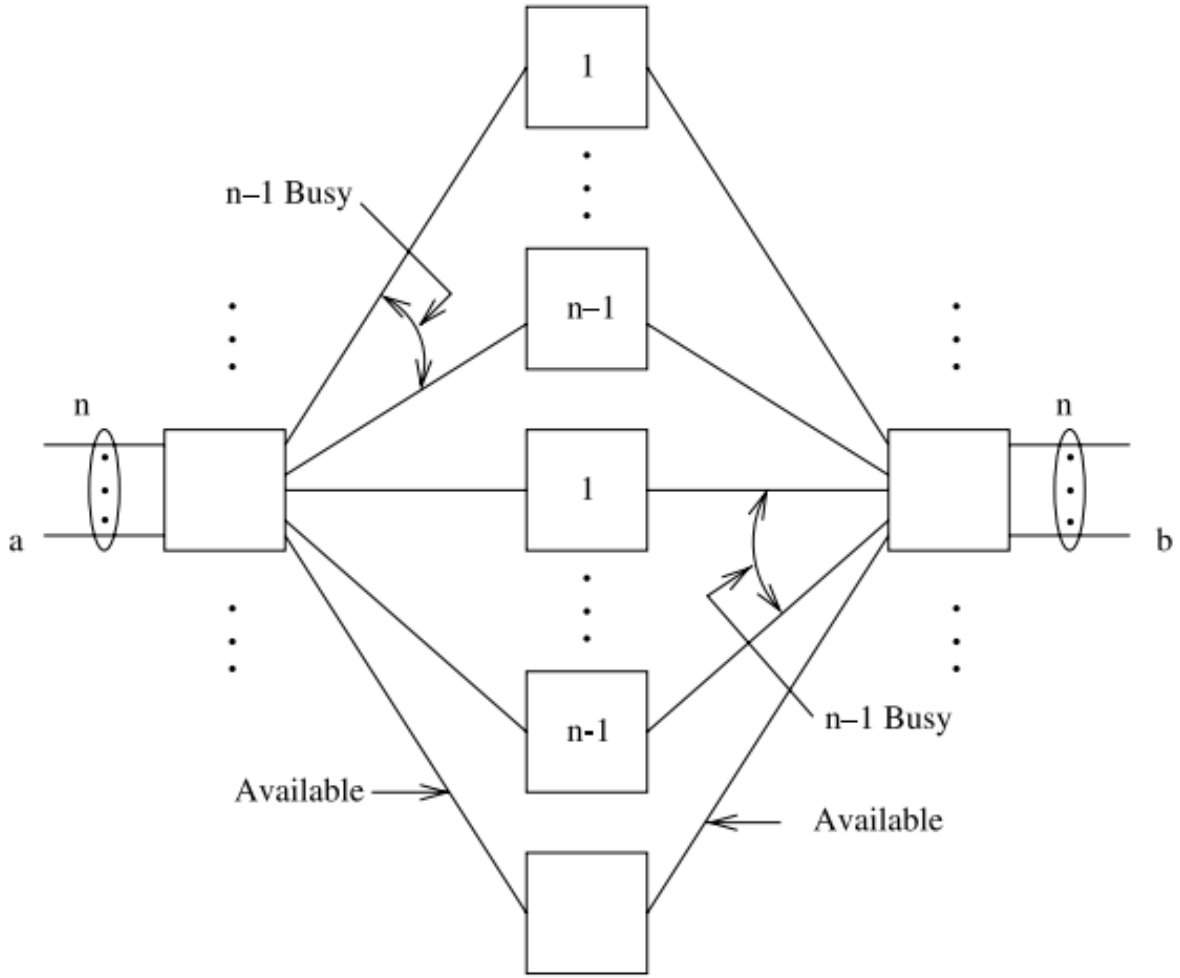
Crossbar Switch Fabric

- 交叉点的数目按站点的平方增加
- 交叉点的丧失将阻隔连接
- 交叉点利用不充分
  - 所有站点连接，只用到很少交叉点，
- 非阻塞的

3-stage Space Division Switching

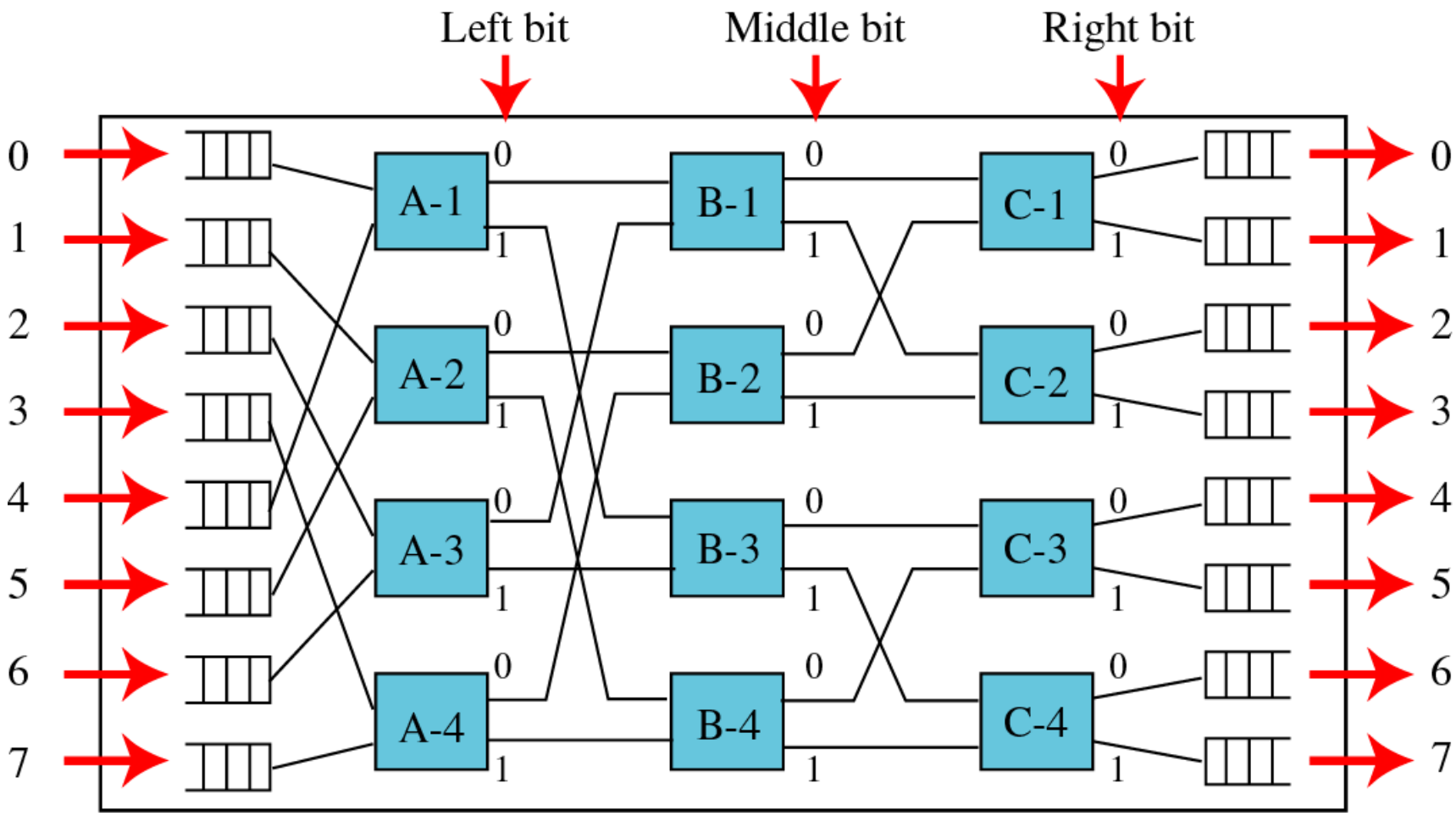


3-stage Space Division Switching

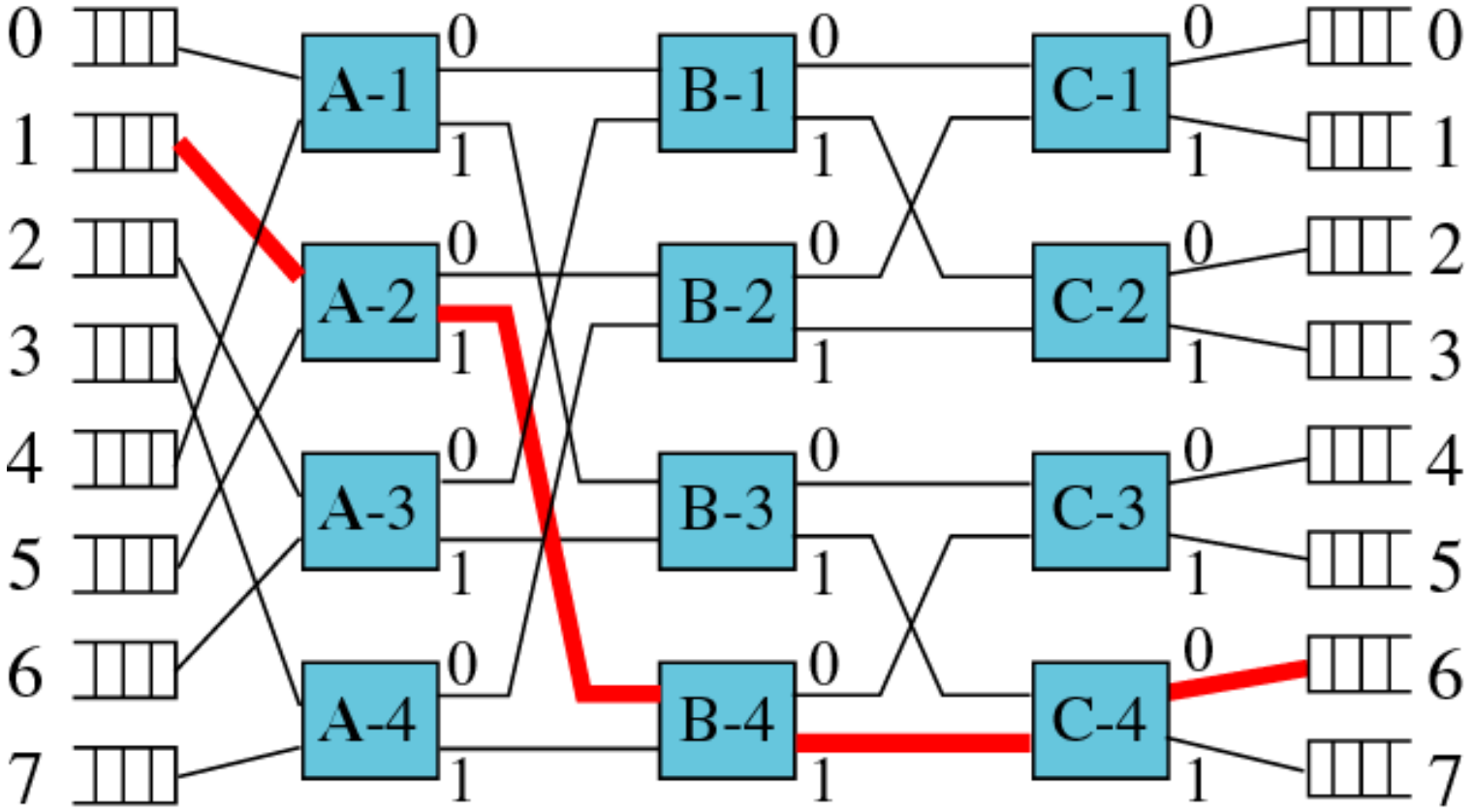


Nonblocking condition for a three-stage Clos switch $m \geq 2n - 1$

Banyan Switch

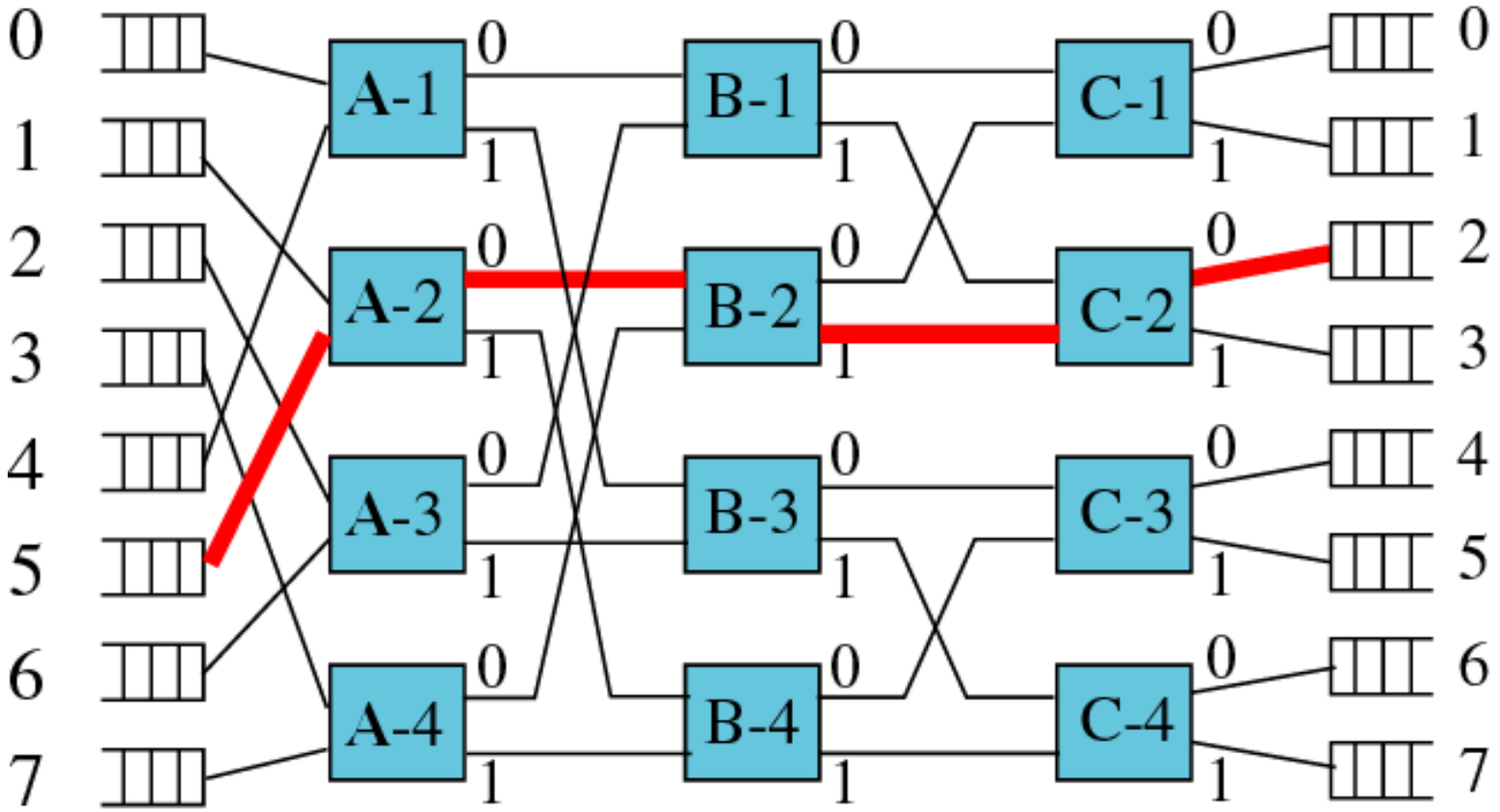


Routing in a Banyan Switch (a)



a. Input 1 sending a cell to input 6 (110)

Routing in a Banyan Switch (b)



b. Input 5 sending a cell to input 2 (010)

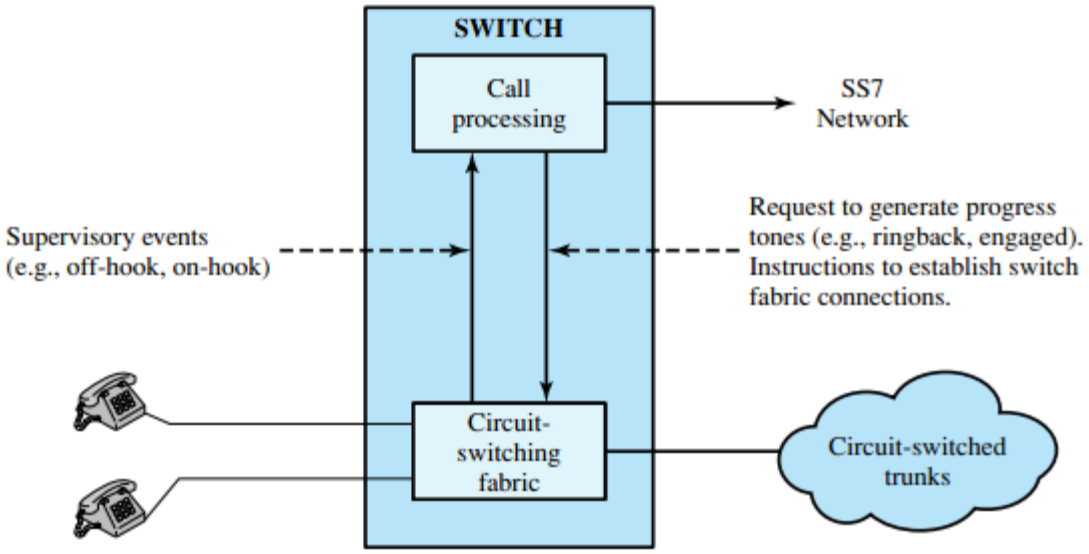
Time Division Switching

- modern digital systems use intelligent control of space & time division elements
- use digital time division techniques to set up and maintain virtual circuits
- partition low speed bit stream into pieces that share higher speed stream
- individual pieces manipulated by control logic to flow from input to output

