南京大学 软件学院
NANJING UNIVERSITY · SOFTWARE INSTITUTE

WANs

WANs

- WAN Technology & Devices
- WANs & The OSI Model
- WAN Accessing Methods
  - PPP/HDLC
  - ISDN
  - ADSL
  - SONET
  - HFC

WAN Services

- A WAN is the communications network that connects LANs through a WAN Service Provider
- WANs operate at the first three layers of the OSI, but focus mainly on the physical and data link layers.

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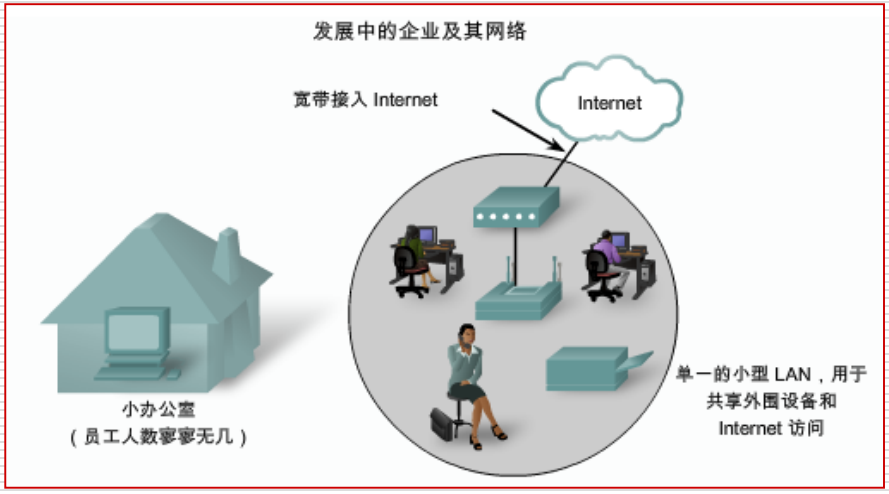
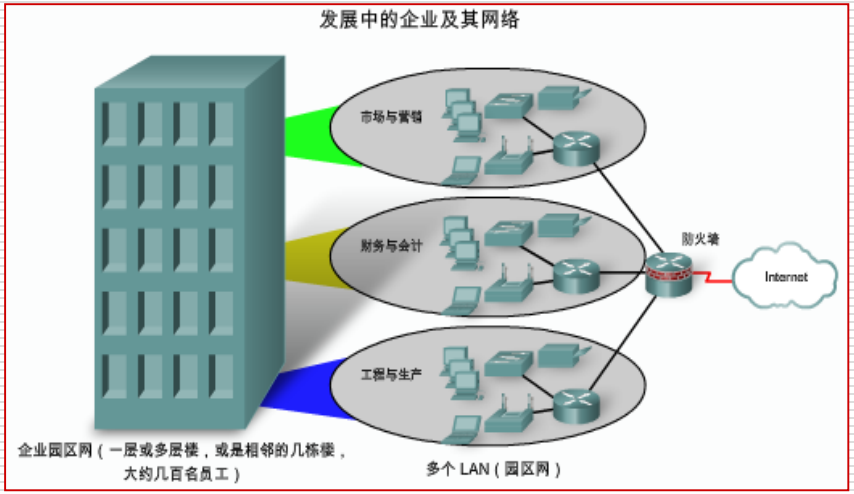
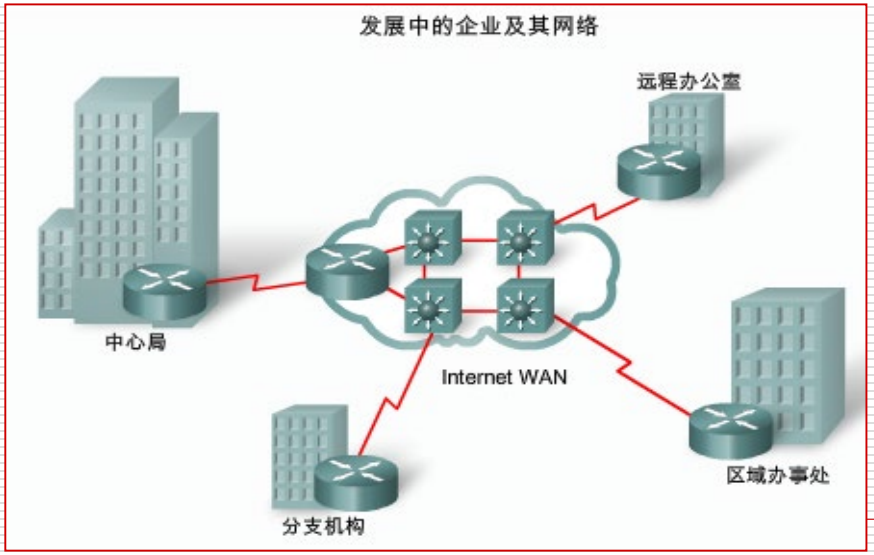
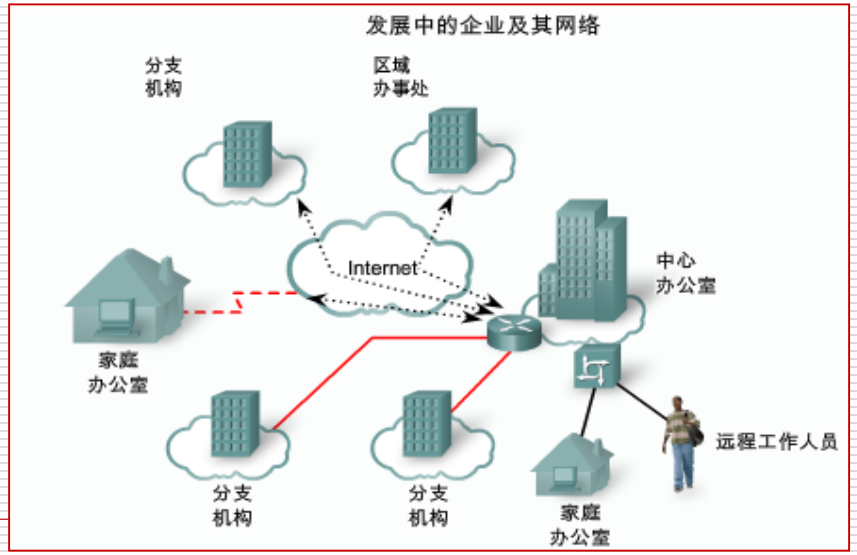
The Evolving Enterprise