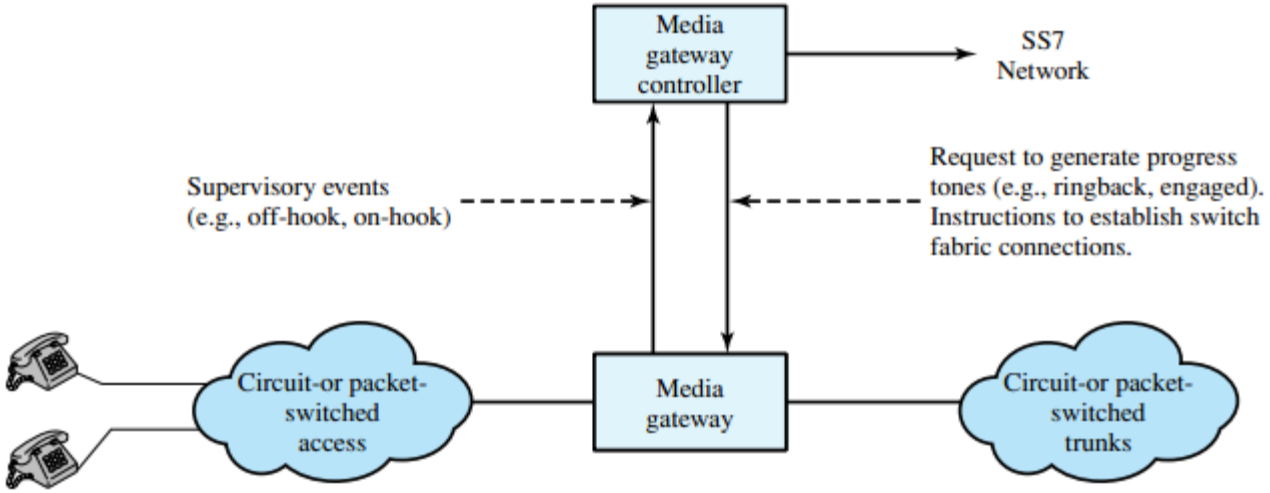
Softswitch Architecture

- latest trend in circuit-switching technology
- computer running specialized software that turns it into a smart phone switch
- costs less and provides more functionality
- Media gateway (MG) – physical switching
- Media gateway controller (MGC) – call processing logic

Traditional Circuit Switching vs. Softswitch



(a) Traditional circuit switching



(b) Softswitch architecture

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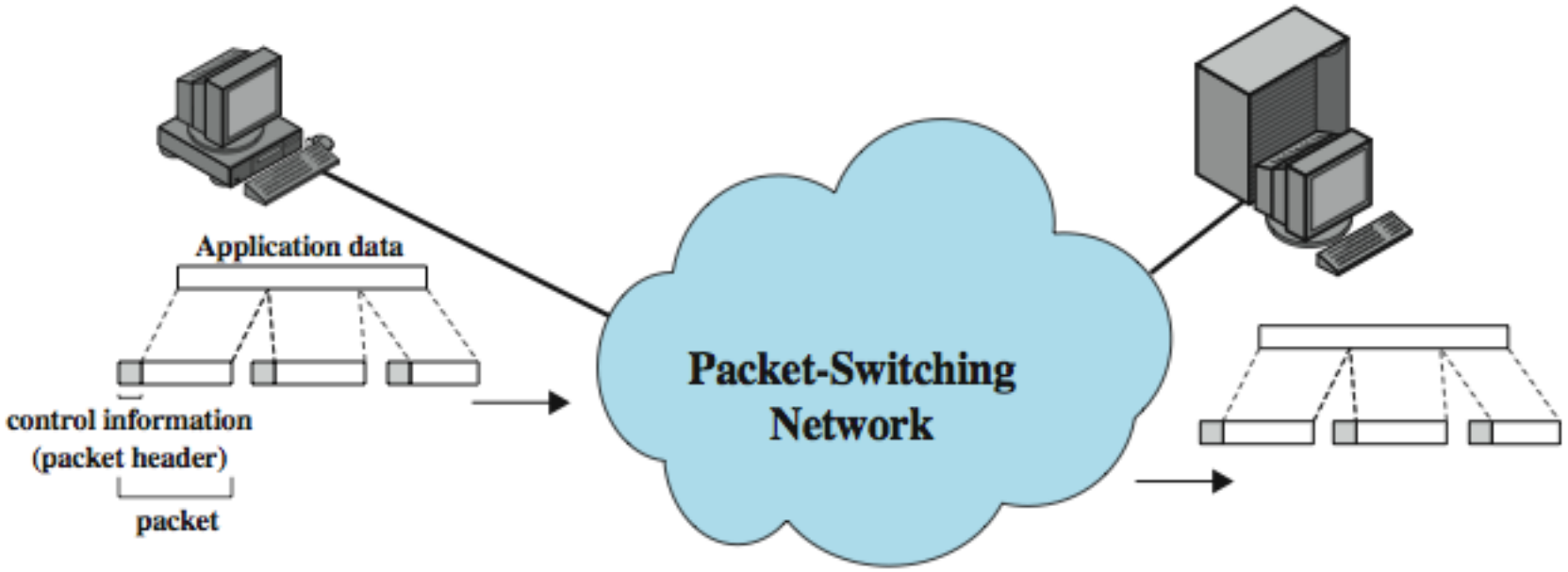
Packet Switching

- circuit switching was designed for voice
- packet switching was designed for data
- transmitted in small packets
- packets contains user data and control info
  - user data may be part of a larger message
  - control information includes routing (addressing)
- packets are received, stored briefly (buffered) and passed on to the next node

Packet Switching



Advantages

- line efficiency
  - single link shared by many packets over time
  - packets queued and transmitted as fast as possible
- data rate conversion
  - stations connects to local node at own speed
  - nodes buffer data if required to equalize rates
- packets accepted even when network is busy
- priorities can be used

Switching Techiniques

- station breaks long message into packets
- packets sent one at a time to the network
- packets can be handled in two ways:
  - datagram
    - each packet is treated independently with no reference to previous packets
  - virtual circuit
    - a preplanned route is established before any packets are sent

Datagram Diagram and VC Diagram

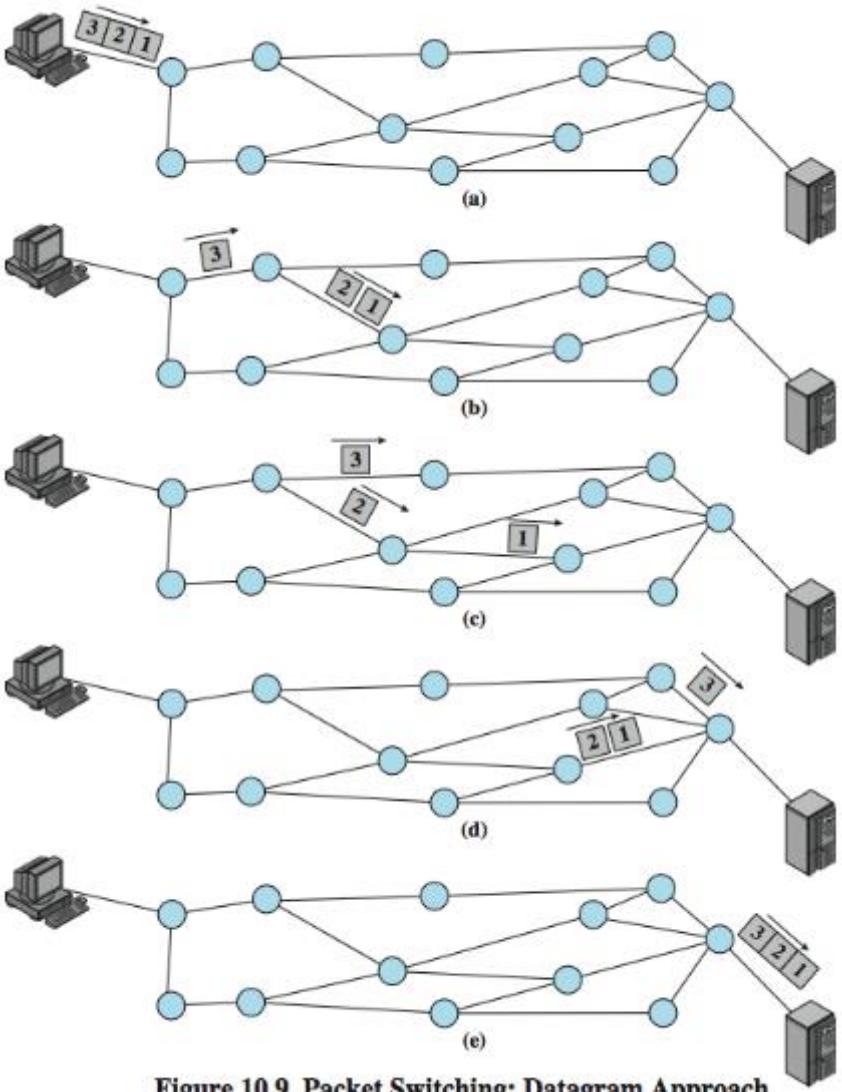


Figure 10.9 Packet Switching: Datagram Approach

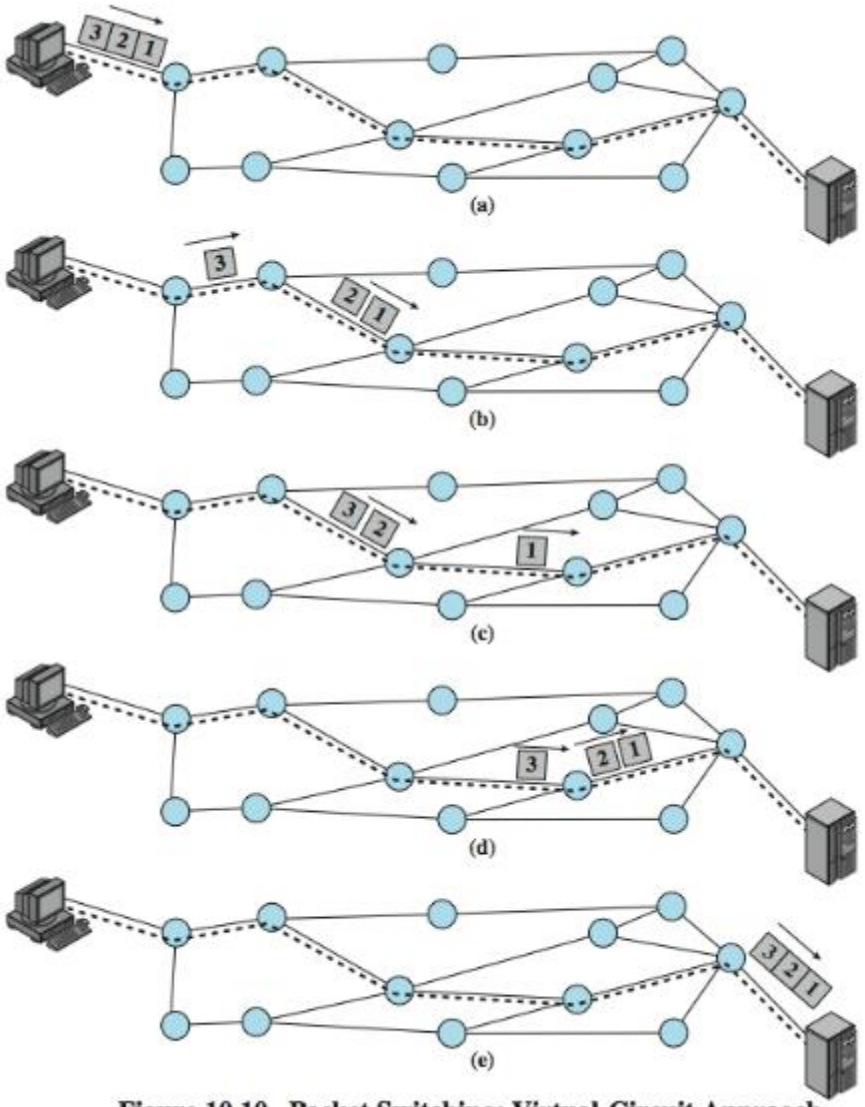
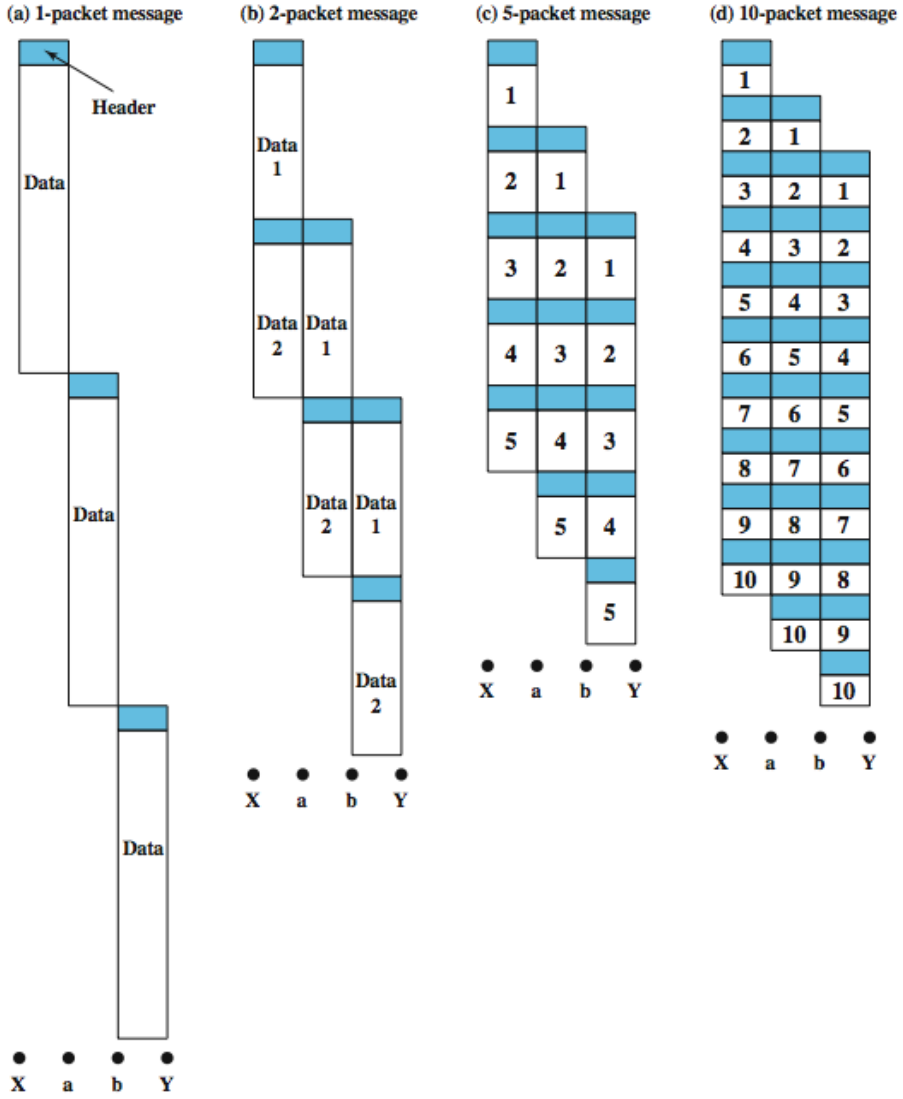


Figure 10.10 Packet Switching: Virtual-Circuit Approach

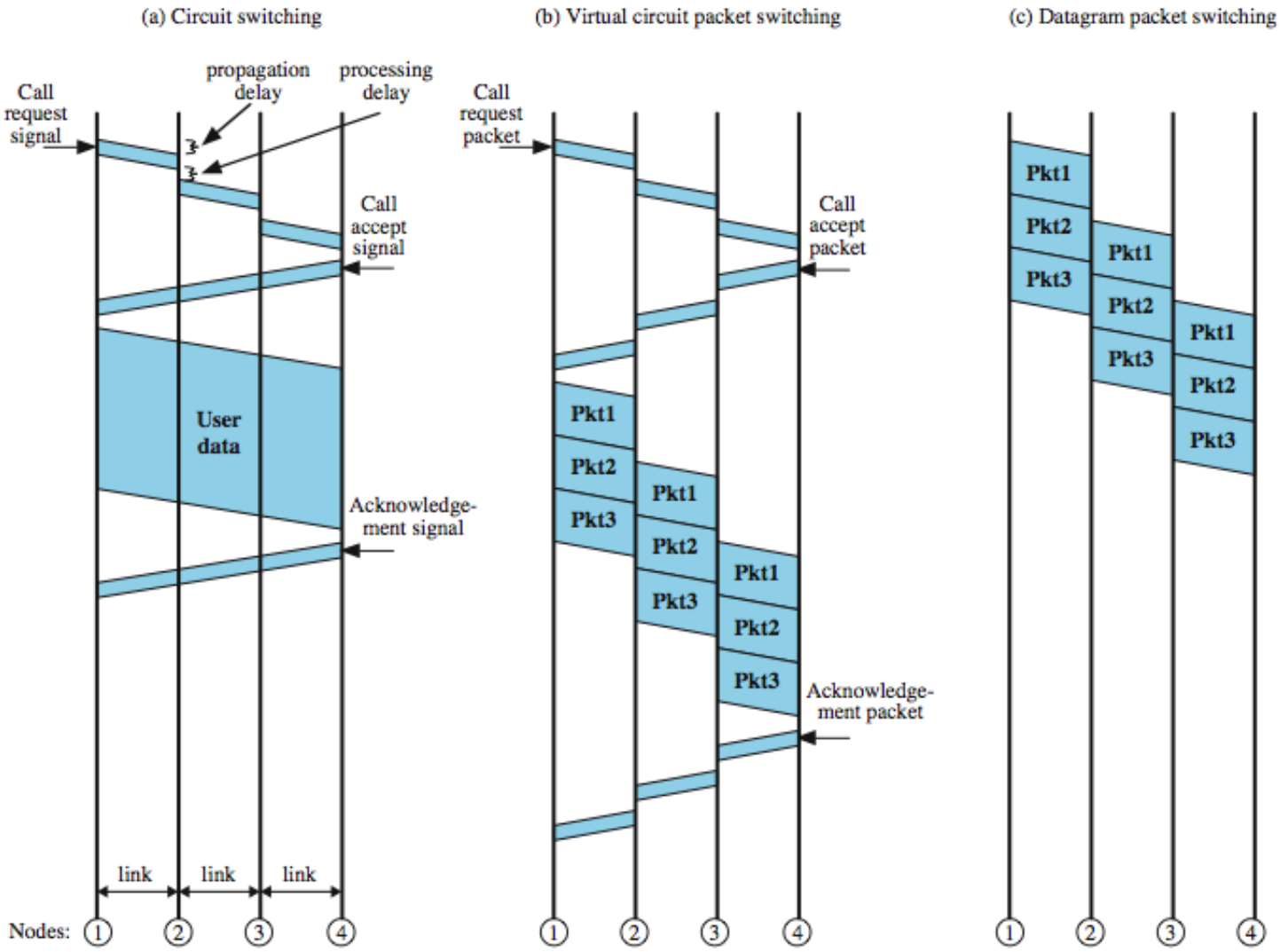
Virtual Circuits vs. Datagram

- virtual circuits
  - network can provide sequencing and error control
  - packets are forwarded more quickly
  - less reliable
- datagram
  - no call setup phase
  - more flexible
  - more reliable

Packet Size and Transmission Time



Event Timing



Communication Switching Techniques

Circuit Switching	Datagram Packet Switching	Virtual Circuit Packet Switching
Dedicated transmission path	No dedicated path	No dedicated path
Continuous transmission of data	Transmission of packets	Transmission of packets
Fast enough for interactive	Fast enough for interactive	Fast enough for interactive
Messages are not stored	Packets may be stored until delivered	Packets stored until delivered
The path is established for entire conversation	Route established for each packet	Route established for entire conversation
Call setup delay; negligible transmission delay	Packet transmission delay	Call setup delay; packet transmission delay
Busy signal if called party busy	Sender may be notified if packet not delivered	Sender notified of connection denial
Overload may block call setup; no delay for established calls	Overload increases packet delay	Overload may block call setup; increases packet delay
Electromechanical or computerized switching nodes	Small switching nodes	Small switching nodes
User responsible for message loss protection	Network may be responsible for individual packets	Network may be responsible for packet sequences
Usually no speed or code conversion	Speed and code conversion	Speed and code conversion
Fixed bandwidth	Dynamic use of bandwidth	Dynamic use of bandwidth
No overhead bits after call setup	Overhead bits in each packet	Overhead bits in each packet

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4. **Connection-oriented network and Service Quality**
   1. **X.25, Frame Relay**
   2. **Asynchronous Transfer Mode (ATM)**
   3. **MPLS**

Data Communication Network

无连接（即数据报）还是面向连接？

- 网络可靠性，容错
  - Incast，阻塞（blocking），数据包丢失
  - 不适合实时音频和视频传输

- 服务质量，计费
  - 预先建立连接，子网预约资源（缓冲区，CPU）
  - 服务质量保证
  - 按照连接时间计费

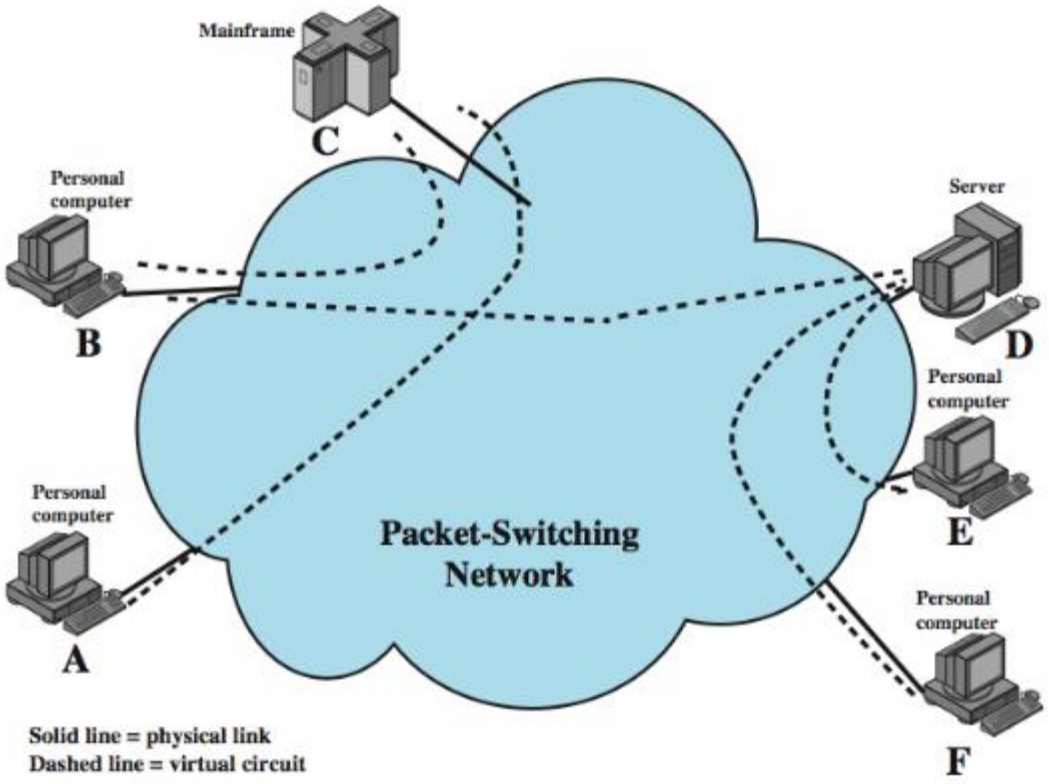
Data Communication Network

无连接（即数据报）还是面向连接？

- 无连接网络
  - Internet（ARPANET）

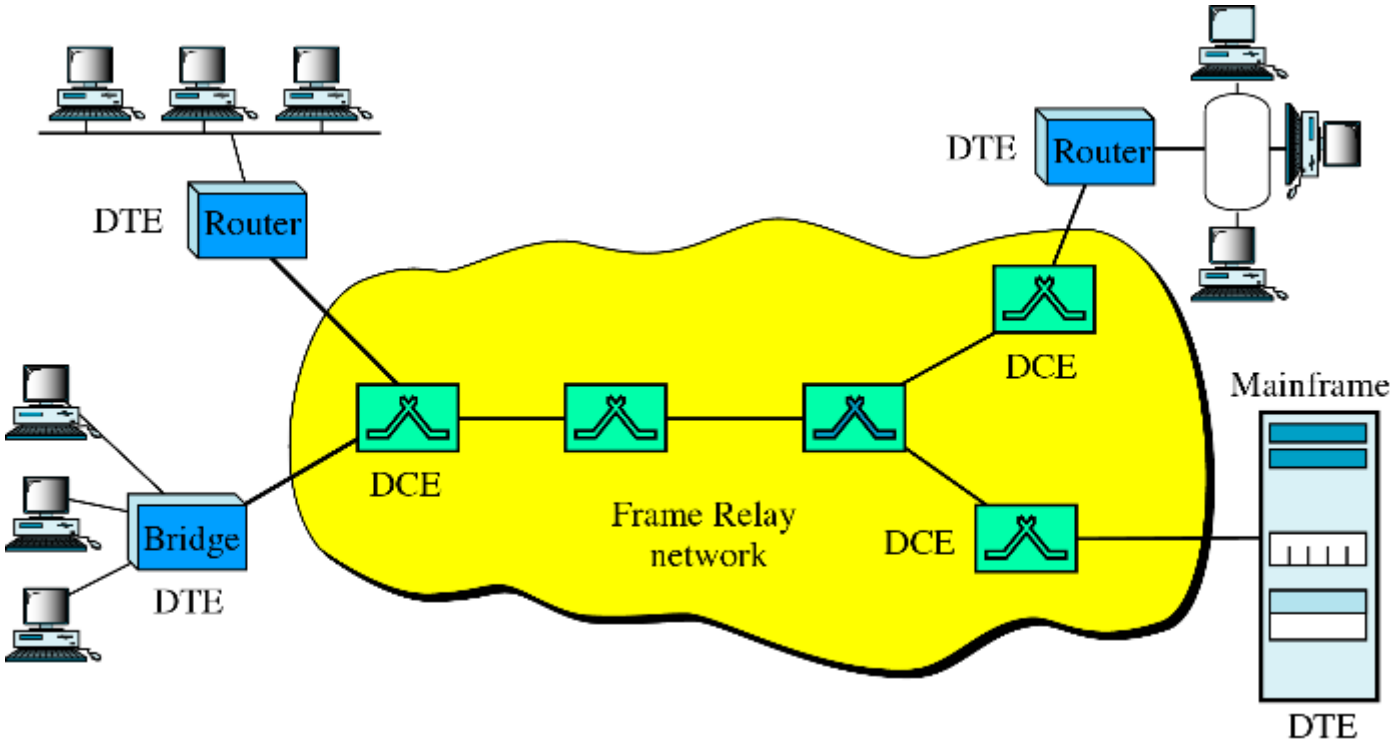
- 面向连接的网络
  - X.25 (Packet Switched Public Data Network)
  - FR (Frame Relay)
  - Asynchronous Transfer Mode （ATM）
  - DDN (Digital Data Network) over ATM/SDH

X.25 Use of Virtual Circuits



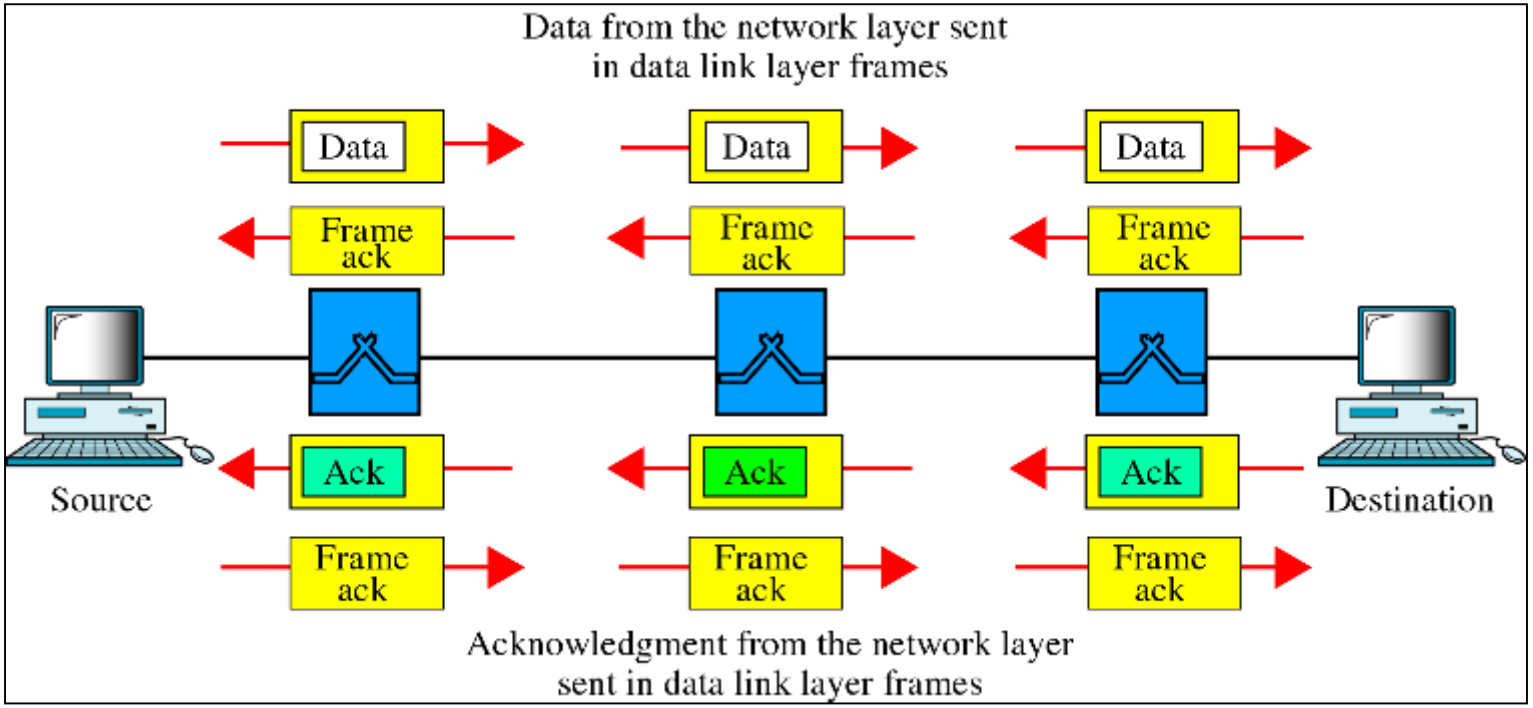
- X. 25技术的主要特征
  - 带内信令
    - 呼叫控制分组与数据分组在相同信道和虚电路上运载
  - 虚电路的复用在第三层
  - 第二层与第三层都含流量控制和差错控制
  - 中间节点必须等到整个分组接收完毕才能转发
- 主要问题
  - 相当可观的额外开销
  - 与高可靠性的现代数字系统不相适应

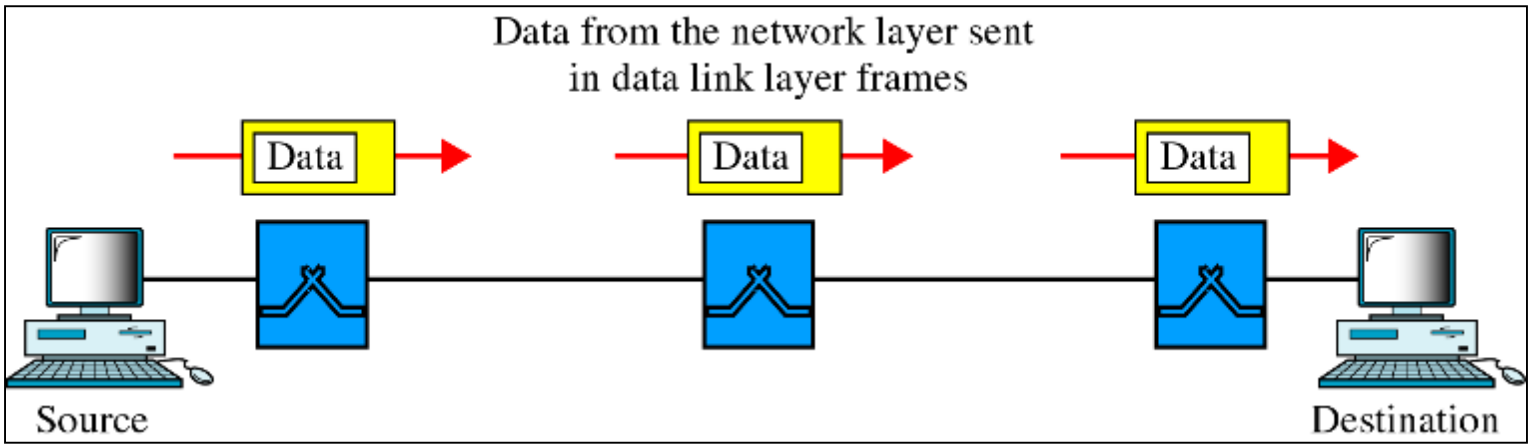
Frame Relay Network



- 以独立的信道运载呼叫控制，更经常是提供永久虚电路
- 复用与交换都在第二层， 减少了一层的处理
- 步采用逐跳的差错控制与流量控制
  - 假如需要，由高层完成端到端的流量控制和差错控制
- 中间节点收到一帧的帧头，解析完虚电路标识就可立即转发
- 一个用户数据帧从源站发往目的站，来自高层的确认帧则由反向的一个帧返回

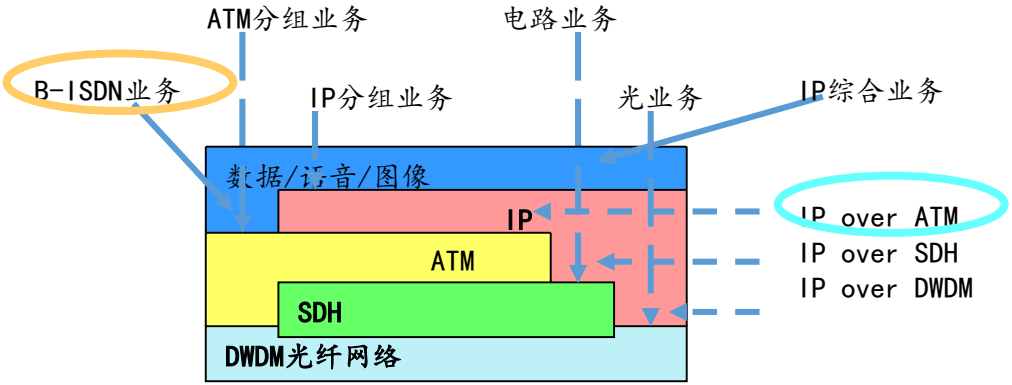
X.25 vs. Frame Relay Network





异步传输模式

- Asynchronous Transfer Mode（ATM）
  - 电话网是同步的，ATM是异步的？
- ATM的目标
  - 期望解决所有的网络和通信问题
  - 语音，数据，有线电视，电报等合并到一个集成系统
    - 像不像OSI（ATM比OSI成功得多，应用在了电话系统承载IP报文）