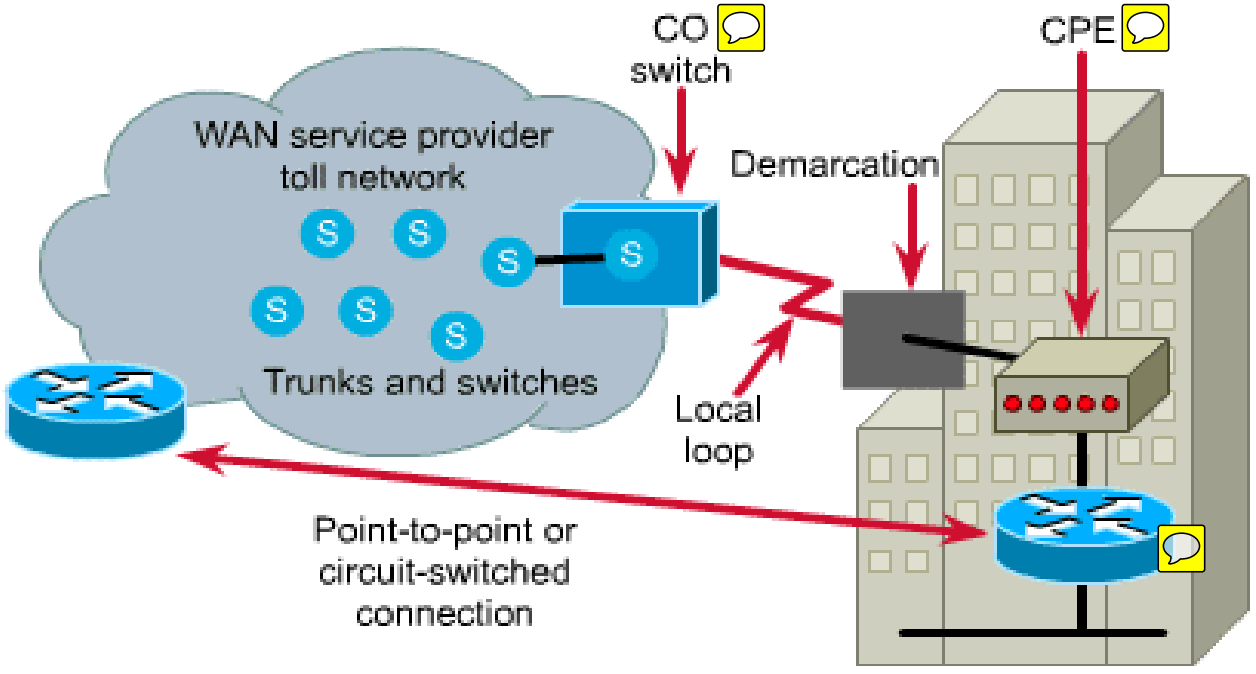


WAN Physical Structure

Toll Network – collection of switches/trunks in WAN cloud

CO Switch – nearest point of presence for the WSP's service

- CPE: Customer Premises Equipment
- CO: Central Office



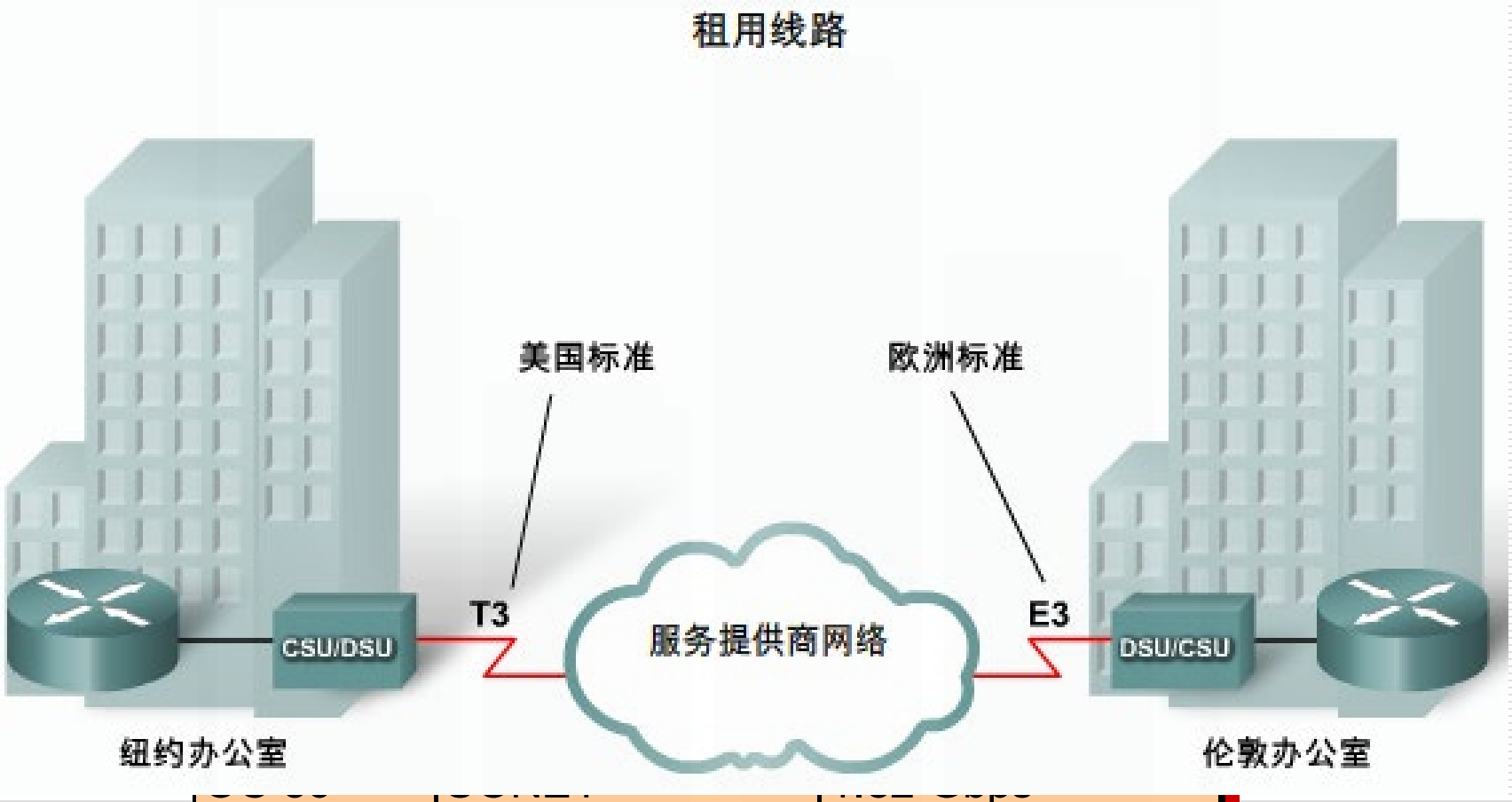
Local loop – extends from the CPE (at the demarc) to the CO

CPE – devices located on premises, either owned or leased

WAN Virtual Circuits

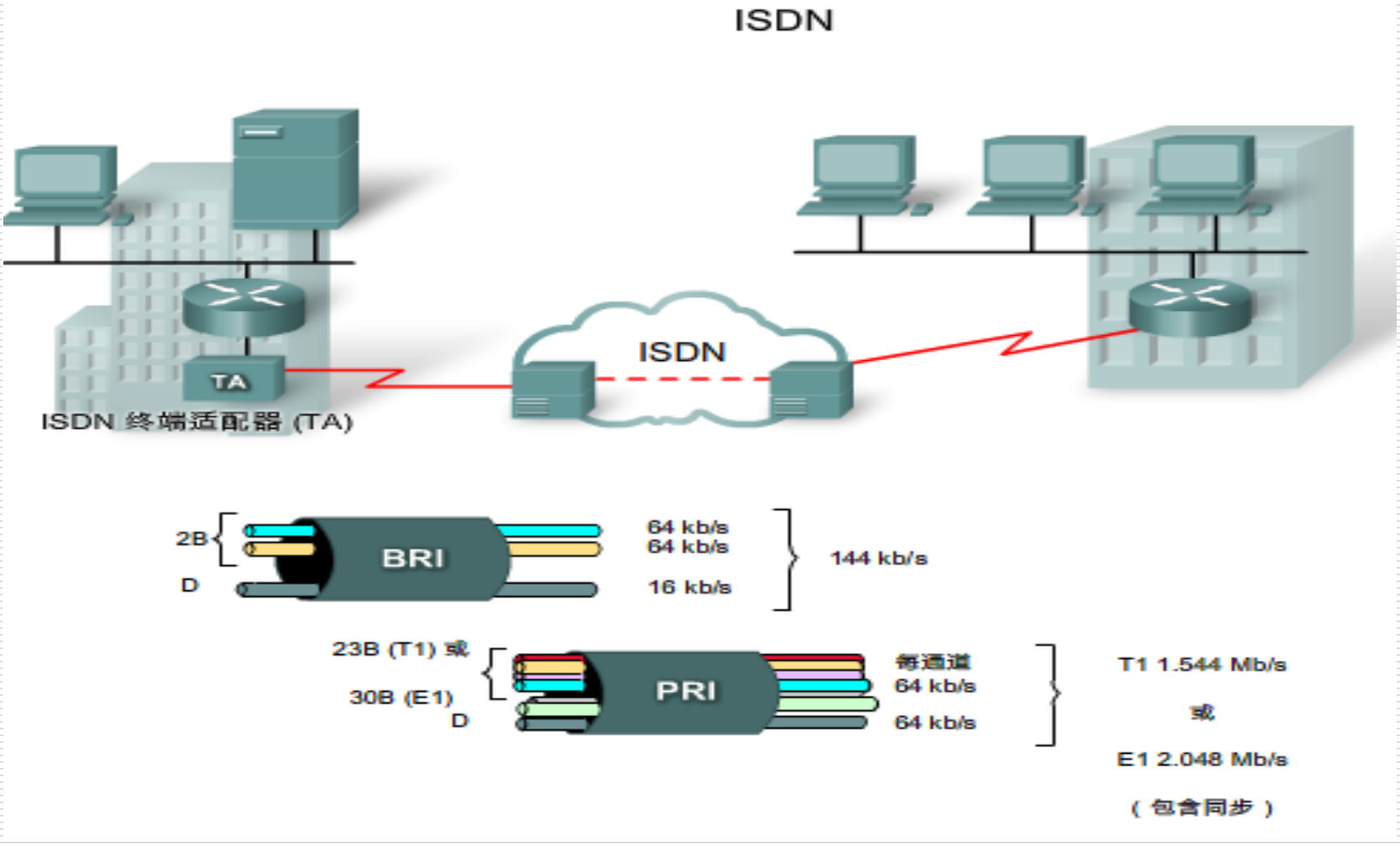
- Switched Virtual Circuits (SVCs) are WAN paths to the destination established and terminated on demand.
  - Three phases:
    - Circuit establishment – creates the virtual circuit
    - Data transfer – sending and receiving user data
    - Circuit termination – tearing down the virtual circuit
  - Telephone service and ATM use SVCs
  - Increased use of bandwidth but decreased cost
- Permanent Virtual Circuits (PVCs) are permanently established circuits with one mode: data transfer
  - X.25 and Frame Relay use PVCs
  - Decreased use of bandwidth but increased cost