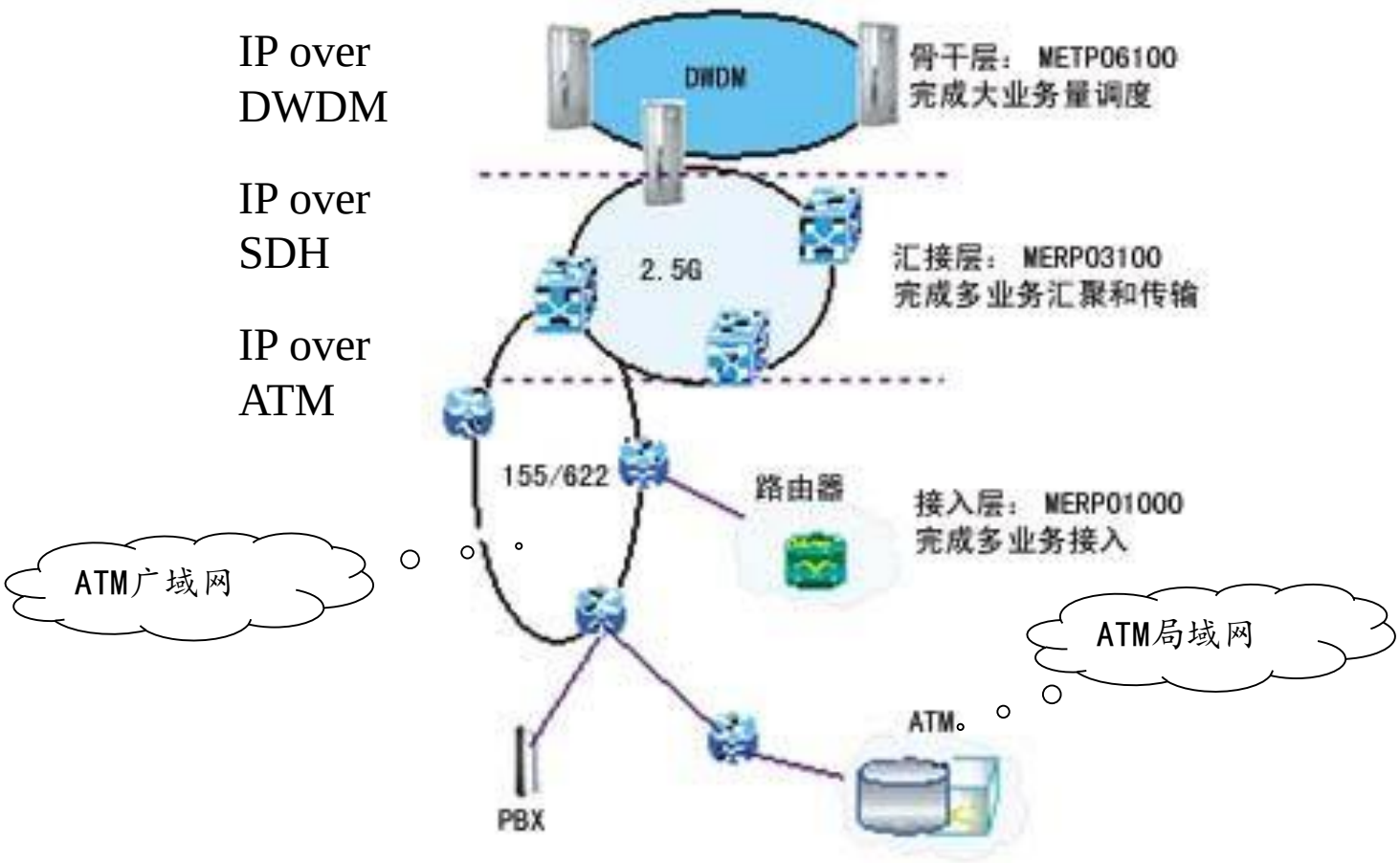


典型宽带网层次体系结构

IP over DWDM

IP over SDH

IP over ATM



ATM交换机现在已经能够支持直接的OC-192接口（10Gbps）

ATM

- ITU-T leading the development of standards
- ATM Forum ensures interoperability among private and public ATM implementations
- commonly used to implement WANs
- DSL uses ATM for multiplexing and switching
- used as a backbone in IP networks and Internet

ATM

- connection-oriented : a streamlined packet transfer interface
- performance of a circuit-switching network & flexibility and efficiency of a packet-switching network
- ATM uses fixed sized packets called **cells**
- minimal error and flow control capabilities
- operates at high data rates
- supports data, voice, video
- transmission based on priority and QoS

Reference Model Planes

user plane

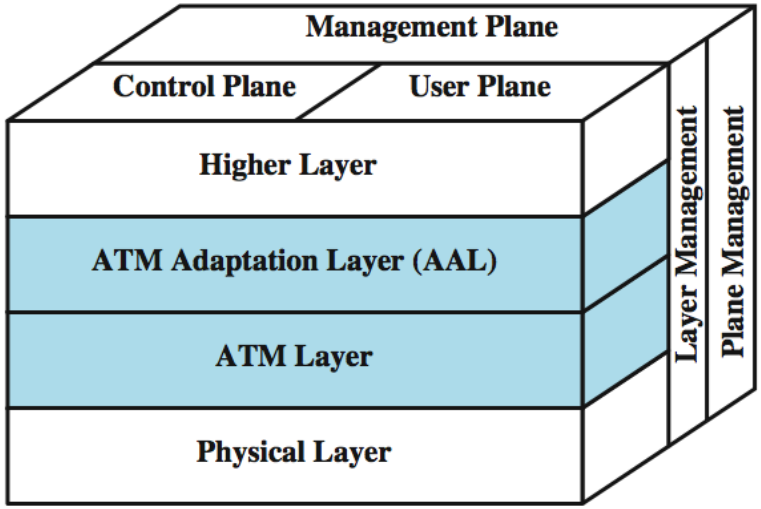
- provides for user information transfer

control plane

- call and connection control

management plane

- plane management
  - whole system management and coordination between all the planes
- layer management
  - resources and parameters in protocol entities

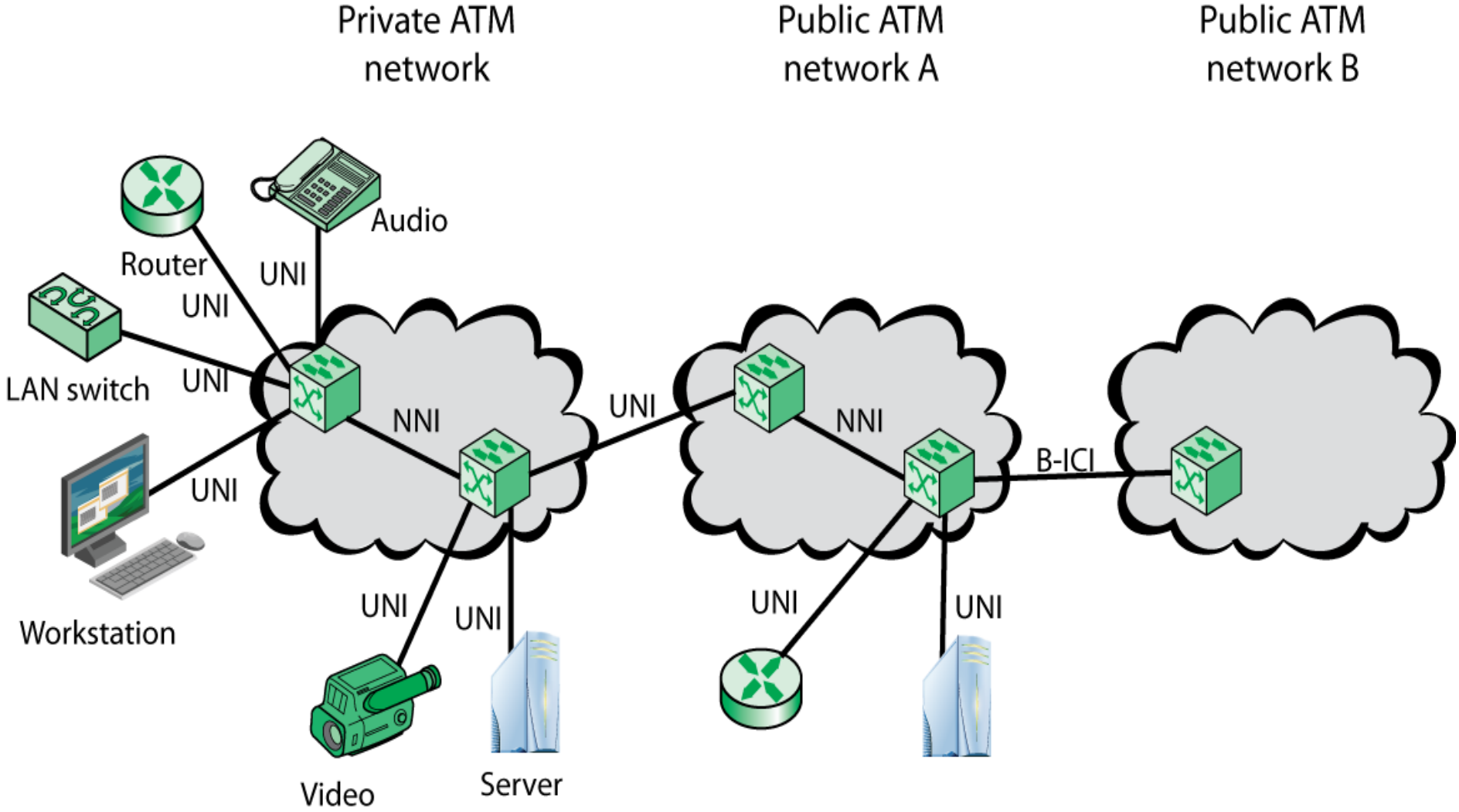


ATM Network Interfaces

Switches are interconnected by point-to-point ATM links called **interfaces**

- user–network interface (UNI)
- network node interface (NNI)
- interface specification includes:
  - definition of link types allowed
  - addressing formats
  - cell format
  - control signaling protocols

ATM Network Interfaces



ATM Logical Connections

virtual channel connections (VCC)

- analogous to virtual circuit in X.25

basic unit of switching between two end users

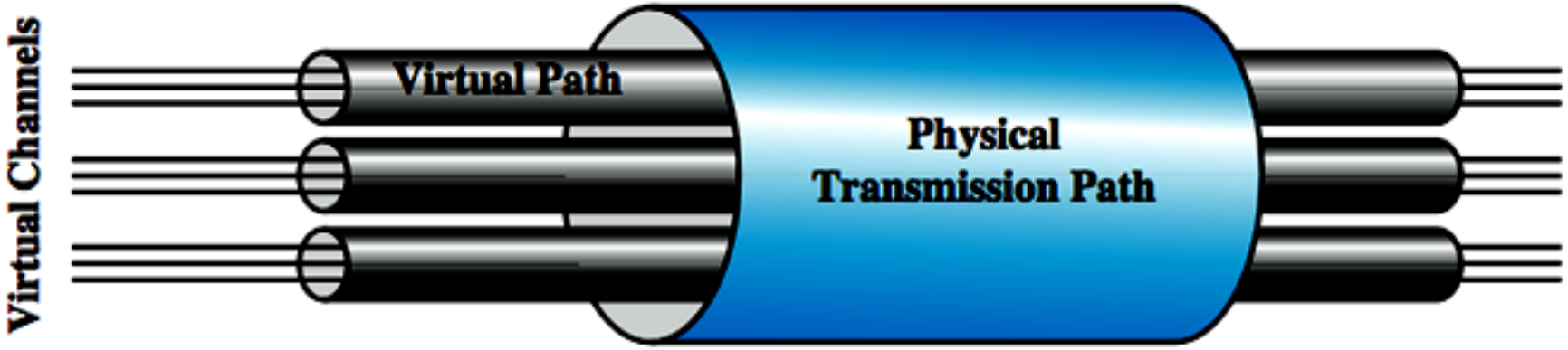
- variable rate
- full duplex
- fixed size cells

VCCs also used for

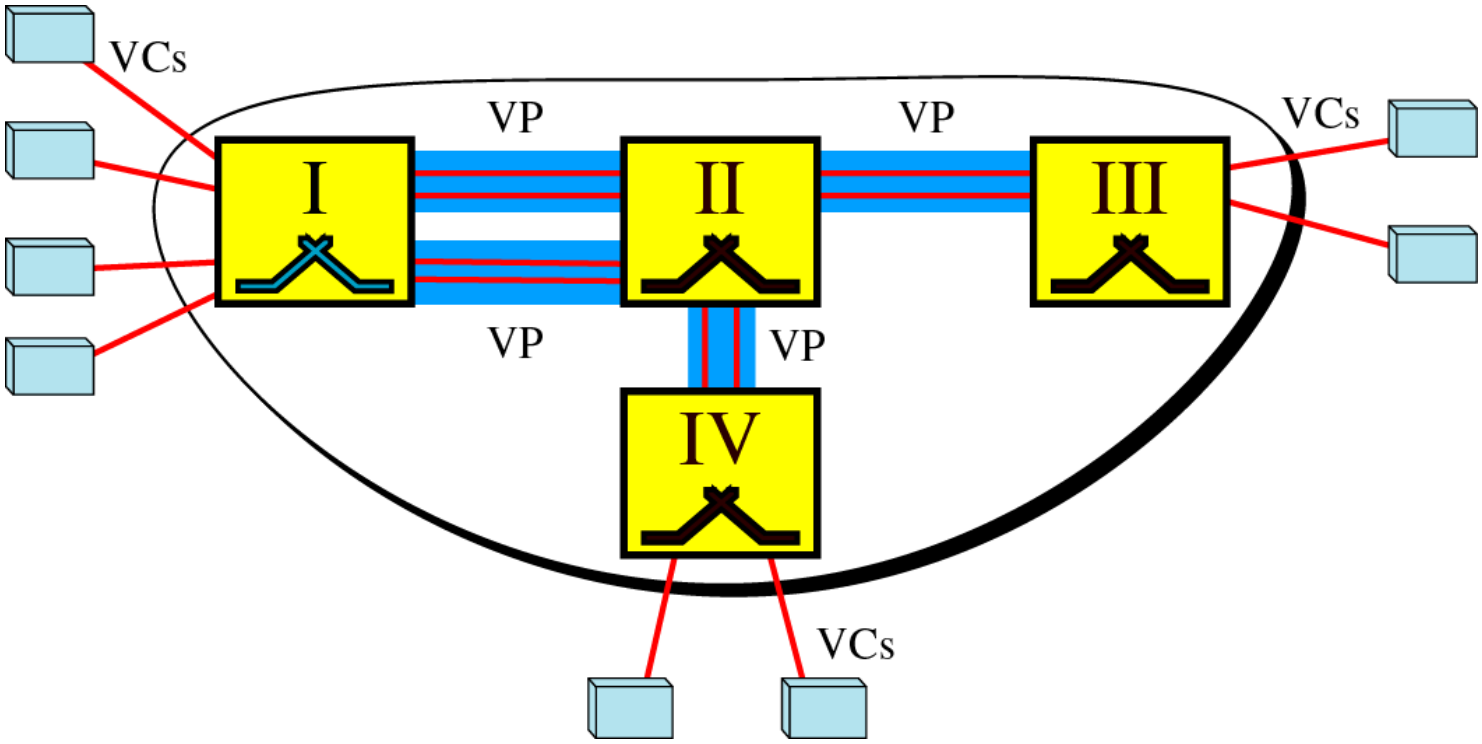
- user-network exchange (control signaling)
- network-network exchange (network management and routing)

ATM Virtual Path Connection

- virtual path connection (VPC)
  - bundle of VCC with same end points



Example of VPs and VCs



Advantages of Virtual Paths

Several advantages can be listed for the use of virtual paths:

-simplified network architecture

-increased network performance and reliability

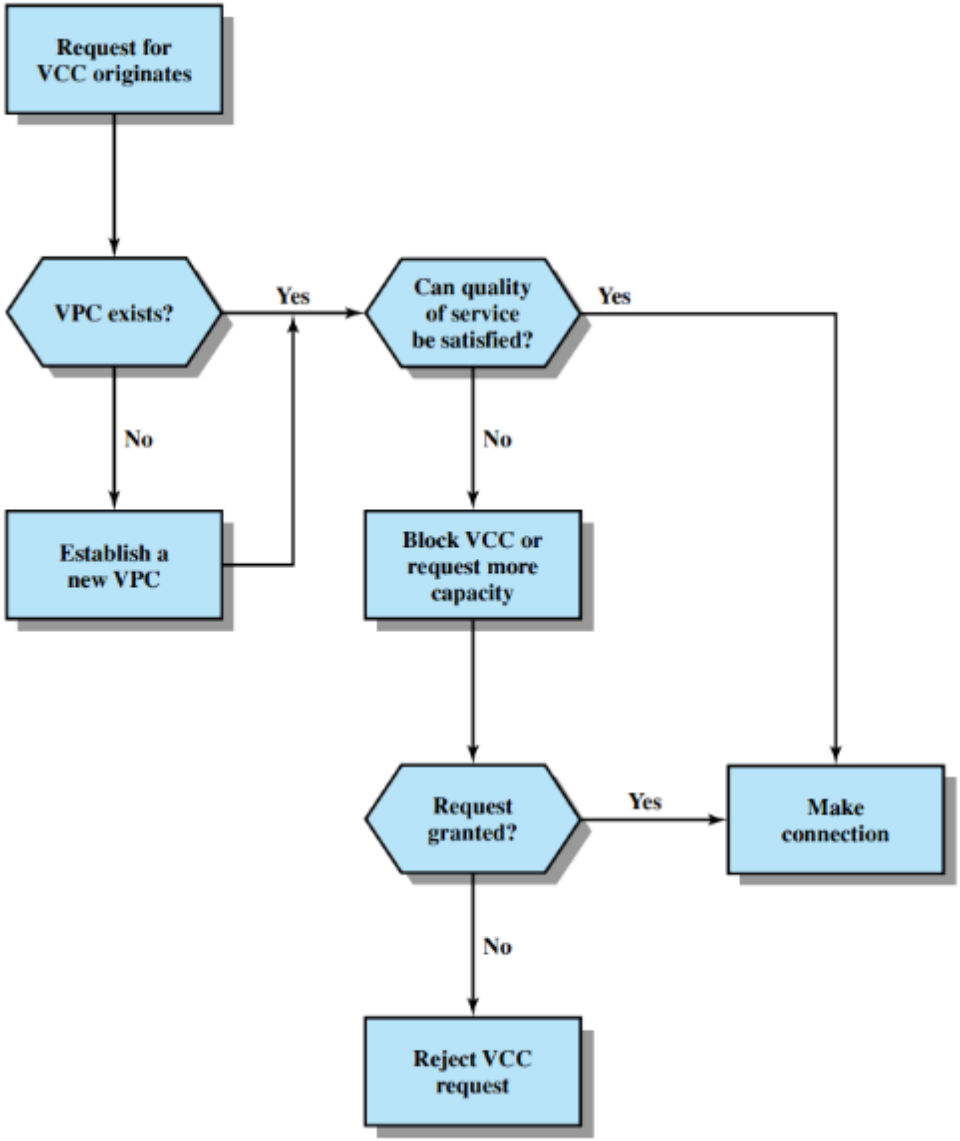
-reduced processing and short connection setup time

-enhanced network services

Virtual Path/Channel Terminology

Virtual Channel (VC)	A generic term used to describe unidirectional transport of ATM cells associated by a common unique identifier value.
Virtual Channel Link	A means of unidirectional transport of ATM cells between a point where a VCI value is assigned and the point where that value is translated or terminated.
Virtual Channel Identifier (VCI)	A unique numerical tag that identifies a particular VC link for a given VPC.
Virtual Channel Connection (VCC)	A concatenation of VC links that extends between two points where ATM service users access the ATM layer. VCCs are provided for the purpose of user-user, user-network, or network-network information transfer. Cell sequence integrity is preserved for cells belonging to the same VCC.
Virtual Path	A generic term used to describe unidirectional transport of ATM cells belonging to virtual channels that are associated by a common unique identifier value.
Virtual Path Link	A group of VC links, identified by a common value of VPI, between a point where a VPI value is assigned and the point where that value is translated or terminated.
Virtual Path Identifier (VPI)	Identifies a particular VP link.
Virtual Path Connection (VPC)	A concatenation of VP links that extends between the point where the VCI values are assigned and the point where those values are translated or removed, i.e., extending the length of a bundle of VC links that share the same VPI. VPCs are provided for the purpose of user-user, user-network, or network-network information transfer.

Call Establishment Using VPs



Virtual Channel Connection Uses

between end users

- end to end user data
- carries control signaling
- VPC provides overall capacity
  - VCC organization done by users

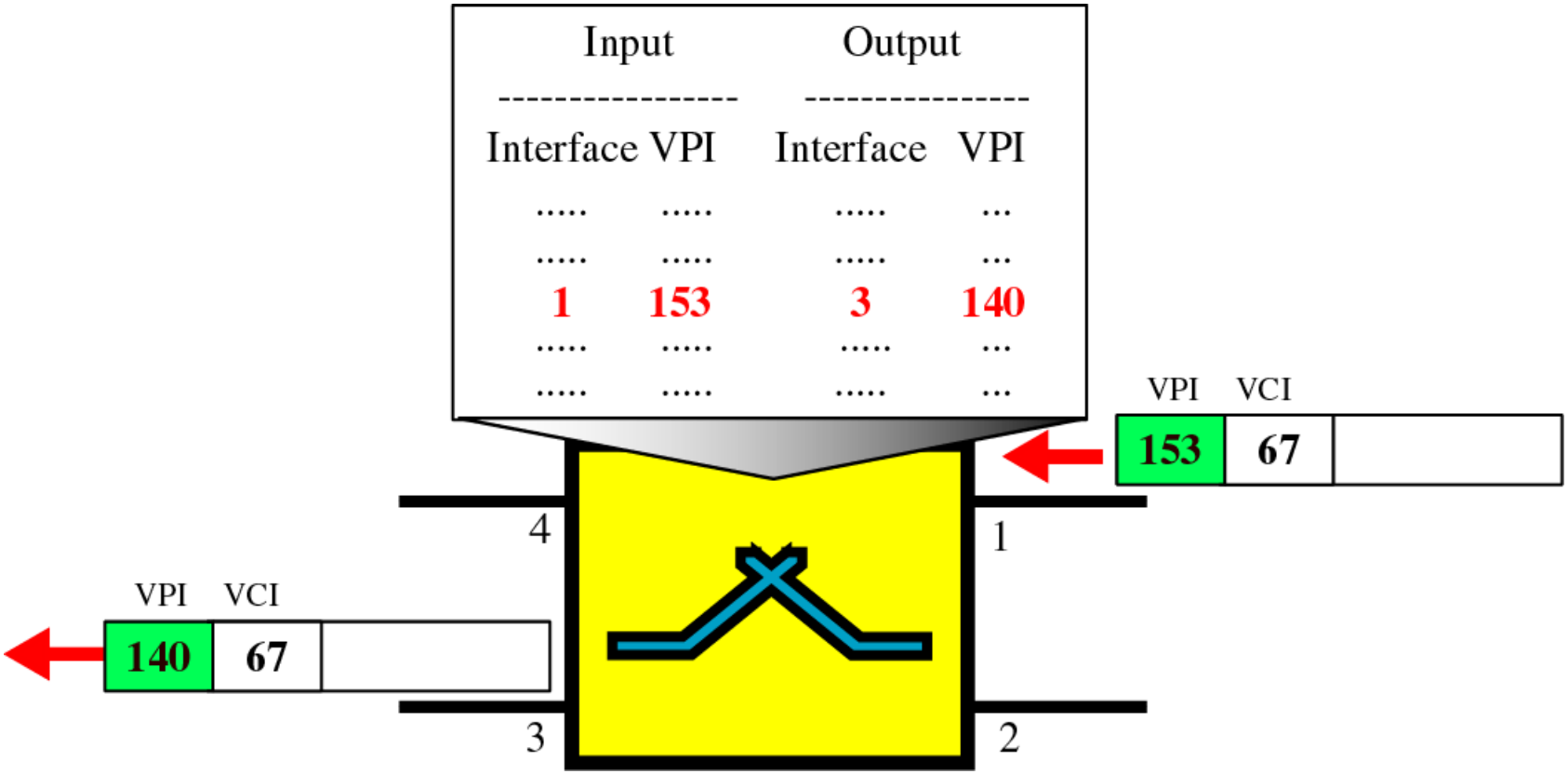
between end user and network

- control signaling
- VPC used to aggregate traffic

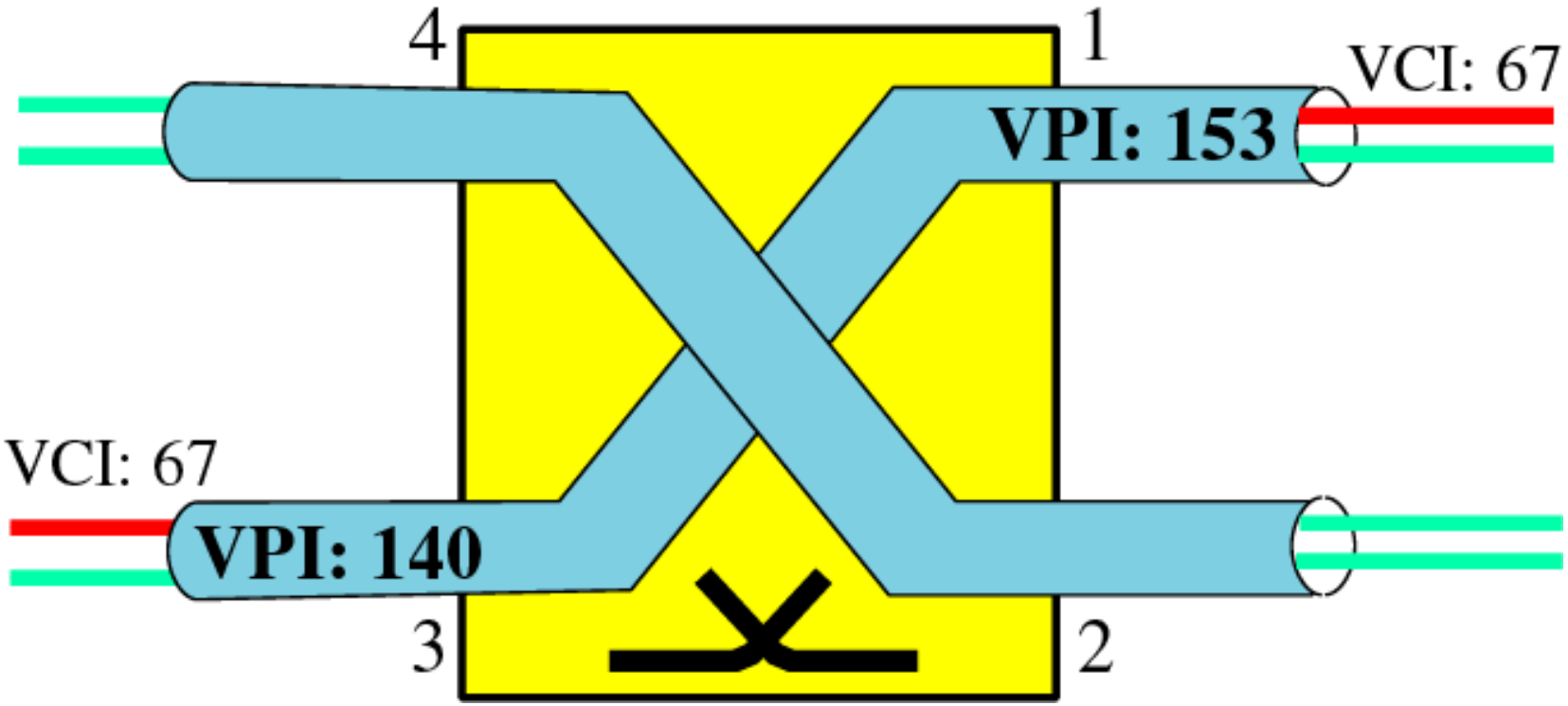
between network entities

- network traffic management
- routing

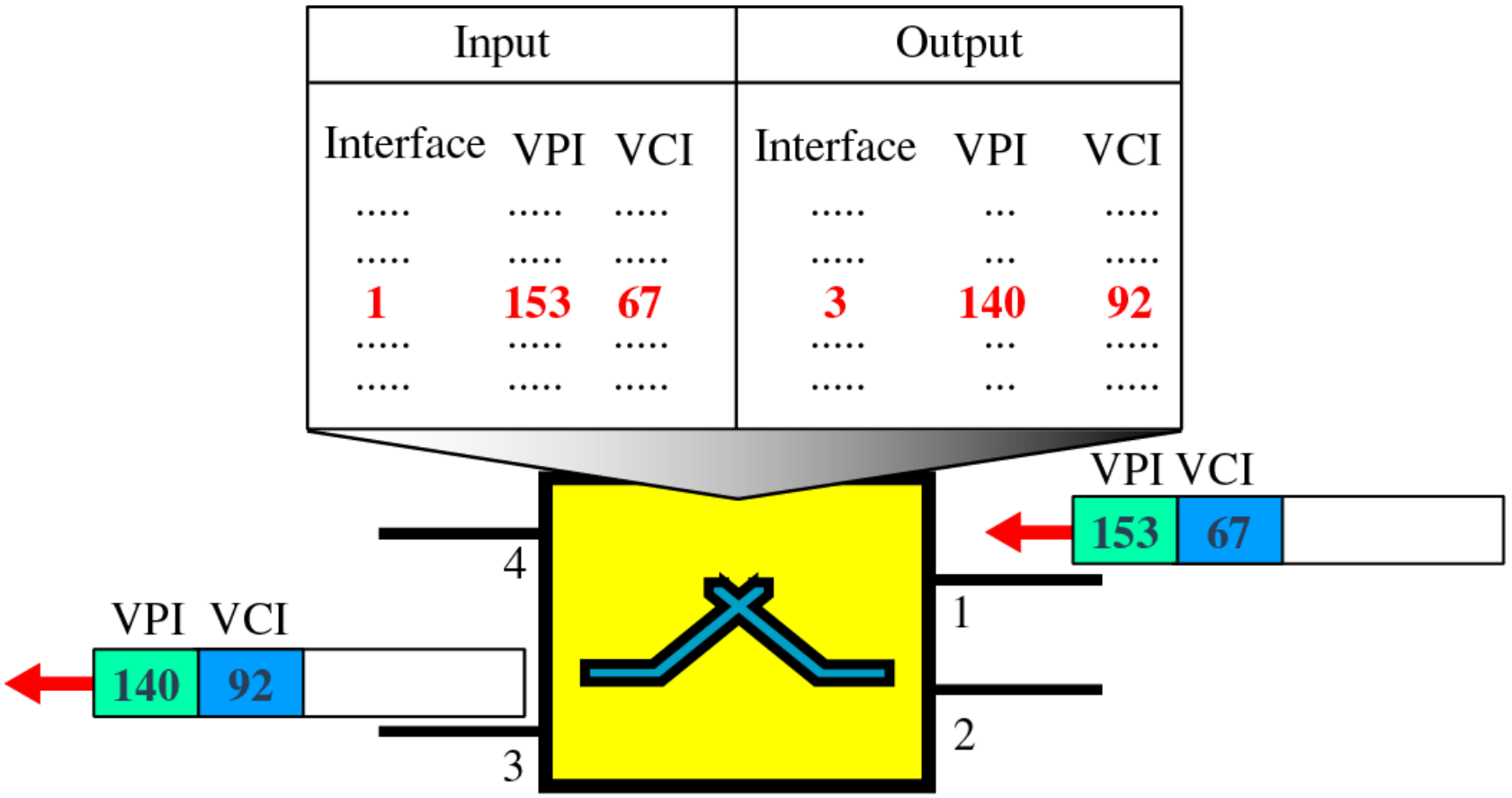
Routing with a VP switch



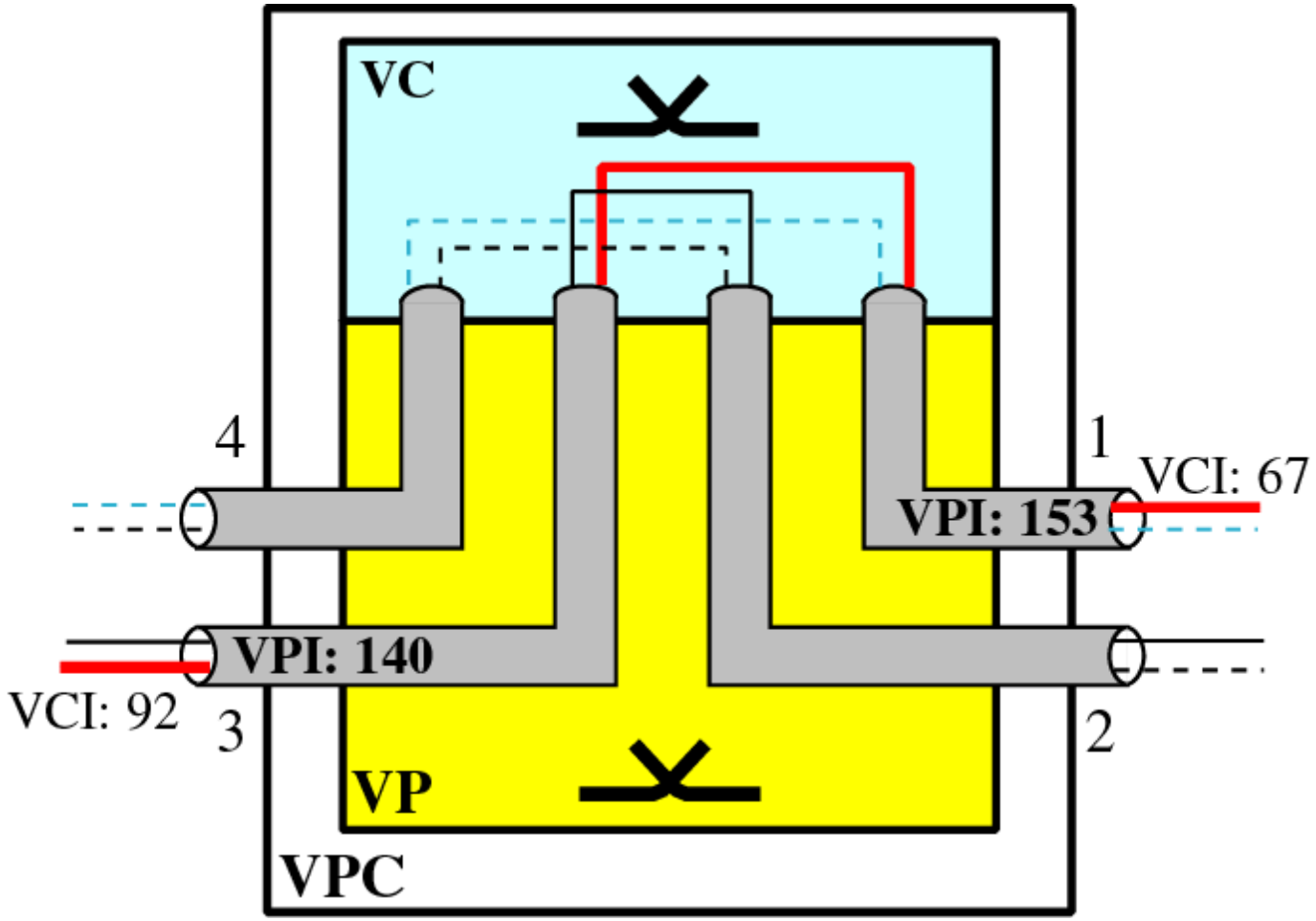
A Conceptual View of a VP switch



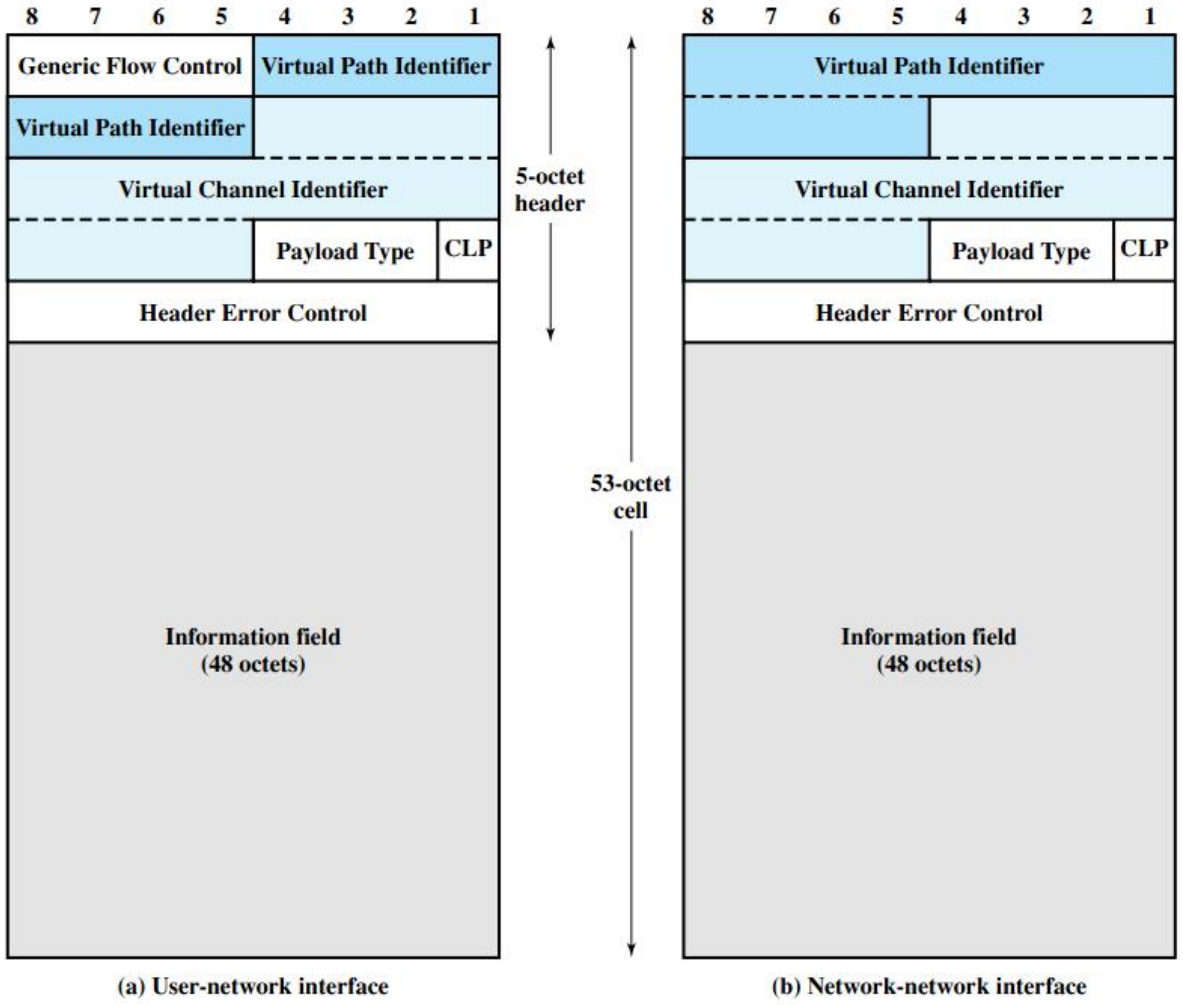
Routing with a VPC Switch



A Concept View of a VPC Switch



ATM Cell Format



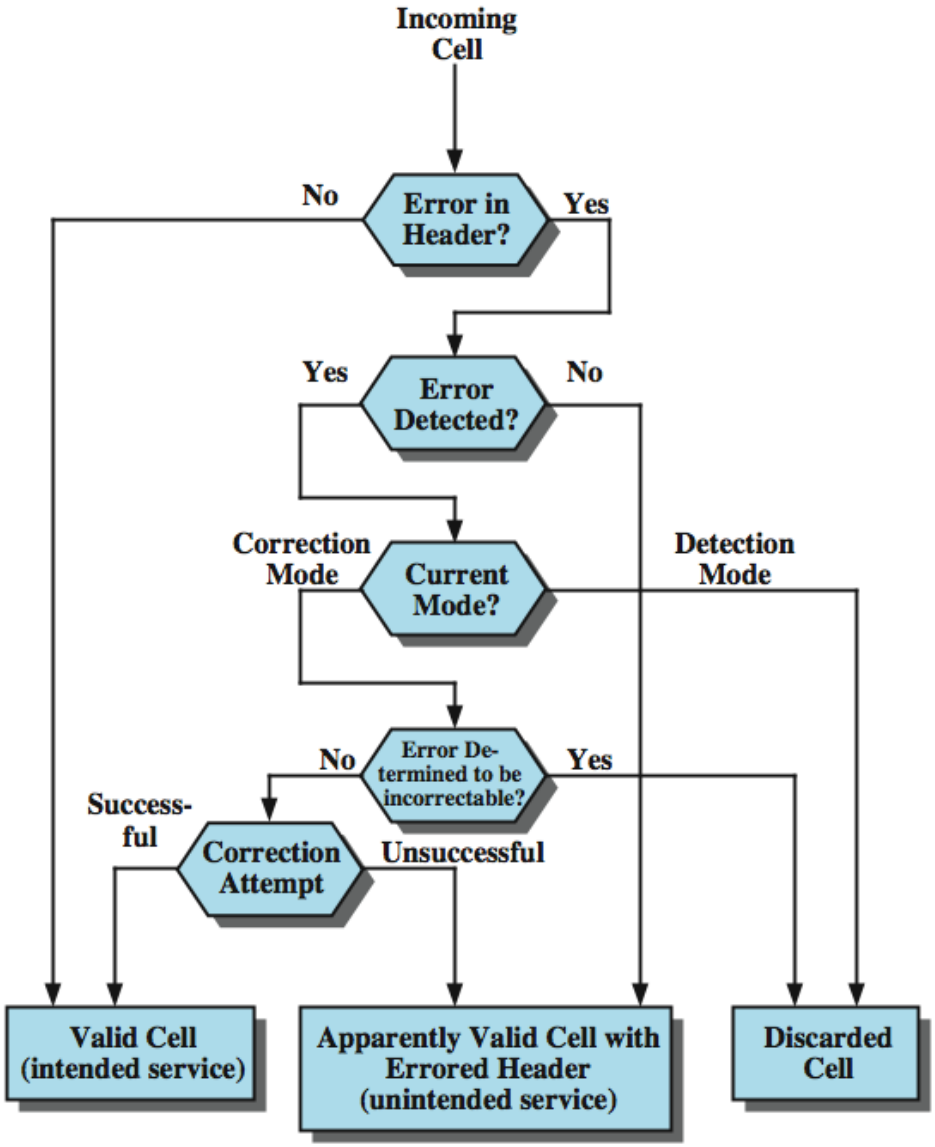
头部：
连接标识符

信元路由：
硬件实现

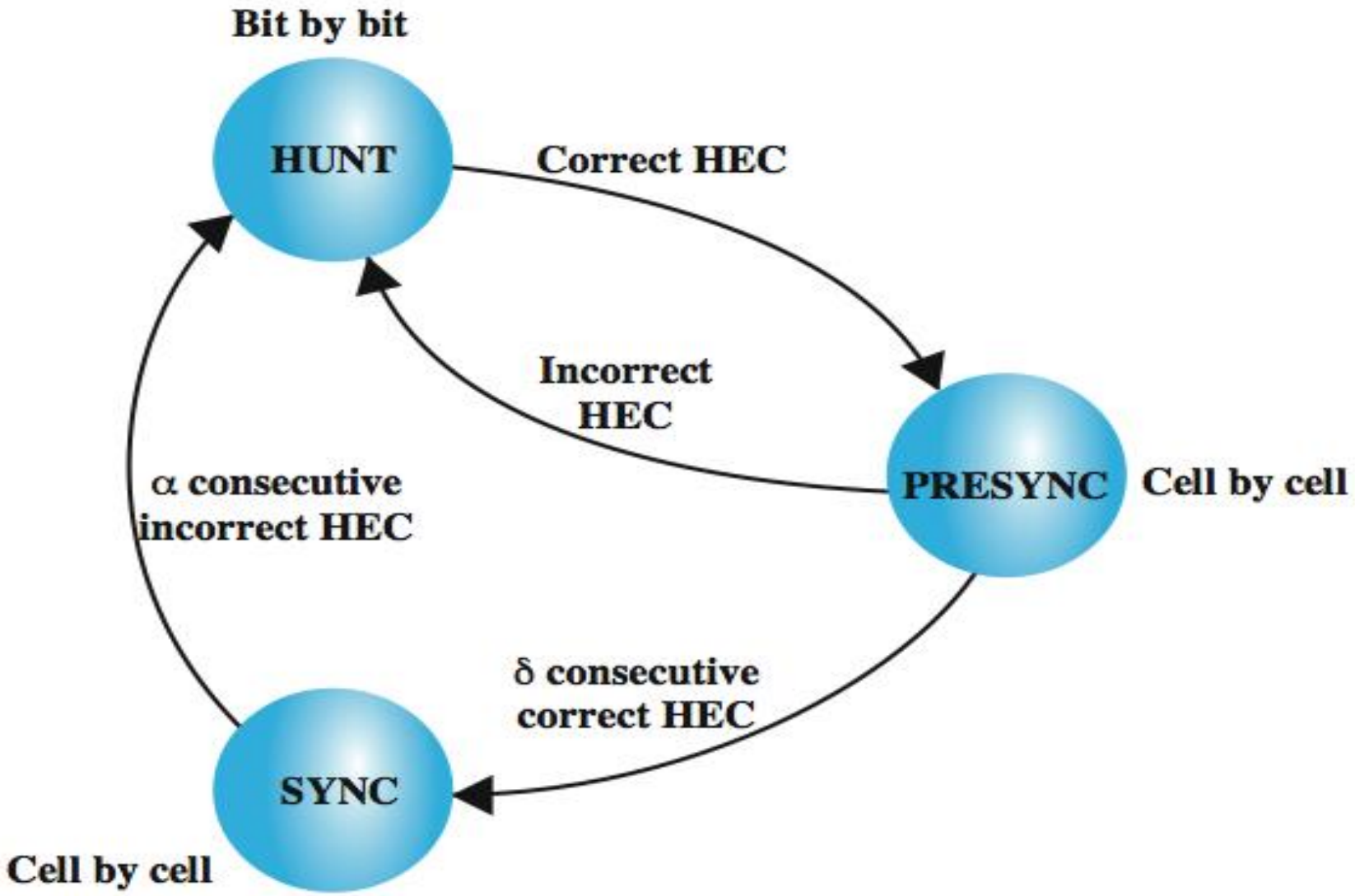
固定长度：
硬件友好
复制信元(多播)
降低阻塞(QoS)

虚电路：
保序

Effect of Error in Cell Header



Cell Delineation State Diagram



ATM Service Categories

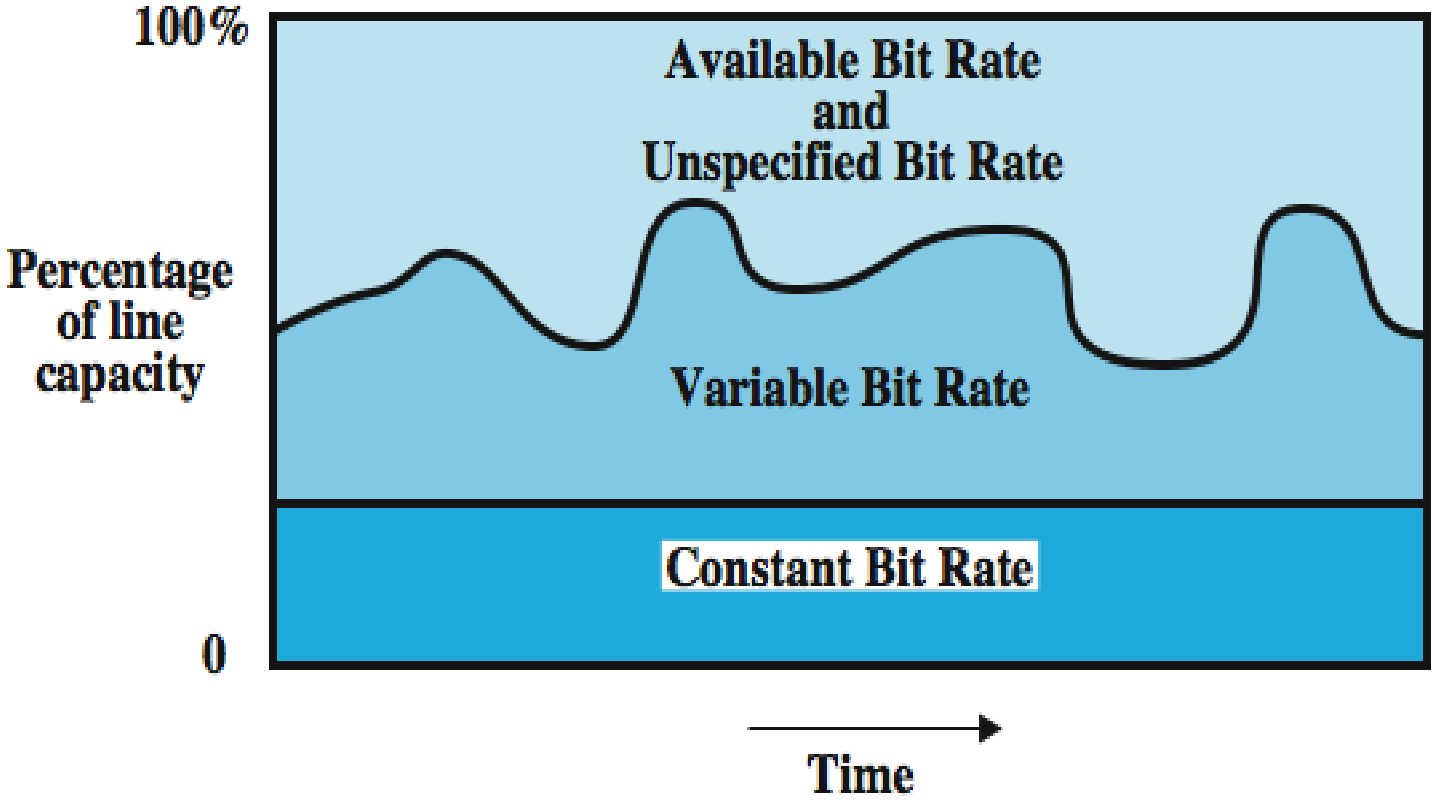
Real time - limit amount/variation of delay

- Constant bit rate (CBR)
- Real time variable bit rate (rt-VBR)

Non-real time - for bursty traffic

- Non-real time variable bit rate (nrt-VBR)
- Available bit rate (ABR)
- Unspecified bit rate (UBR)
- Guaranteed frame rate (GFR)

ATM Bit Rate Services



Constant Bit Rate (CBR)

- fixed data rate continuously available
- tight upper bound on delay
- uncompressed audio and video
  - video conferencing
  - interactive audio
  - A/V distribution and retrieval

Real-Time Variable Bit Rate (rt-VBR)

- for time sensitive applications
  - tightly constrained delay and delay variation
- rt-VBR applications transmit data at a rate that varies with time
- characterized as bursty
- allow more flexibility than CBR

Non-Real-Time Variable Bit Rate (nrt-VBR)

- used for data transfers with critical response time
  - airline reservations, banking transactions
- end system specifies:
  - a peak cell rate
  - a sustainable or average cell rate
  - measure of how bursty or clumped cells can be

Unspecirfied Bit Rate (UBR)

- may be additional capacity over and above that used by CBR and VBR traffic