Link Types & Bandwidth

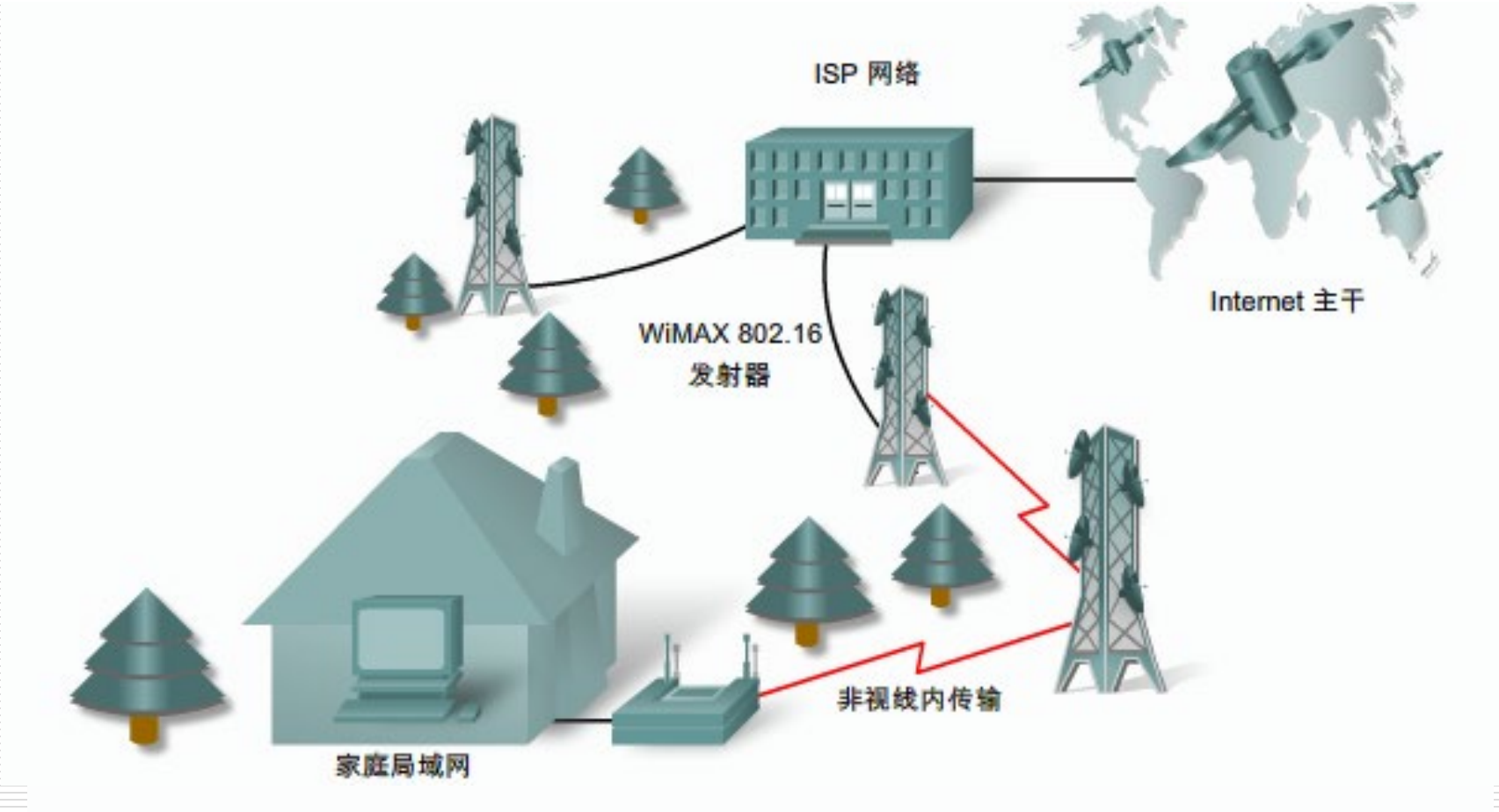


OC-48	SONET	2.43 Gbps

Circuit Switched Connection



Internet Connection

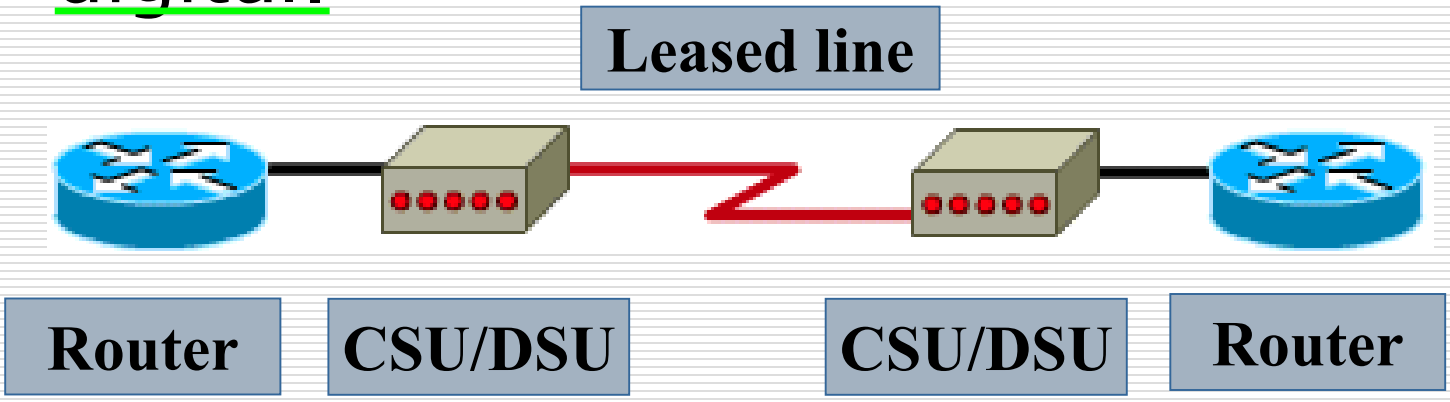


WAN Devices

- In order to connect to a leased line, the customer must have…
  - Access to the service provider's circuit
  - An appropriate router port available
  - A CSU/DSU, modem, ISDN Terminal Adapter, etc.

Modems

- Also called CSU/DSUs (channel service units/digital service units)
- Interface with voice-grade connection in order to convert analog signal to digital.



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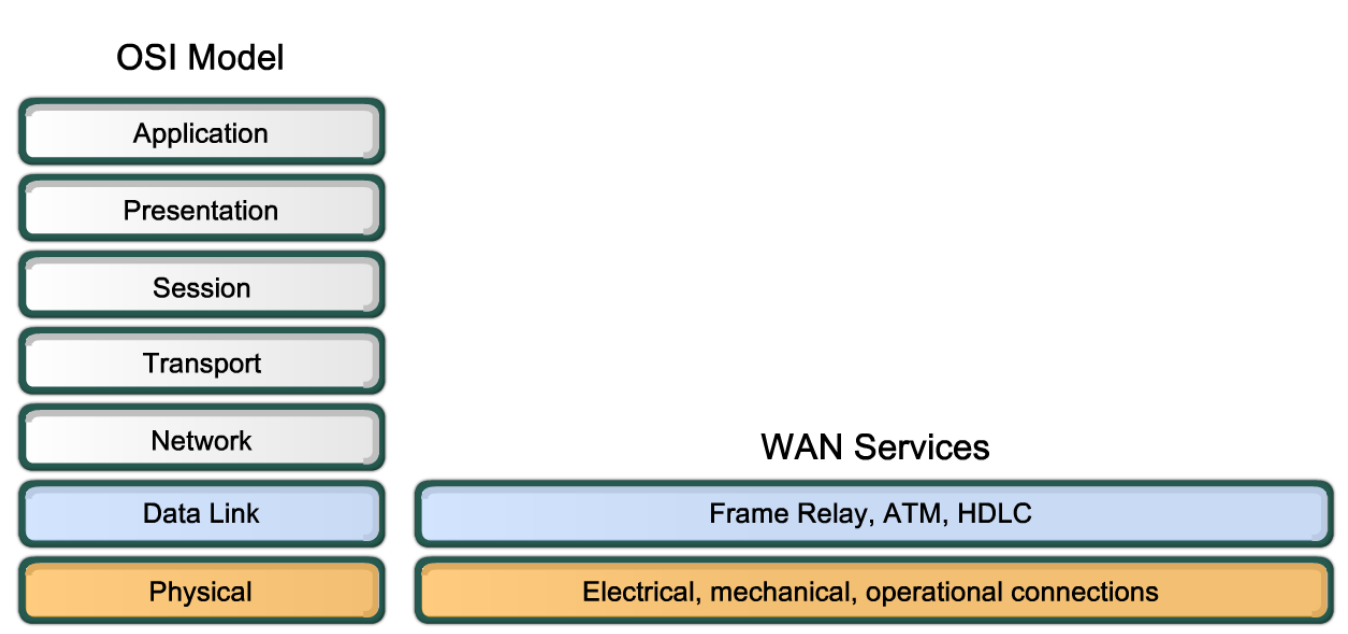
WAN Standards

- What layers of the OSI model do WAN standards mainly describe?



WAN Physical Layer

- Protocols that describe how to provide electrical, mechanical, operational, and functional connections for WAN services.
- These services are most often obtained from WAN service providers, alternate carriers, post-telephone, and telegraph (PTT) agencies.
- Describes the interface between the data terminal equipment (DTE) and the data circuit-terminating equipment (DCE).

WAN Physical Layer

- Typically, the DCE is the service provider and the DTE is the attached device.
- In this model, the services offered to the DTE are made available through a modem or a CSU/DSU.

WAN Physical Layer

- Several physical layer standards specifying this interface between the DTE & DCE are...
  - EIA/TIA-232 (RS-232)
  - EIA/TIA-449
  - V.24
  - V.35
  - X.21
  - G.703
  - EIA-530

WAN Data-Link Layer

- WAN data link protocols describe how frames are carried between systems on a single data link.
- They include protocols designed to operate over dedicated point-to-point, multipoint, and multi-access switched services.
- WAN standards are defined and managed by a number of recognized authorities, including the following agencies: ITU-T, ISO, IETF, & EIA

Data-link Encapsulations

- The WAN data link layer defines how data is encapsulated for transmission to remote sites
  - **Point-to-Point Protocol (PPP)**: developed by the IETF. PPP contains a protocol field to identify the network-layer protocol
  - **High-Level Data Link Control (HDLC)**: an ISO standard, HDLC not compatible between different vendors because of the way each vendor has chosen to implement it. HDLC supports point-to-point/multipoint configurations
  - **Frame Relay**: uses simplified encapsulation with no error correction over high-quality digital facilities.
  - **ISDN**: a set of digital services that transmits voice and data over existing phone lines.
  - **Link Access Procedure, Balanced (LAPB)**: For packet-switched networks used to encapsulate packets at Layer 2 of the X.25 stack. Provides reliability and flow control on a point-to-point basis.

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Serial line frame fields

- The two most common point-to-point WAN encapsulations are HDLC and PPP
- All the serial line encapsulations share a common frame format, which has the following fields

PPP

Flag	Address	Control	Protocol	Data	FCS	Flag

HDLC

Flag	Address	Control	Proprietary	Data	FCS	Flag

- The choice of encapsulation protocol depends on the WAN technology and the communicating equipment.