  - not all resources dedicated to CBR/VBR traffic
  - unused cells due to bursty nature of VBR
- for application that can tolerate some cell loss or variable delays
  - eg. TCP based traffic
- cells forwarded on FIFO basis
- best effort service
- examples:
  - text/data/image transfer
  - telecommuting

Available Bit Rate (ABR)

- application specifies peak cell rate (PCR) and minimum cell rate (MCR)
- resources allocated to give at least MCR
- spare capacity shared among all ARB sources
  - eg. LAN interconnection

网络层设计要点

- 存储-转发分组交换
- 向传输层提供的服务
  - 所提供的服务应该独立于路由器技术
  - 路由器的数量，类型，拓扑对传输层不可见
  - 传输层可以使用的网络地址具有统一的编址方案
    跨WAN、LAN

Again:　无连接的，面向连接的？
区分数据报路由和虚电路路由！

服务质量

- 需求
  - 电子邮件，文件传输，web访问，音频，视频，电话
  - 可靠性， 延迟， 抖动， 带宽
  - 根据QoS对网络数据流分类（参考ATM）
- 获得好的服务质量的技术
  - 冗余资源
  - 缓冲能力
  - 流量整形 - 发送速率 （区分滑动窗口协议）
- 综合服务
  - 资源预留协议（RSVP） - 多播路由
  - 区分服务（Differentiated Service）

Multiprotocol Label Switching

- MPLS is a set of IETF specifications for including routing and traffic engineering information in packets
- comprises a number of interrelated protocols - - MPLS protocol suite
  - is used to ensure that all packets in a particular flow take the same route over a backbone
  - deployed by many telecommunication companies and service providers
  - delivers QoS required to support real-time voice and video and SLAs that guarantee bandwidth

Role of MPLS

- efficient technique for forwarding and routing packets
- designed with IP networks in mind
  - can be used with any link-level protocol
- fixed-length label encapsulates an IP packet or a data link frame
- MPLS label contains all information needed to perform routing, delivery, Qos, and traffic management functions
- connection oriented

Label Assignment

- based on:

destination unicast routing

traffic engineering

multicast

virtual private network (VPN)

QoS

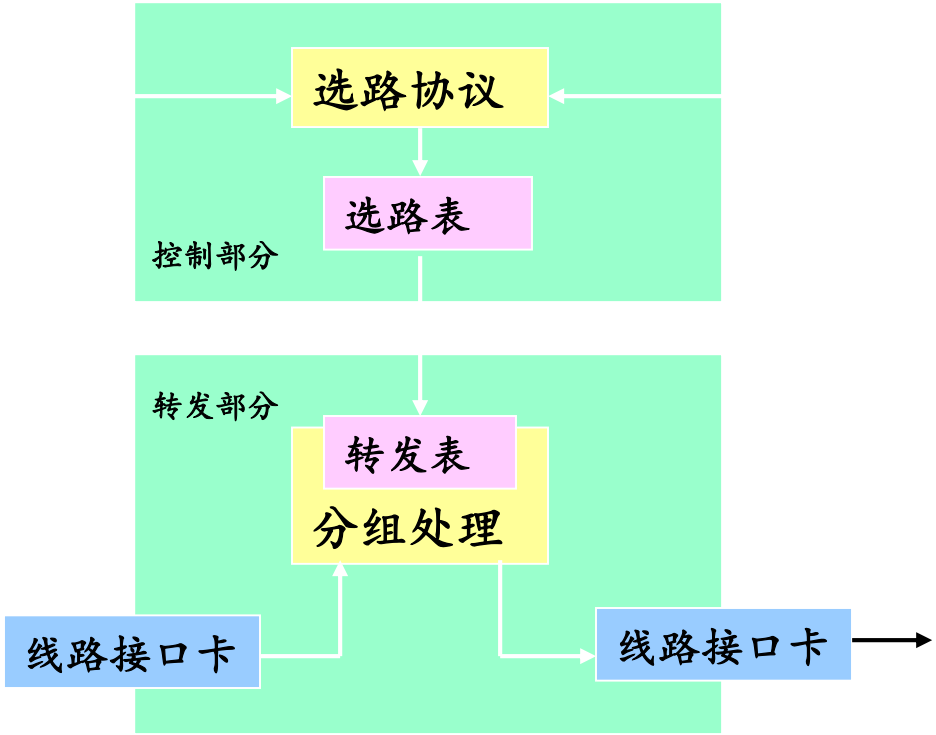
标签交换 MPLS

- 为无连接的IP网络提供面向连接的服务质量支持
  - MPLS支持IP： 面向连接的ATM技术在IP网运行
  - 服务质量支持
    - 为特定应用确保固定的容量，e.g.,音频/视频会议
    - 控制延迟和抖动，e.g.,话音
    - 提供可定量的服务级别或流量
    - 为多个网络客户配置不同程度的服务质量
  - MPLS兼容性:(标记分发协议+链路管理协议）+已有协议
  - MPLS自适应：支持新的应用，e.g.,L2,L3虚拟专用网
  - MPLS支持度量
  - MPLS可扩展

传统路由器结构分析与MPLS的理念

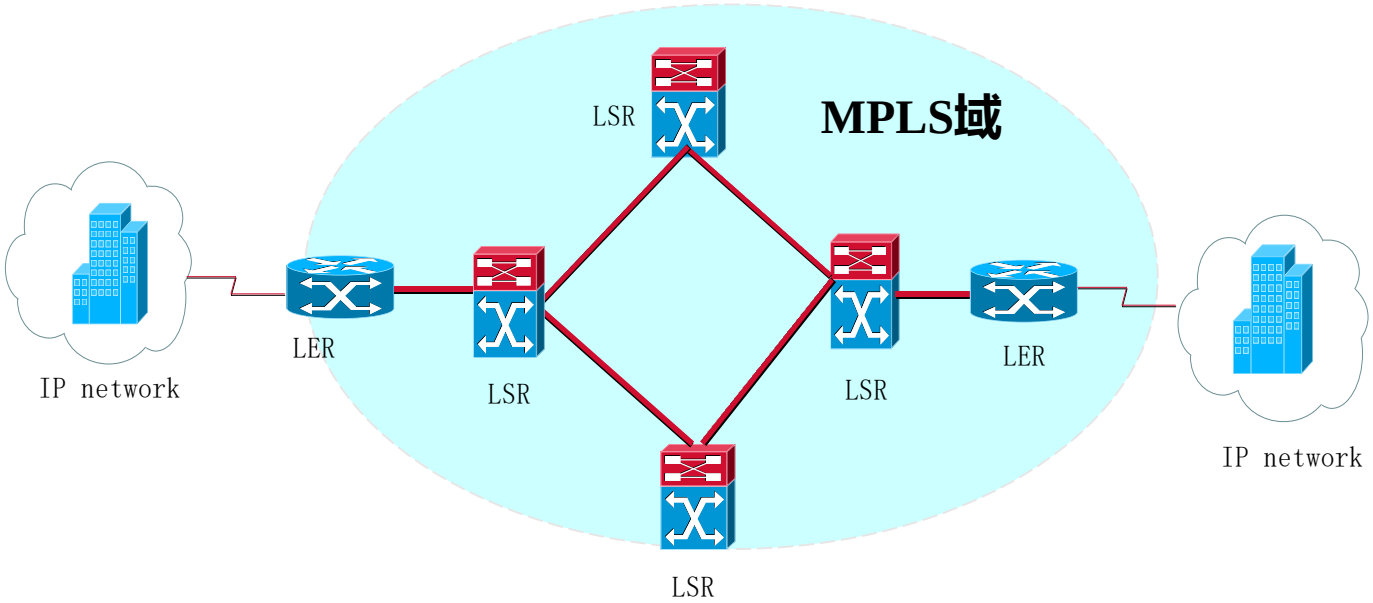
- 传统的路由器由两部分组成
  - 控制部分
  - 转发部分
- “路由选择”
  - 笼统地指将分组从一节点沿某条路径移到另一节点
- MPLS细化后的“路由选择”
  - 第三层功能（软件实现）
  - 按分组首部中目的IP地址找出下一跳IP地址
- MPLS的“转发”或“交换”
  - 第二层功能（主要硬件实现，通常是无阻塞交换）
  - 根据转发表或 VCI将数据从路由器的一个端口转送到另一端口
  - 细化后的“交换”和通常的“交换”含义不同
- 路由表与转发表
  - 一个用于选路，一个用于指定分组的输出端口

- MPLS的一个重要特点
  - 分离了“控制”与“转发”功能
  - 实现第二层快速转发
  - 省去了分组每到一节点都到第三层查找路由表的过程



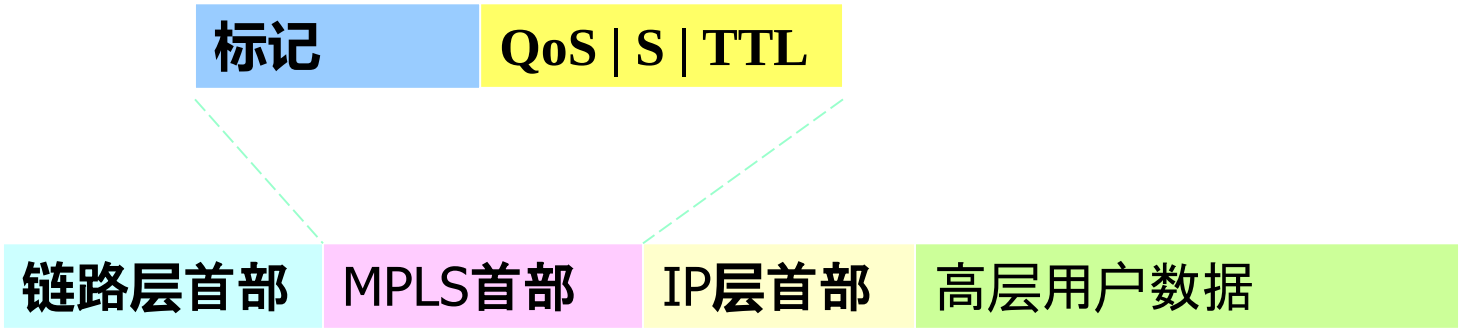
MPLS工作原理与网络结构

- MPLS网络(MPLS域)中所有路由器都支持MPLS技术
- 支持MPLS的路由器称为标记交换路由器（LSR — Label Switching Router）
- 两类LSR：核心LSR和边缘LSR。通常将核心LSR就称LSR, 将边缘LSR称为标记边缘路由器（LER — Label Edge Router）
- MPLS分组转发过程
  - 边缘LSR将进入MPLS网络的分组快速分类，打上适当的标记
  - 核心LSR处理分组上的标记，并基于标记在第二层快速转发
  - 边缘LSR对离开MPLS网络的分组去掉标记，恢复为按IP地址转发



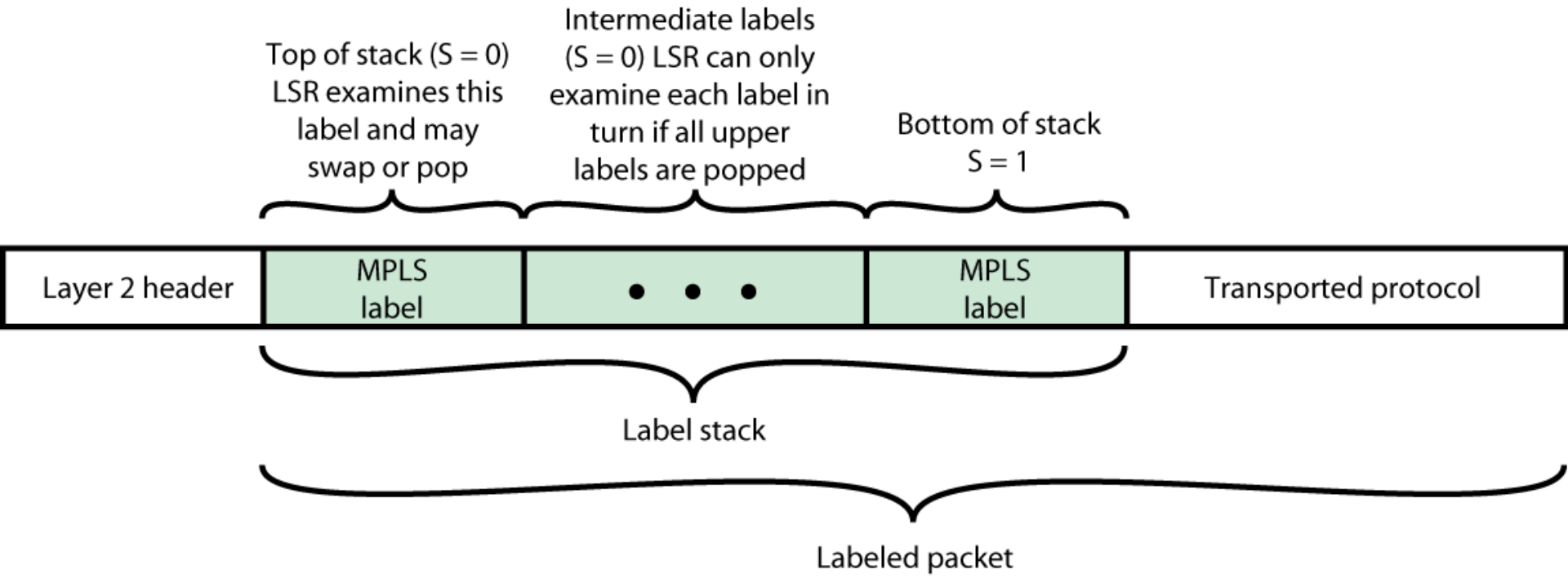
标签交换 MPLS

- 思想：标记分组路由
  - 在每个分组的前端打标签
  - 根据标签而不是根据目标地址进行路由
  - 路由 – 表格查询
  - 优点 – 快速，容易沿途预留资源



链路层的帧(包括ATM的AAL帧)

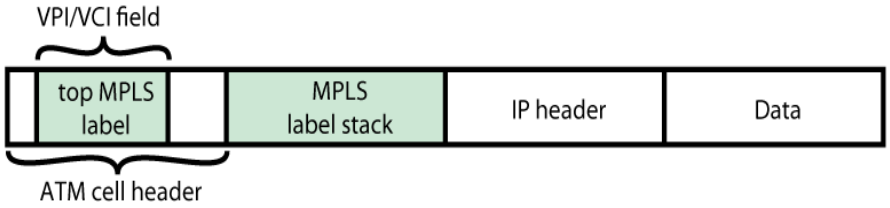
Label Placement



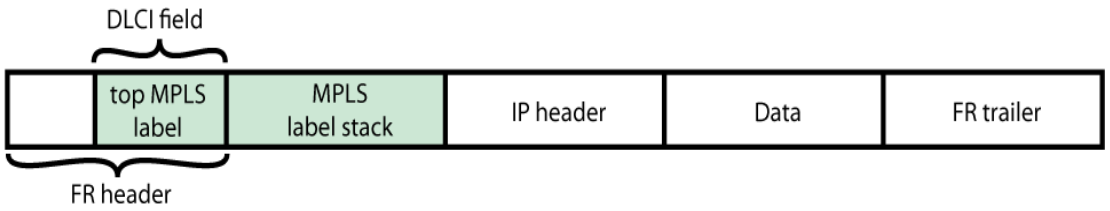
Label Stack

(a) Data link frame

(b) IEEE 802 MAC frame



(c) ATM cell



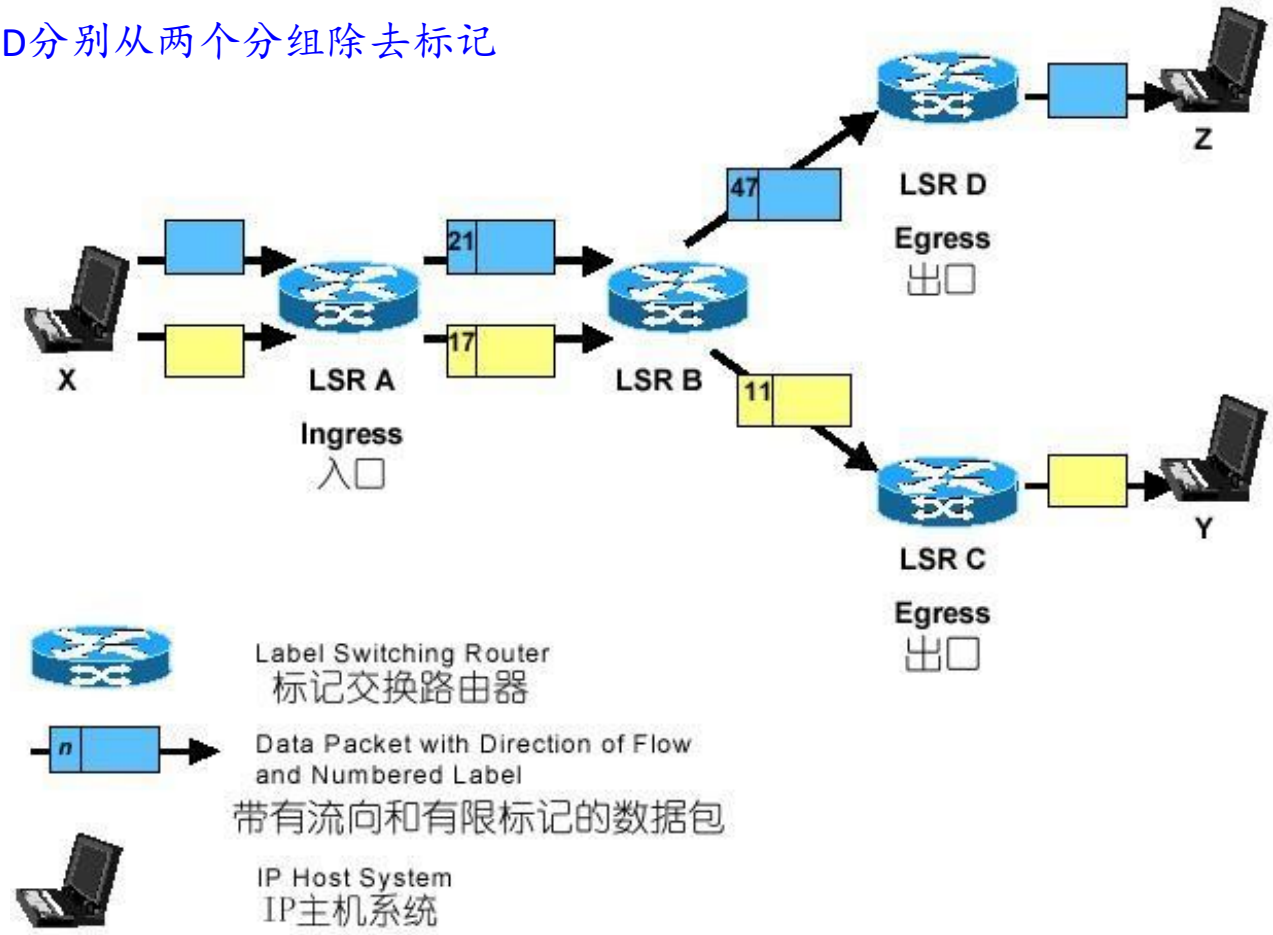
(d) Frame relay frame

MPLS的标记

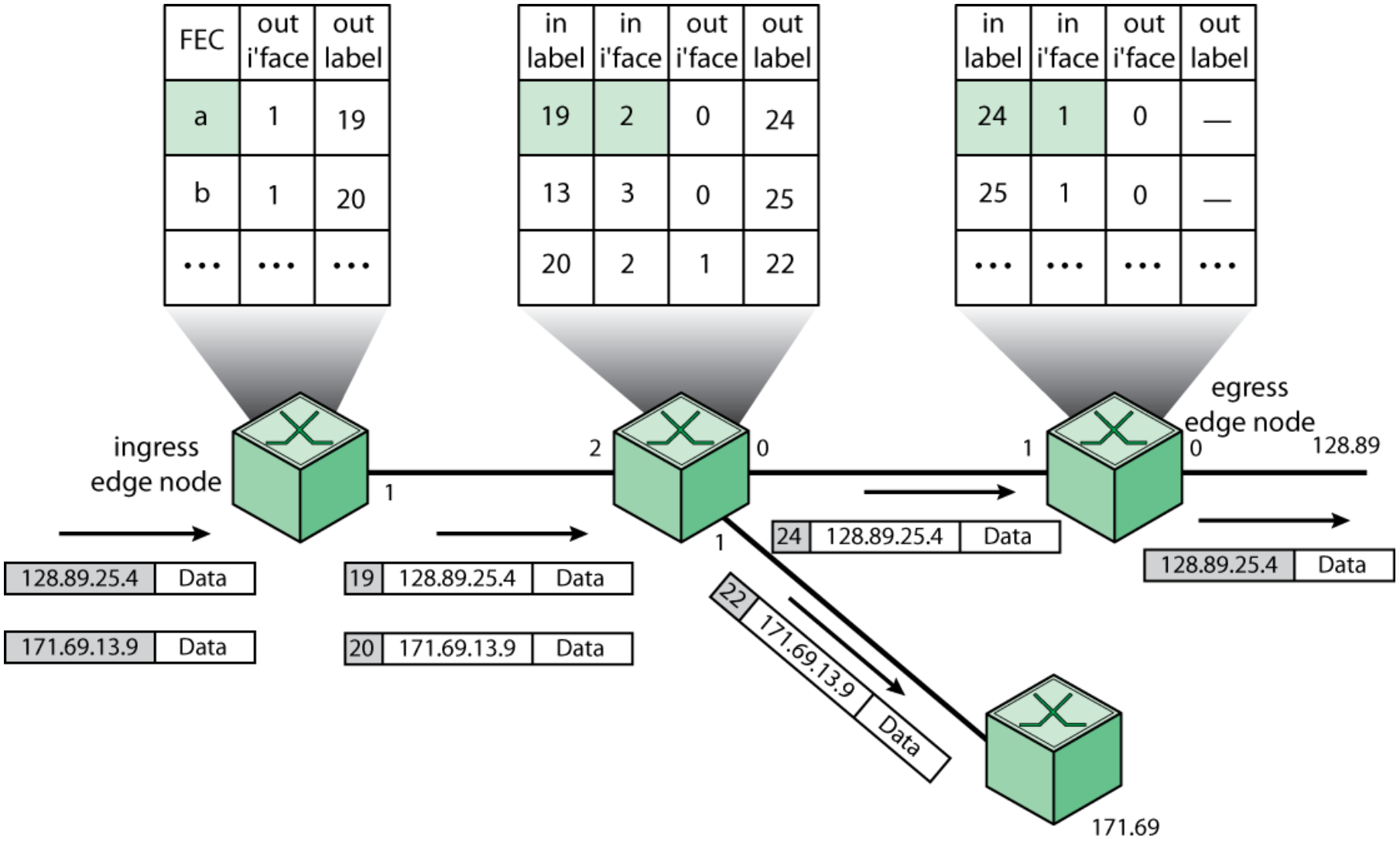
- 转发等价类FEC (Forwarding Equivalence Class)
  - LER并非给每个分组指派不同标记
  - 将分组映射为FEC
  - 将按相同方式转发的许多分组定义为一个FEC类
    - 例1：将源地址和目的地址都相同的分组划为同一类
    - 例2：目的地址与某一特定IP地址前缀匹配的分组划为同一类
- 标记分配协议LDP (Label Distribution Protocol)
  - 为从FEC得到的标记在MPLS域中建立一条连接
  - 该连接称为标记交换路径LSP（Label Switched Path）
  - 打上标记的分组沿LSP传送
- 标记对换（Swap）
  - 标记只具有本地意义
  - 每经过一个LSR就要按照转发表进行标记对换
  - 这和VPI/VCI交换有些相像，但只有一个层次的标识