PPP and HDLC

- PPP is a standard serial-line encapsulation method
  - Developed by IETF; replacing SLIP
  - Contains a field to identify the network layer protocol
  - PPP can check for link quality during connection establishment
  - Provides authentication through Password Authentication Protocol (PAP) and Challenge Handshake Authentication Protocol (CHAP).
- HDLC is Cisco's default encapsulation for serial lines
  - No windowing or flow control
  - A proprietary type code is inserted in the frame which means that HDLC framing is not interoperable with other vendors' equipment.
  - Used when both ends of a dedicated-line connection are routers running Cisco IOS

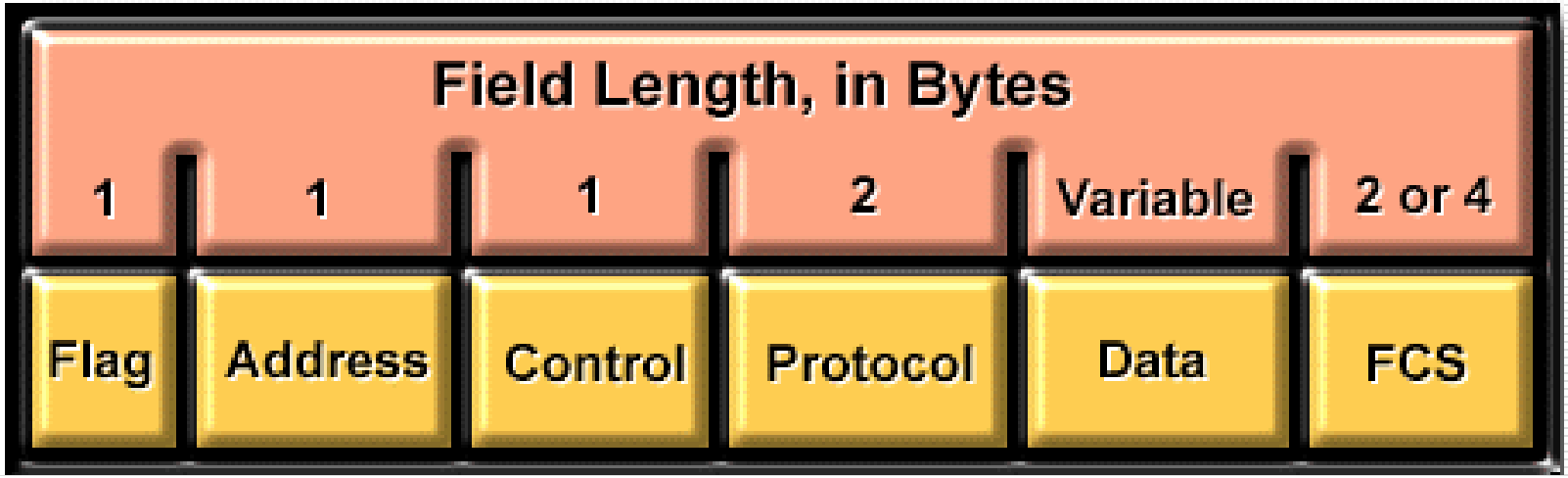
PPP

- The most widely used layer-2 protocol over serial links
- Developed from SLIP, which
  - Supports only IP protocol
  - Doesn't support dynamic IP assignment
  - Doesn't support authentication
  - Doesn't support compression
  - Doesn't support error detection
- PPP offers the following features:
  - Network protocol multiplexing
  - Dynamic assignment of IP addresses
  - Authentication: PAP, CHAP
  - Compression
  - Error detection

PPP components

- Uses HDLC(ISO HDLC, not Cisco HDLC) as a basis to encapsulate layer 3 datagrams.
- Implements LCP (Link Control Protocol) for:
  - Connection establishment
  - Connection configuration options
  - Link-quality testing
- Implements NCP (Network Control Protocol) to select and configure layer 3 protocol.

PPP frame format



- Flag: Beginning or end of a frame, 01111110
- Address:11111111,broadcast address
- Control:00000011,user data is transferred as disorder frames
- Protocol: The protocol type in data field
- Data: Datagram, maximum default is 1500 bytes
- FCS: Error controlling

PPP session establishment/ termination

- To establish communications over a point-to-point link, PPP goes through four distinct phases：
  - Link establishment and configuration negotiation (LCP).
  - Link quality testing.
  - Network layer protocol configuration (NCP).
  - Link termination.

Phase 1. Link establishment

PPP Session Establishment/Termination

- Link Estalishment Phase
- Link Quality Phase
- Network-Layer Protocol Phase
- Link Termination Phase

Phase 1. Link establishment

- Link establishment is the first phase before any network-layer datagrams can be exchanged
  - Each PPP device sends LCPs to open the connection
  - LCP packets contain a configuration option field that allows devices to negotiate the use of options such as compression and authentication protocol, etc.
  - If a configuration option is not included in an LCP packet, the default value for that configuration option is assumed.
  - This phase is complete when a configuration acknowledgment frames has been sent and received.

Phase 2. Link quality determination

- LCP packets are sent and received to measure the error rate on the link if configured to do so
- Authentication, if used, takes place before the network-layer protocol configuration phase begins.
- LCP can delay transmission of network-layer protocol information until this phase is completed.

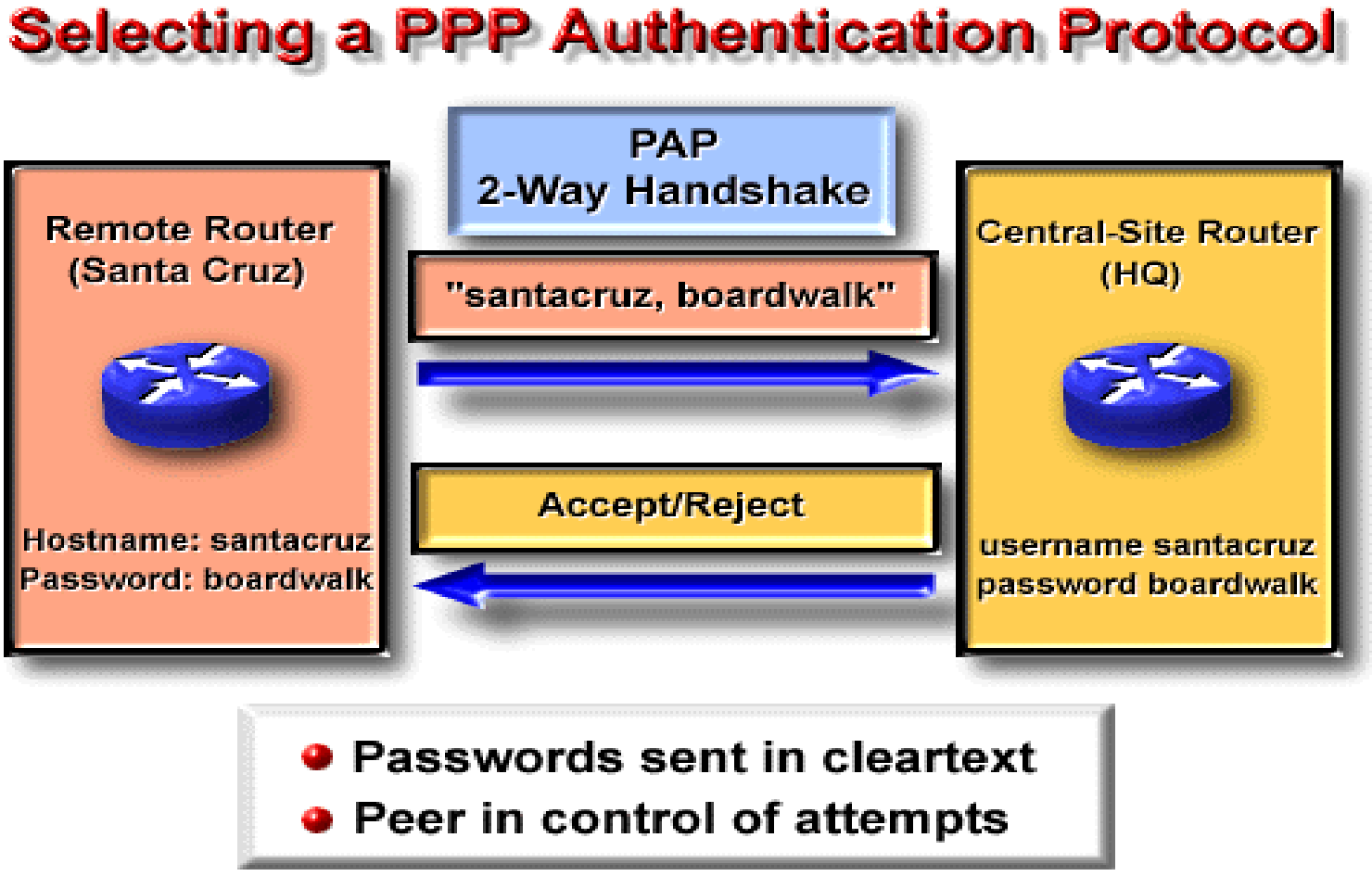
Phase3. Network layer protocol configuration

- In this phase, the PPP devices send NCP packets to choose and configure one or more network-layer protocols (such as IP).
- When each of the chosen network-layer protocols has been configured, datagrams from each network-layer protocol can be sent over the link.

Phase4. Link termination

- LCP can terminate the link at any time:
  - At the user request;
  - Quality of the link;
  - Timeout.
- When LCP closes the link, it informs the network-layer protocols so that they can take appropriate action.

PAP


Selecting a PPP Authentication Protocol
PAP
2-Way Handshake
Remote Router
(Santa Cruz)
Hostname: santacruz
Password: boardwalk
"santacruz, boardwalk"
Accept/Reject
Central-Site Router
(HQ)
username santacruz
password boardwalk
Passwords sent in cleartext
Peer in control of attempts

PAP

- The calling side of the link enter authentication information to help ensure that the user has the network administrator's permission to make the call.
- Remote node establishes its identity, using a ***two-way handshake PAP***.
- Username/password pair ***is repeatedly sent*** by the remote node until authentication is acknowledged or the connection is terminated
- Passwords are sent across the link in ***clear text***.
- Remote node is authenticated only once after the connection establishment phase.