一个MPLS网络中的两条LSP

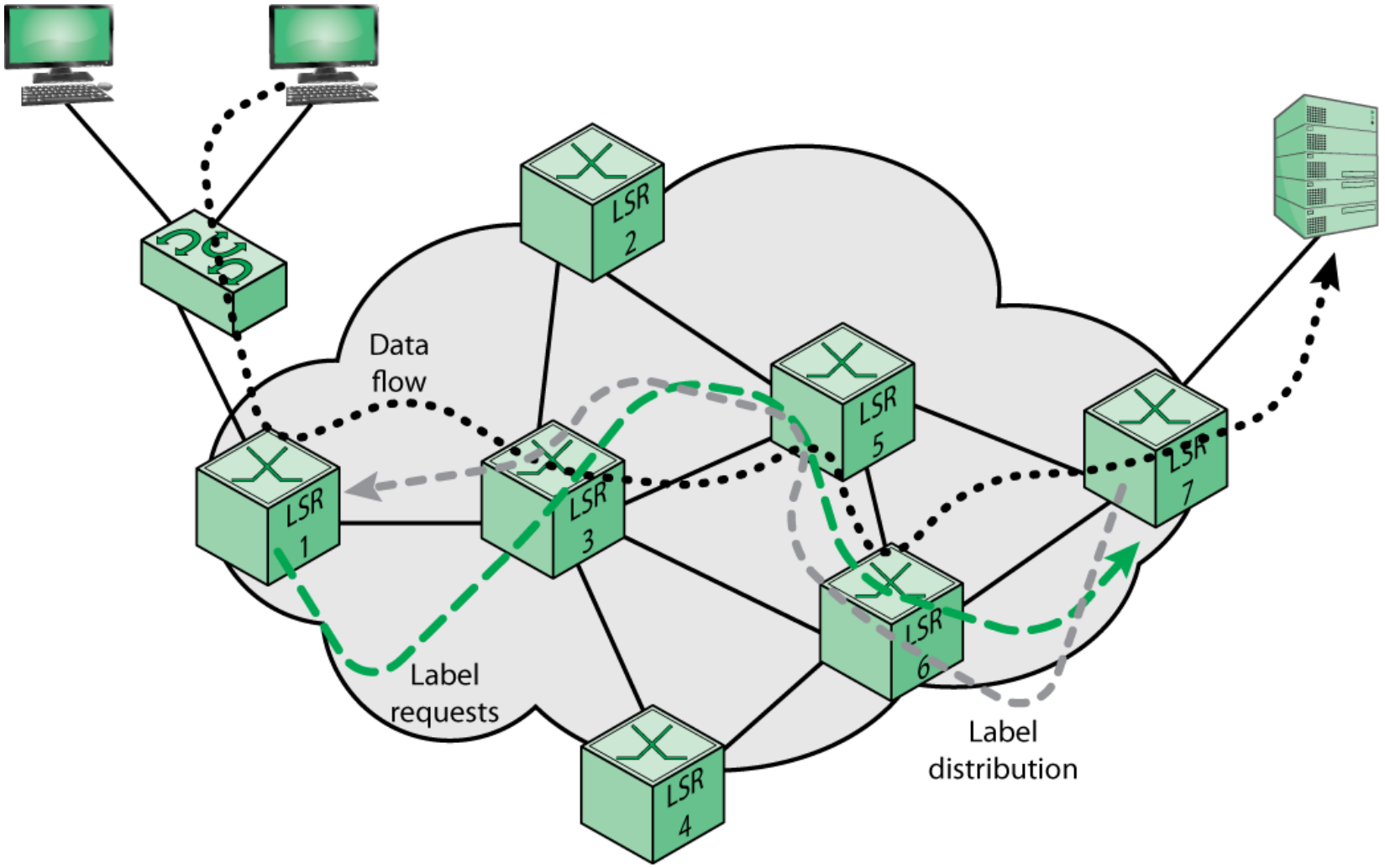
- LSR A分别对两个分组加上标记21和17
- LSR B分别将两个分组标记对换为47和11
- LSR C和LSR D分别从两个分组除去标记



MPLS Packet Forwarding



LSP Creation and Packet Forwarding



Route Selection

- refers to the selection of an LSP for a particular FEC
- supports two options:
  - hop-by-hop routing
    - each LSR independently chooses the next hop for each FEC
    - does not readily support traffic engineering or policy routing
  - explicit routing
    - a single LSR specifies some or all of the LSRs
    - can be set up ahead of time or dynamically

Requirements for Label Distribution

- label distribution protocol enables two LSRs to learn each other's MPLS capabilities
- RFC 3031 refers to a new label distribution protocol and to enhancements of existing protocols

hop-by-hop route selection

- no attention is paid to traffic engineering or policy routing concerns
- ordinary routing protocol is used to determine the next hop by each LSR

Label Distribution Protocol

- protocols that communicate which label goes with which Forwarding Equivalence Class (FEC)
  - Label Distribution Protocol (LDP; RFC 5036)
  - Resource Reservation Protocol – Traffic Engineering (RSVP-TE; RFC 3209)
  - multiprotocol BGP as extended for Layer 3 VPNs (L3VPNs; RFC 4364)

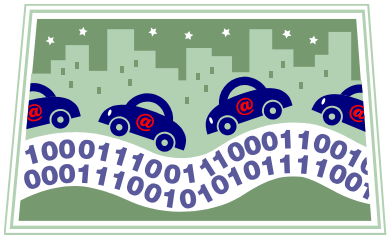
➢ once a route is established LDP is used to establish the LSP and assign labels

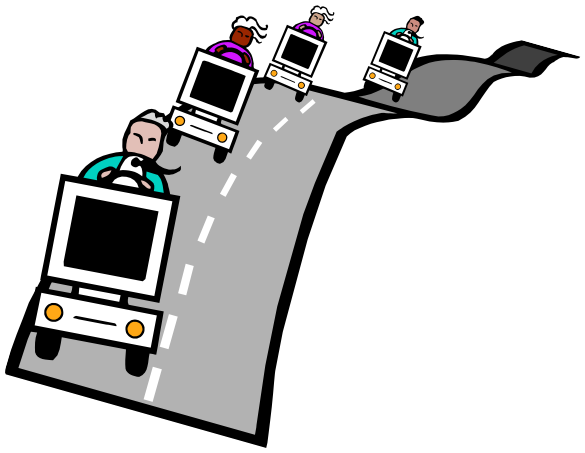
LDP Messages

- Discovery
  - each LSR announces and maintains its presence in a network
    - Hello messages
    - ➢Session establishment and maintenance
  - LDP peers
    - ➢Advertisement
  - create, change, and delete label mappings for FECs
    - ➢Notification messages
  - provide advisory information and to signal error information

Traffic Engineering

- RFC 2702
- allocate traffic to the network to maximize utilization of the network capacity
- ensure the most desirable route through the network while meeting QoS requirements





Traffic Engineering

- ability to define routes dynamically, plan resource commitments on the basis of known demand, and optimize network utilization
- effective use can substantially increase usable network capacity
- ATM provided strong traffic engineering capabilities prior to MPLS
- with basic IP there is a primitive form

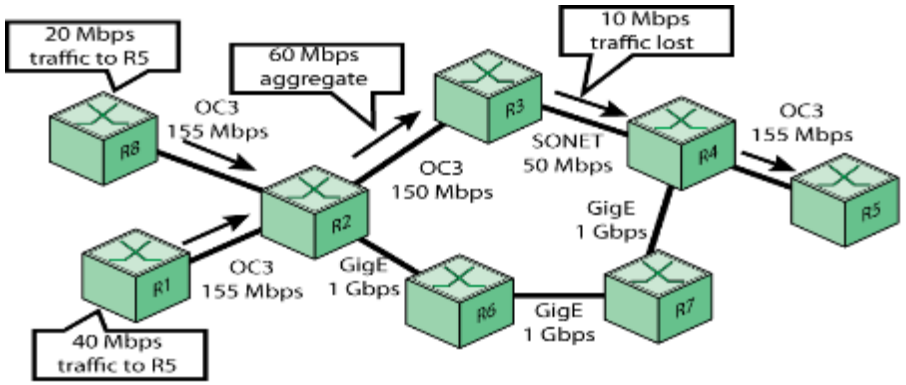
MPLS:

- **is aware of flows with QoS requirements**
- **possible to set up routes on the basis of flows**
- **paths can be rerouted intelligently**

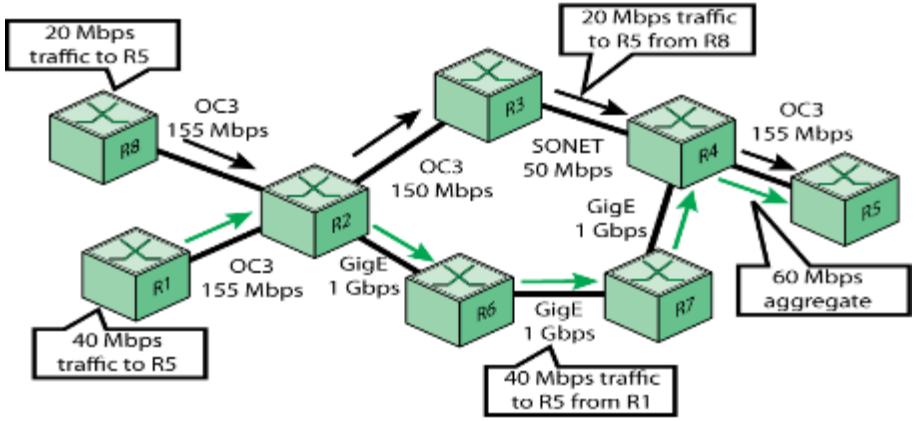
Elements of MPLS Traffic Engineering

- Information distribution
  - a link state protocol is necessary to discover the topology of the network
- Path calculation
  - shortest path through a network that meets the resource requirements of the traffic flow
- Path setup
  - signaling protocol to reserve the resources for a traffic flow and to establish the LSP
- Traffic forwarding
  - accomplished with MPLS using the LSP

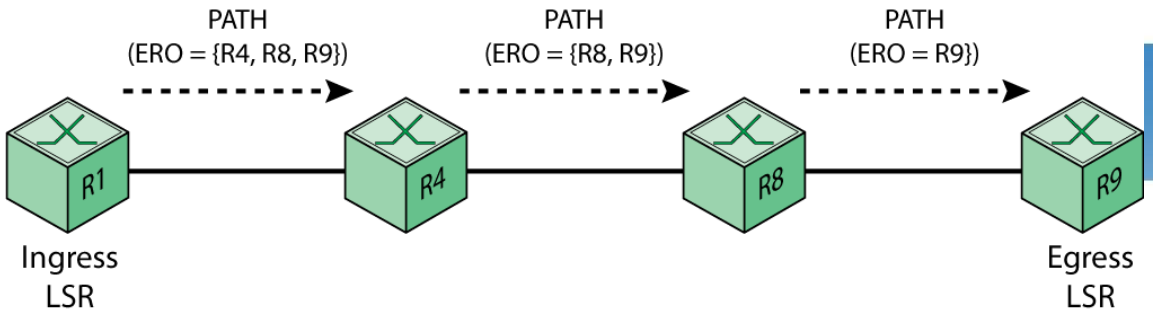
Example of Traffic Engineering



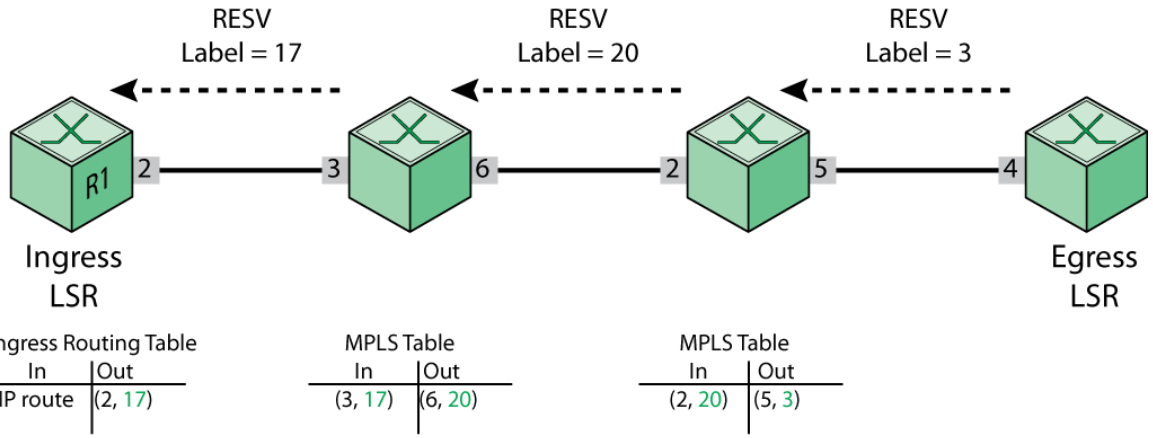
(a) A shortest-path solution



(b) A traffic-engineered solution



(a) Use of PATH message



(b) Use of RESV message

Figure 21.11 RSVP-TE Operation

Virtual Private Network (VPN)

- private network configured within a public network in order to take advantage of management facilities of larger networks

widely used by enterprises to:

- create wide area networks (WANs)
- provide site-to-site communications to branch offices
- allow mobile user to dial up their company LANs

- traffic designated as VPN traffic can only go from a VPN source to a destination in the same VPN

VPN Terminology

Attachment circuit (AC) In a Layer 2 VPN the CE is attached to PE via an AC. The AC may be a physical or logical link.

Customer edge (CE) A device or set of devices on the customer premises that attaches to a provider provisioned VPN.

Layer 2 VPN (L2VPN) An L2VPN interconnects sets of hosts and routers based on Layer 2 addresses.

Layer 3 VPN (L3VPN) An L3VPN interconnects sets of hosts and routers based on Layer 3 addresses.

Packet switched network (PSN) A network through which the tunnels supporting the VPN services are set up.

Provider edge (PE) A device or set of devices at the edge of the provider network with the functionality that is needed to interface with the customer.

Tunnel Connectivity through a PSN that is used to send traffic across the network from one PE to another. The tunnel provides a means to transport packets from one PE to another. Separation of one customer's traffic from another customer's traffic is done based on tunnel multiplexers

Tunnel multiplexer An entity that is sent with the packets traversing the tunnel to make it possible to decide which instance of a service a packet belongs to and from which sender it was received. In an MPLS network, the tunnel multiplexor is formatted as an MPLS label.

Virtual channel (VC) A VC is transported within a tunnel and identified by its tunnel multiplexer. In an MPLS-enabled IP network, a VC label is an MPLS label used to identify traffic within a tunnel that belongs to a particular VPN; i.e., the VC label is the tunnel multiplexer in networks that use MPLS labels.

Virtual private network (VPN) A generic term that covers the use of public or private networks to create groups of users that are separated from other network users and that may communicate among them as if they were on a private network.

Layer 2 VPN Concepts

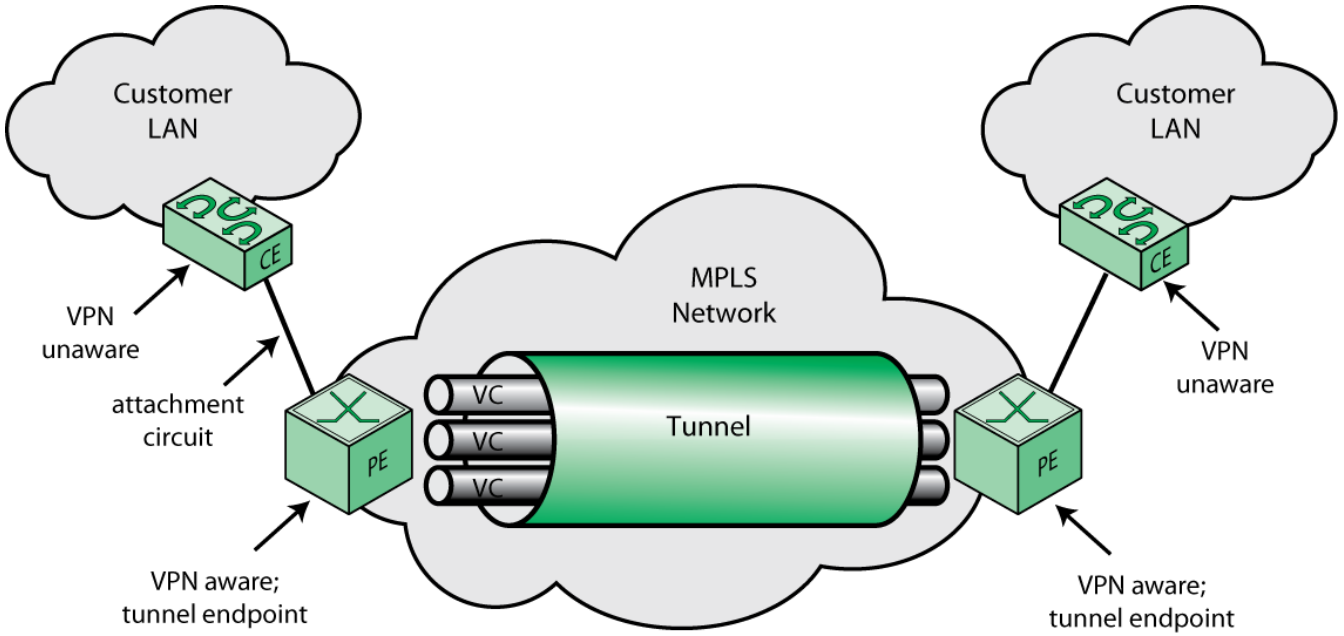


Figure 21.12 Layer 2 VPN Concepts

Layer 3 VPN

- based on VPN routes between CEs based on IP addresses
- CE implements IP and is thus a router
- CE routers advertise network to provider
- provider uses an enhanced version of BGP to establish VPNs between CEs
- MPLS tools establish routes

Summary

- The role of MPLS
  - background, QoS, traffic engineering, VPN
- MPLS operation
- Labels
  - stacking, format, placement
- FECs, LSPs, and labels
- Label distribution
  - LPD Messages/format
- Traffic engineering
  - elements
- VPN
  - layer 2, layer 3

总结

问题？