PAP

Configuration of remote router

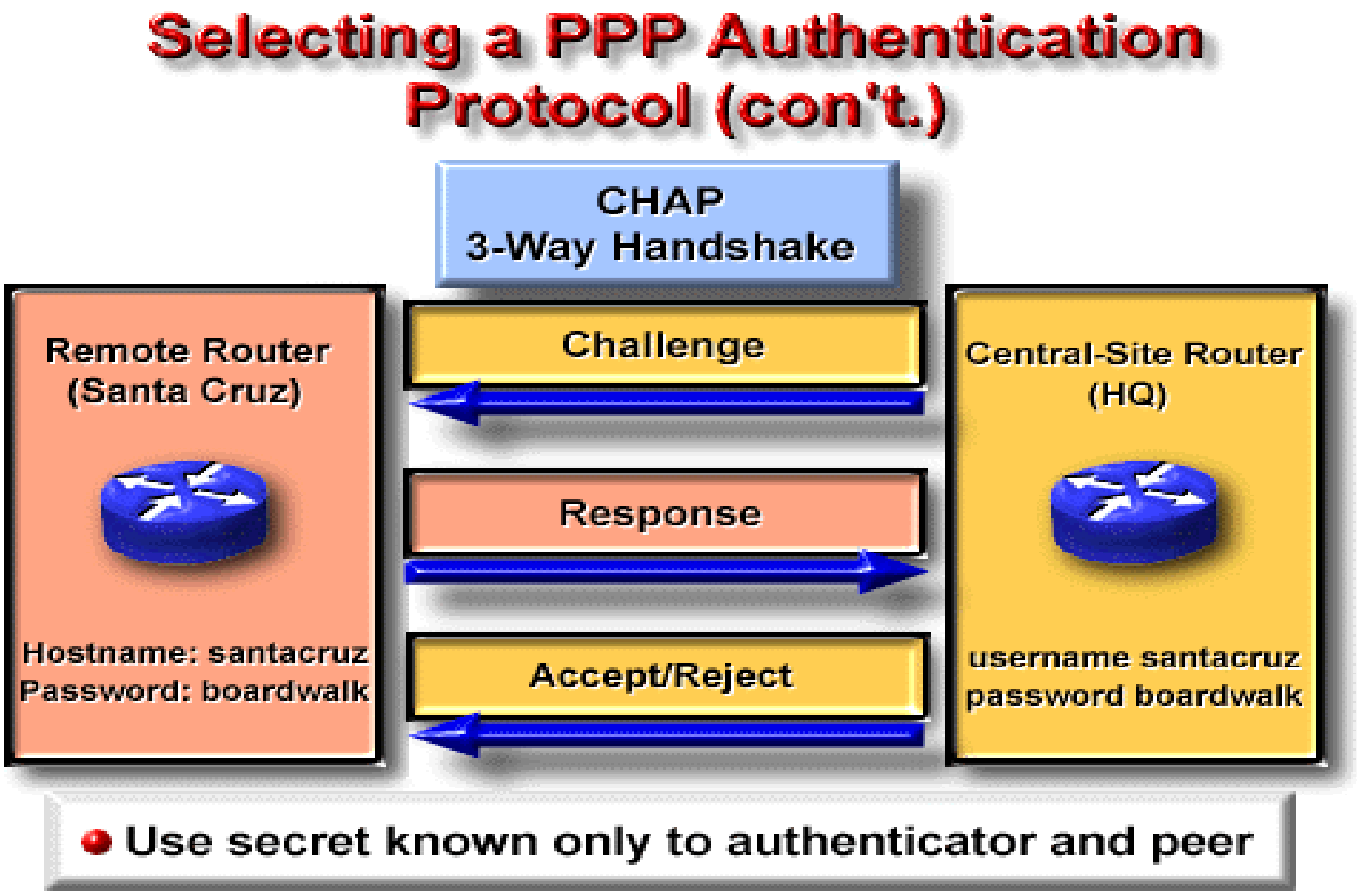
- Router(config)#hostname RTA
- RTA(config)#int s0
- RTA(config)#ip address 192.168.2.1 255.255.255.0
- RTA(config)#encapsulation ppp
- RTA(config)#ppp pap sent-username RTA password ciscoA
- RTA(config)#no shut

PAP

Configuration of service provider router

- Router(config)#hostname RTB
- RTB(config)#username RTA password CiscoA
- RTB(config)#int s0
- RTB(config)#ip address 192.168.2.2 255.255.255.0
- RTB(config)#clock rate 56000
- RTB(config)#encapsulation ppp
- RTB(config)#ppp authentication pap
- RTB(config)#no shut

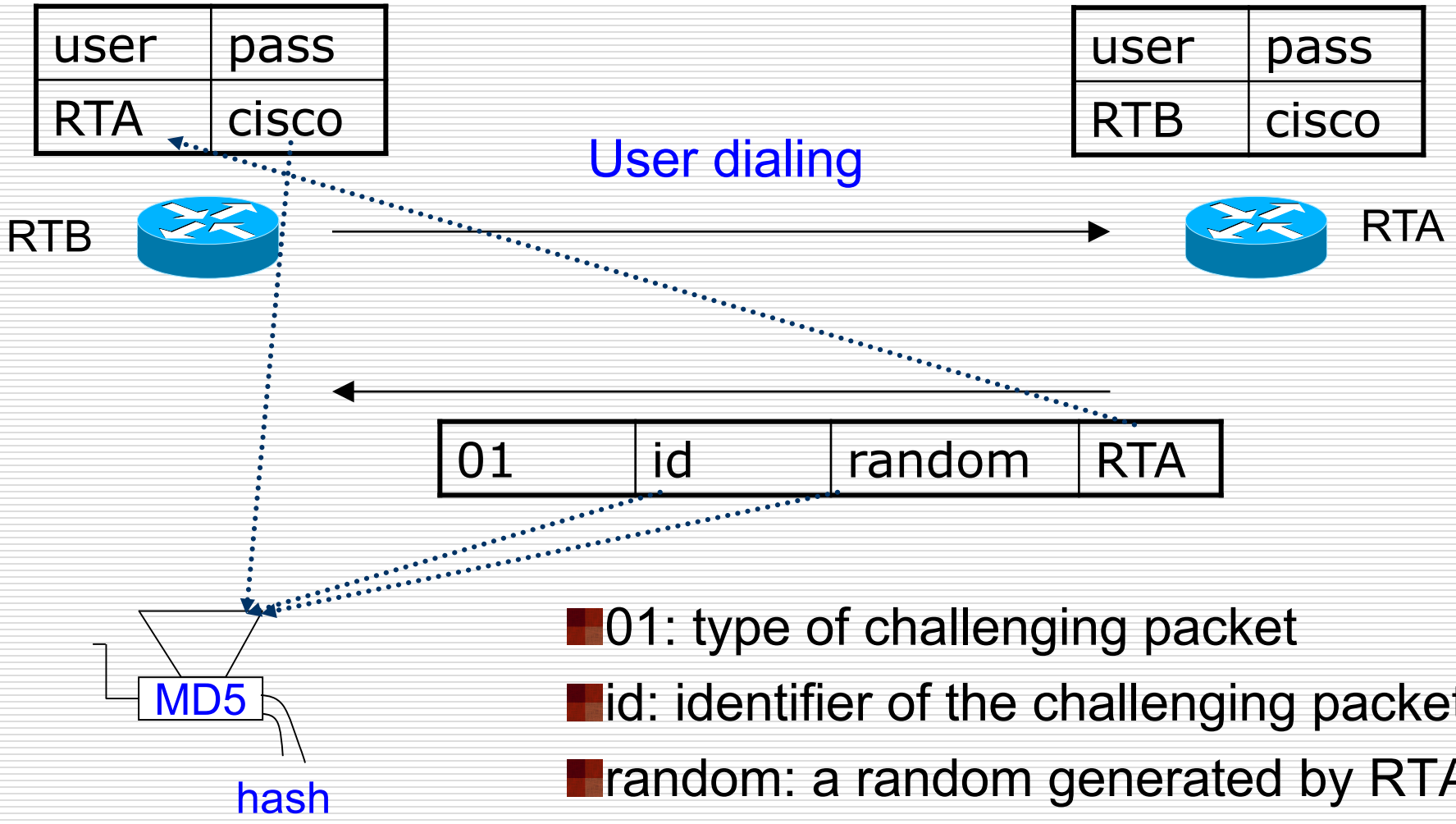
CHAP


Selecting a PPP Authentication Protocol (con't.)
CHAP
3-Way Handshake
Remote Router
(Santa Cruz)
Hostname: santacruz
Password: boardwalk
Challenge
Response
Accept/Reject
Central-Site Router
(HQ)
username santacruz
password boardwalk
Use secret known only to authenticator and peer

CHAP

- The called party periodically verifies the calling side, using a *three-way handshake* CHAP protocol.
- CHAP does not allow a caller to attempt authentication without a challenge (random number).
- The host (called party) sends a ***challenge*** message to the remote node.
- The remote node responds with a value (encrypted value including: the received challenge, its username and its password).
- The host checks the response against its own value
  - If the values match, the authentication is acknowledged
  - Otherwise, the connection is terminated

CHAP: Challenging

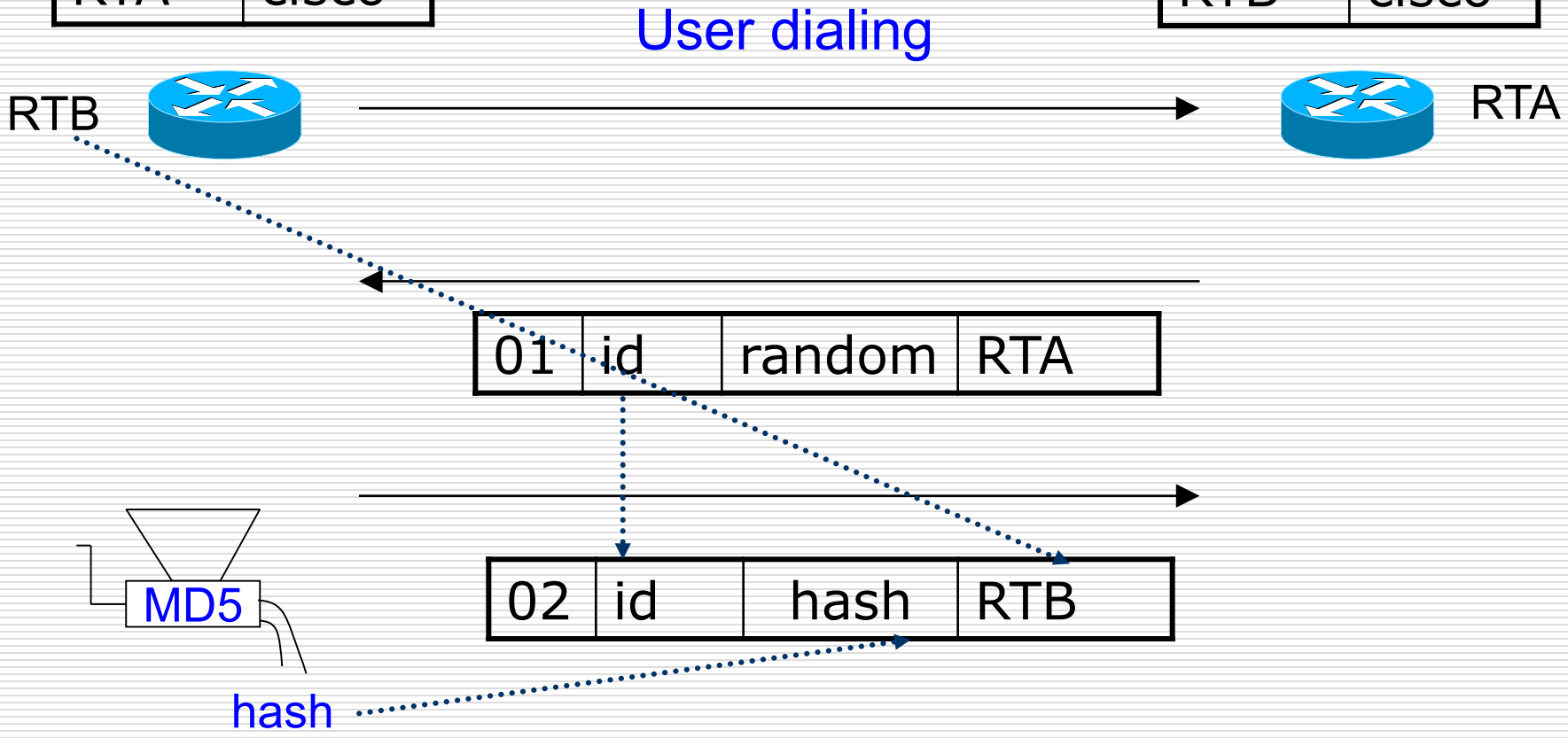


- 01: type of challenging packet
- id: identifier of the challenging packet
- random: a random generated by RTA

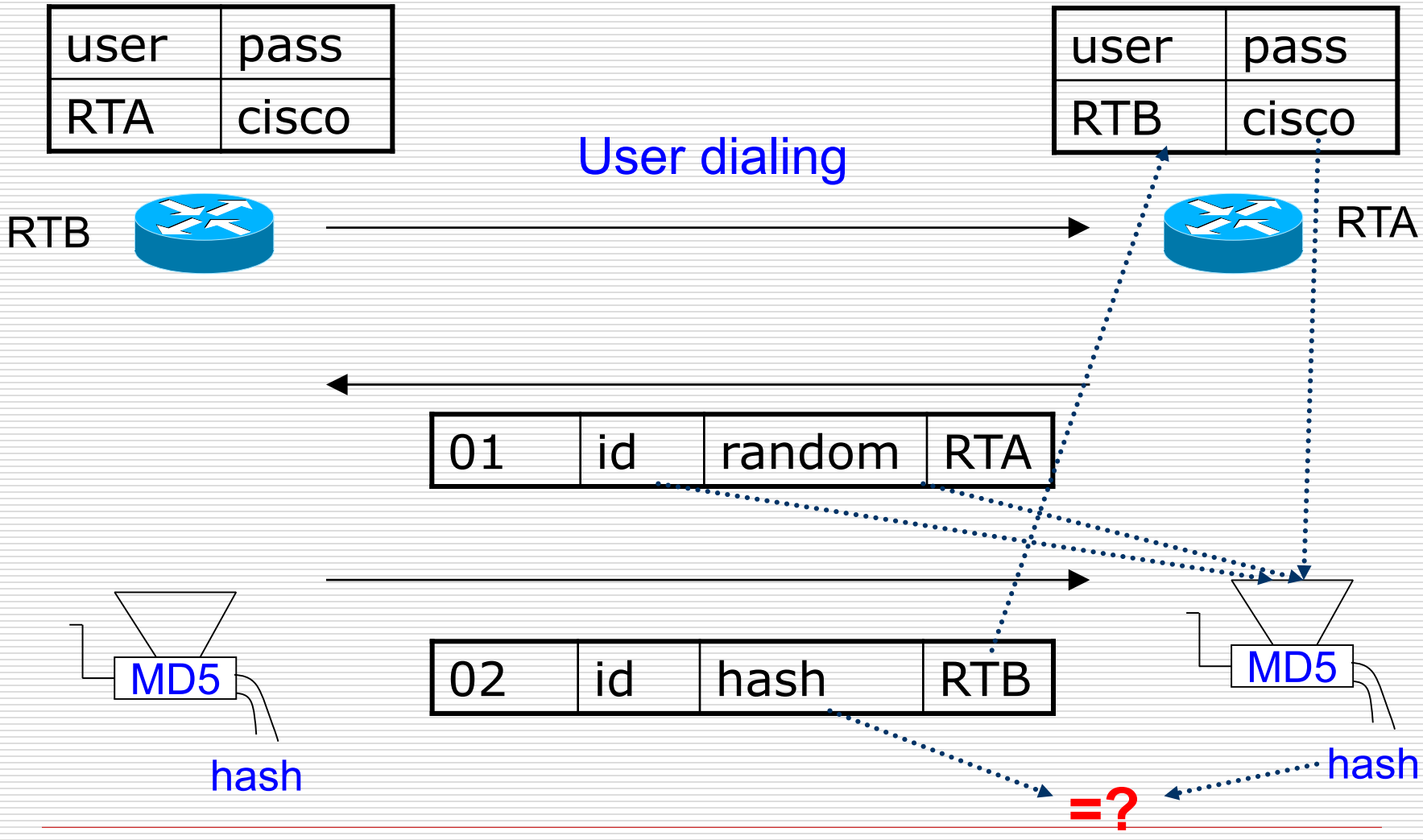
CHAP: Acknowledgement

user	pass
RTA	cisco

user	pass
RTB	cisco



CHAP: Verifying Acknowledgement



CHAP

Configuration of remote router

- Router(config)#hostname RTA
- RTA(config)#username RTB password CiscoA
- RTA(config)#int s0
- RTA(config)#ip address 192.168.2.1 255.255.255.0
- RTA(config)#encapsulation ppp
- RTA(config)#no shut

CHAP

Configuration of service provider router

- Router(config)#hostname RTB
- RTB(config)#username RTA password CiscoA
- RTB(config)#int s0
- RTB(config)#ip address 192.168.2.2 255.255.255.0
- RTB(config)#clock rate 56000
- RTB(config)#encapsulation ppp
- RTB(config)#ppp authentication chap
- RTB(config)#no shut

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What is ISDN?

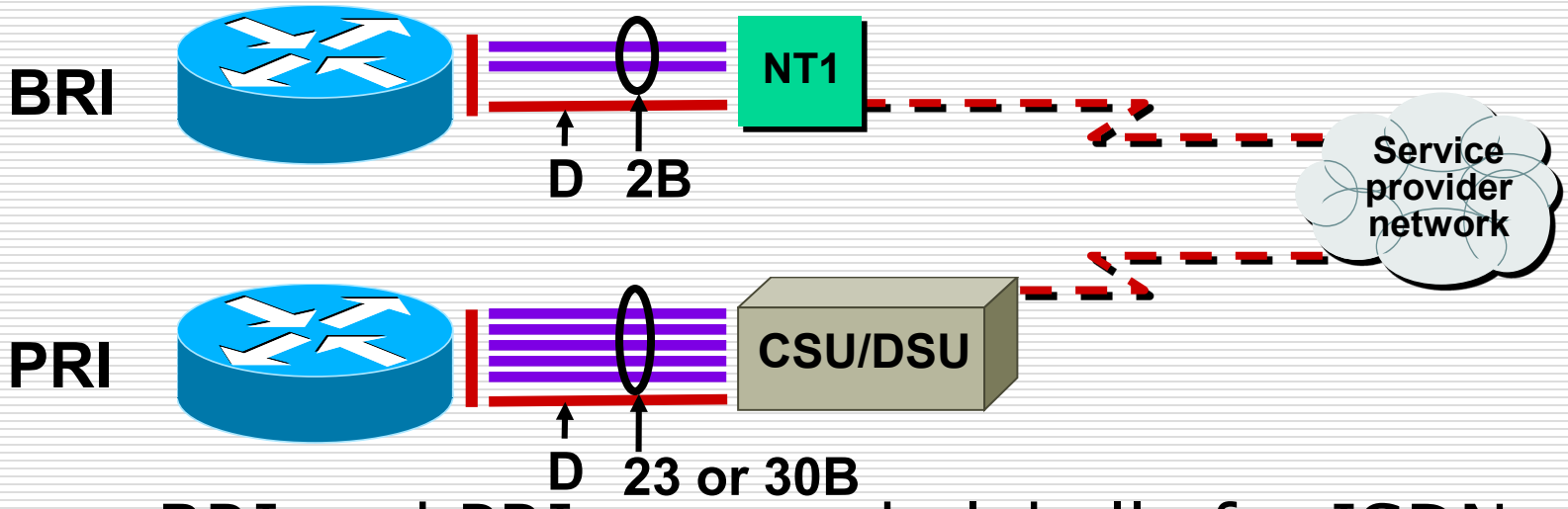
- **I**ntegrated **S**ervices **D**igital **N**etworks allow digital signals to be transmitted over existing phone lines.
  - Provides connectivity for remote sites
- ISDN has the following benefits:
  - Can carry voice, video, and data
  - Faster call setup than modems (sometimes<1s) using the out-of-band D (or Delta) channel
  - Offers faster data transfer using the B (or Barrier) channels at 64kps

BRI and PRI

- There are two ISDN services:
  - **BRI** (**Basic** Rate Interface)
  - **PRI** (**Primary** Rate Interface).
- The ISDN BRI service offers **two B** channels and **one D** channel.
- ISDN BRI delivers a total bandwidth of a **144-kbps** (2B+D=144kps) line into **three** separate channels.
- BRI B channel service operates at **64 kbps** and is meant to carry user **data** and **voice** traffic.
- The third channel, the **D channel**, is a **16 kbps signalling channel** used to carry instructions that tell the telephone network how to handle each of the B channels.

BRI and PRI

Channel	Capacity	Mostly Used for
B	64kbps	Circuit-switched data (HDLC, PPP)
D	16kbps	Signaling information (LAPD)



- BRI and PRI are used globally for ISDN

Standard

- ISDN utilizes a suite of ITU-T standards spanning the physical, data-link, and network layers of the OSI reference model.
- Several encapsulation choices are available. The two most common encapsulations are PPP and HDLC.
- ISDN defaults to HDLC. However, PPP is much more robust because it provides an excellent mechanism for authentication and negotiation of compatible link and protocol configuration.
- ISDN interfaces allow only a single encapsulation type.

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xDSL技术

- xDSL 技术就是用数字技术对现有的模拟电话用户线进行改造，使它能够承载宽带业务
- 虽然标准模拟电话信号的频带限制在 300~3400kHz 范围内，但用户线本身实际可通过的信号频率仍超过 1 MHz
- xDSL 技术把 0~4 kHz 低端频谱留给传统电话使用，而把原来没有被利用的高端频谱留给用户上网使用
- DSL ： 数字用户线(Digital Subscriber Line)
- DSL 的前缀 x 表示在数字用户线上实现的不同宽带方案

xDSL 的几种类型

- ADSL (Asymmetric Digital Subscriber Line)：非对称数字用户线
- HDSL (High speed DSL)：高速数字用户线
- SDSL (Single-line DSL)：1 对线的数字用户线
- VDSL (Very high speed DSL)：甚高速数字用户线
- IDSL ：ISDN 用户线
- RADSL (Rate-Adaptive DSL)：速率自适应 DSL，是 ADSL 的一个子集，可自动调节线路速率

ADSL 的极限传输距离

- ADSL 的极限传输距离与数据率以及用户线的线径都有很大的关系（用户线越细，信号传输时的衰减就越大），而所能得到的最高数据传输速率与实际的用户线上的信噪比密切相关。
- 例如，0.5 毫米线径的用户线，传输速率为 1.5 ~ 2.0 Mb/s 时可传送 5.5 公里，但当传输速率提高到 6.1 Mb/s 时，传输距离就缩短为 3.7 公里。
- 如果把用户线的线径减小到0.4毫米，那么在6.1 Mb/s的传输速率下就只能传送2.7公里

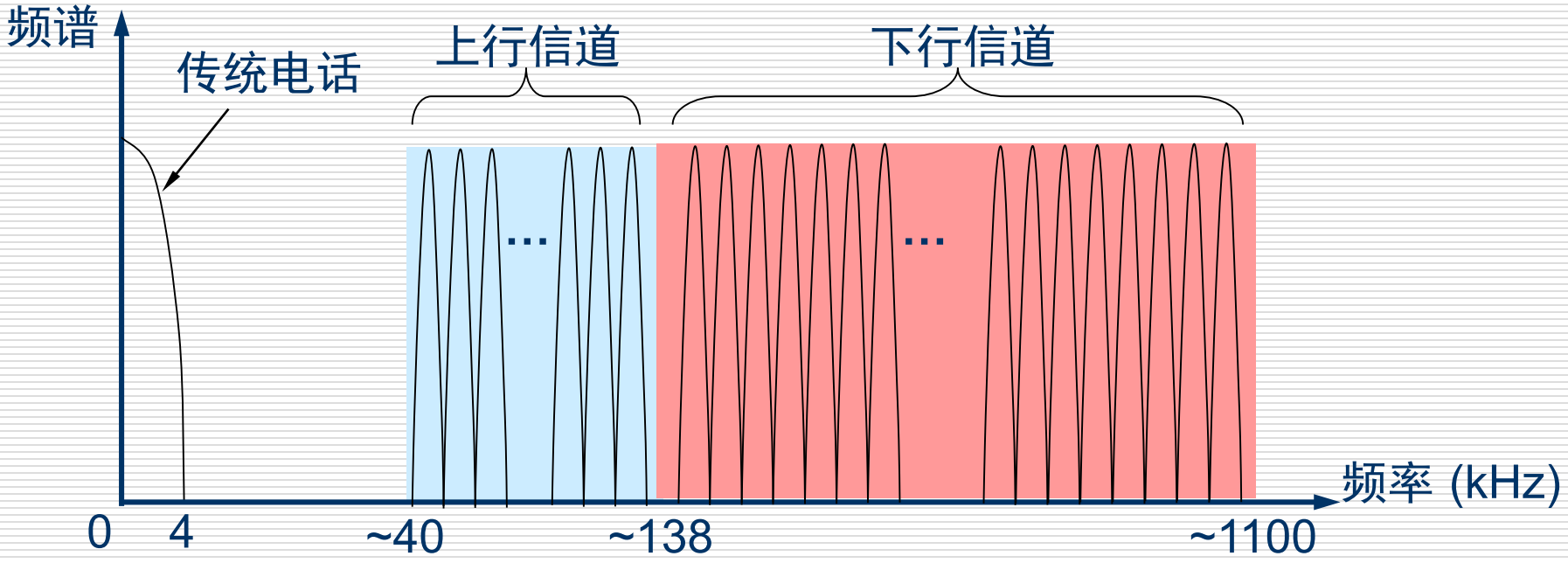
ADSL 的特点

- 上行和下行带宽不对称
  - 上行指从用户到 ISP，而下行指从 ISP 到用户
- ADSL 在用户线（铜线）的两端各安装一个 ADSL 调制解调器。
- 我国目前采用的方案是离散多音调 **DMT** (Discrete Multi-Tone)调制技术。这里的“多音调”就是“多载波”或“多子信道”的意思。

DMT 技术

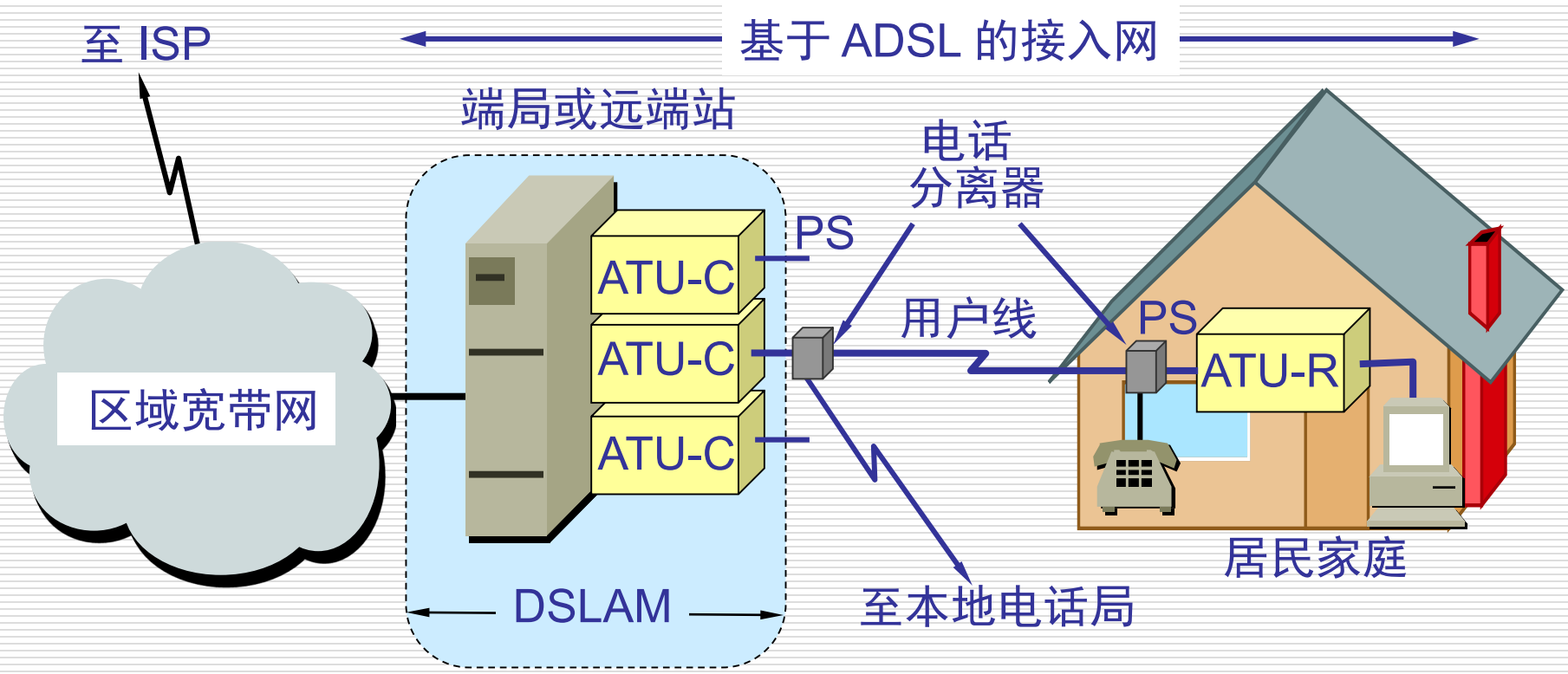
- DMT 调制技术采用频分复用的方法，把 40 kHz 以上一直到 1.1 MHz 的高端频谱划分为许多的子信道，其中 25 个子信道用于上行信道，而 249 个子信道用于下行信道。
- 每个子信道占据 4 kHz 带宽（严格讲是 4.3125 kHz），并使用不同的载波（即不同的音调）进行数字调制。这种做法相当于在一对用户线上使用许多小的调制解调器并行地传送数据。

DMT 技术的频谱分布



ADSL 的数据率

- 由于用户线的具体条件往往相差很大（距离、线径、受到相邻用户线的干扰程度等都不同），因此 ADSL 采用自适应调制技术使用户线能够传送尽可能高的数据率。
- 当 ADSL 启动时，用户线两端的 ADSL 调制解调器就测试可用的频率、各子信道受到的干扰情况，以及在每一个频率上测试信号的传输质量。
- ADSL 不能保证固定的数据率。对于质量很差的用户线甚至无法开通 ADSL。
- 通常下行数据率在 32 kb/s 到 6.4 Mb/s 之间，而上行数据率在 32 kb/s 到 640 kb/s 之间。



数字用户线接入复用器 DSLAM (DSL Access Multiplexer)
接入端接单元 ATU (Access Termination Unit)
ATU-C（C 代表端局 Central Office）
ATU-R（R 代表远端 Remote）
电话分离器 PS (POTS Splitter)

第二代 ADSL

- ADSL2（G.992.3 和 G.992.4）
  ADSL2+（G.992.5）
- 通过提高调制效率得到了更高的数据率。例如，ADSL2 要求至少应支持下行 8 Mb/s、上行 800 kb/s的速率。而 ADSL2+ 则将频谱范围从 1.1 MHz 扩展至2.2 MHz，下行速率可达 16 Mb/s（最大传输速率可达25 Mb/s），而上行速率可达 800 kb/s。
- 采用了无缝速率自适应技术 SRA (Seamless Rate Adaptation)，可在运营中不中断通信和不产生误码的情况下，自适应地调整数据率。
- 改善了线路质量评测和故障定位功能，这对提高网络的运行维护水平具有非常重要的意义。

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  - HFC

同步光纤网SONET和同步数字系列SDH

- 旧的数字传输系统存在着许多缺点。其中最主要的是以下两个方面：
- 速率标准不统一。
  - 如果不对高次群的数字传输速率进行标准化，国际范围的高速数据传输就很难实现。
- 不是同步传输。
  - 在过去相当长的时间，为了节约经费，各国的数字网主要是采用准同步方式。

同步光纤网 SONET

- 同步光纤网 SONET (Synchronous Optical Network) 的各级时钟都来自一个非常精确的主时钟（铯原子钟，精度优于10^{-11}秒）
- 第 1 级同步传送信号 STS-1 (Synchronous Transport Signal)的传输速率是 51.84 Mb/s。
- 光信号则称为第 1 级光载波 OC-1，OC 表示 Optical Carrier。

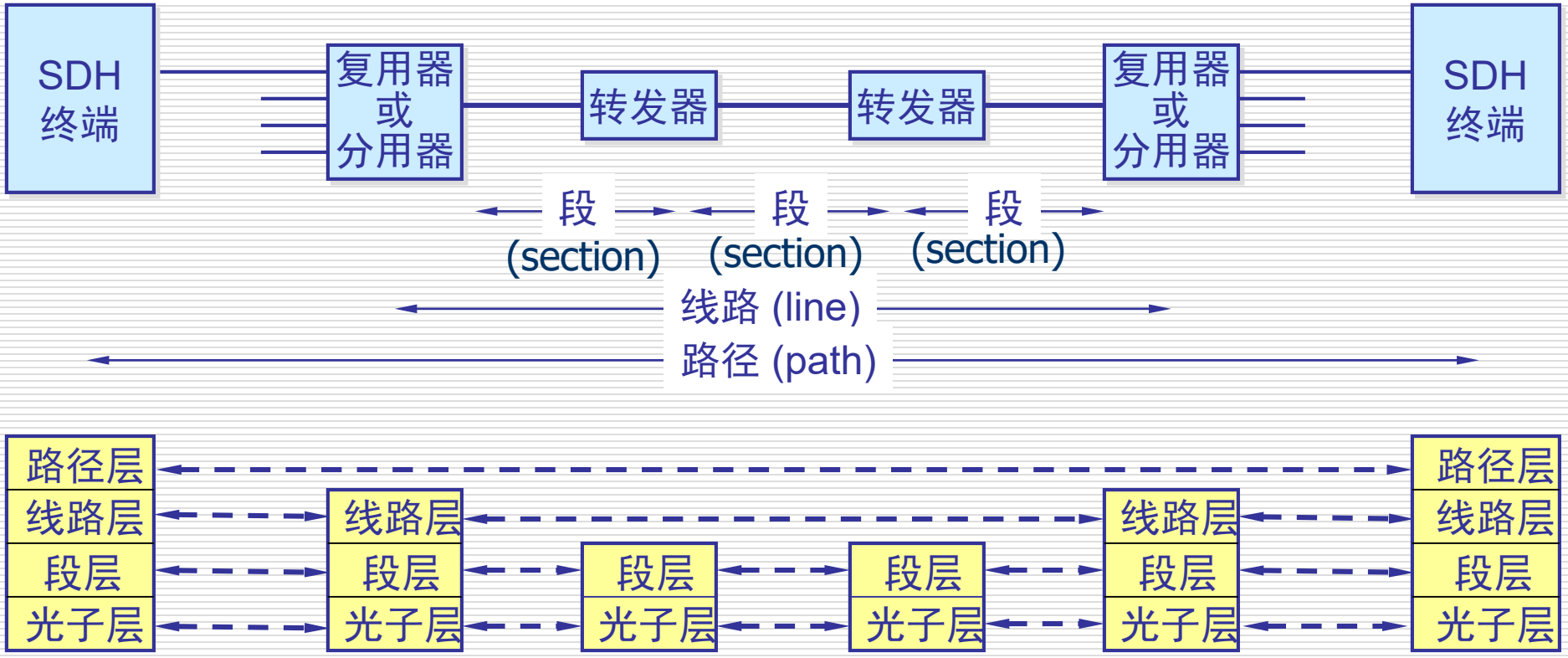
同步数字系列 SDH

- ITU-T 以美国标准 SONET 为基础，制订出国际标准同步数字系列 SDH (Synchronous Digital Hierarchy)。
- 一般可认为 SDH 与 SONET 是同义词。
- SDH 的基本速率为 155.52 Mb/s，称为第 **1** 级同步传递模块 (Synchronous Transfer Module)，即 STM-1，相当于 SONET 体系中的 OC-3 速率。

SONET 的 OC 级/STS 级与 SDH 的 STM 级的对应关系

线路速率 (Mb/s)	SONET 符号	ITU-T 符号	表示线路速率的常用近似值
51.840	OC-1/STS-1	—	
155.520	OC-3/STS-3	STM-1	155 Mb/s
466.560	OC-9/STS-9	STM-3	
622.080	OC-12/STS-12	STM-4	622 Mb/s
933.120	OC-18/STS-18	STM-6	
1244.160	OC-24/STS-24	STM-8	
2488.320	OC-48/STS-48	STM-16	2.5 Gb/s
4976.640	OC-96/STS-96	STM-32	
9953.280	OC-192/STS-192	STM-64	10 Gb/s
39813.120	OC-768/STS-768	STM-256	40 Gb/s

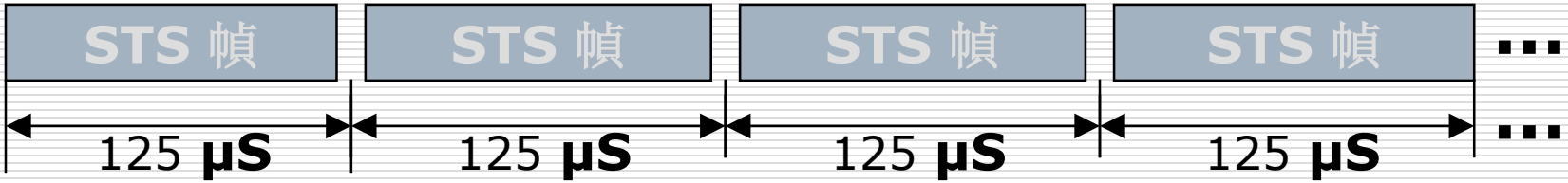
SONET 的体系结构


SDH 终端
复用器或分用器
转发器
转发器
复用器或分用器
SDH 终端
段 (section)
段 (section)
段 (section)
线路 (line)
路径 (path)
路径层
线路层
段层
光子层
线路层
段层
光子层
段层
光子层
段层
光子层
线路层
段层
光子层
路径层
线路层
段层
光子层

同步光纤网 SONET

- SONET 第 1 级同步传送信号 STS-1 （Synchronous Transport Signal) 的传输速率为 51.84 Mb/s，第 3 级同步传送信号 STS-3 传输速率是 STS-1 的3倍，为155.52 Mb/s， …，等等，依此类推。

STS帧为时分复用帧，8000帧/秒，每帧125 μS



- 其对应的光信号则称为第 1 级光载波 OC-1 (OC表示 Optical Carrier)，第 3 级光载波 OC-3， …，等

SONET 标准的四个光接口层

- 光子层(Photonic Layer)
  - 处理跨越光缆的比特传送。
- 段层(Section Layer)
  - 在光缆上传送 STS-N 帧。
- 线路层(Line Layer)
  - 负责路径层的同步和复用。
- 路径层(Path Layer)
  - 处理路径端接设备 PTE (Path Terminating Element)之间的业务的传输。

WANs

- WAN Technology & Devices
- WANs & The OSI Model
- WAN Accessing Methods
  - PPP/HDLC
  - ISDN
  - ADSL
  - SONET
  - HFC

光纤同轴混合网
HFC (Hybrid Fiber Coax)

南京大学 NANJING UNIVERSITY

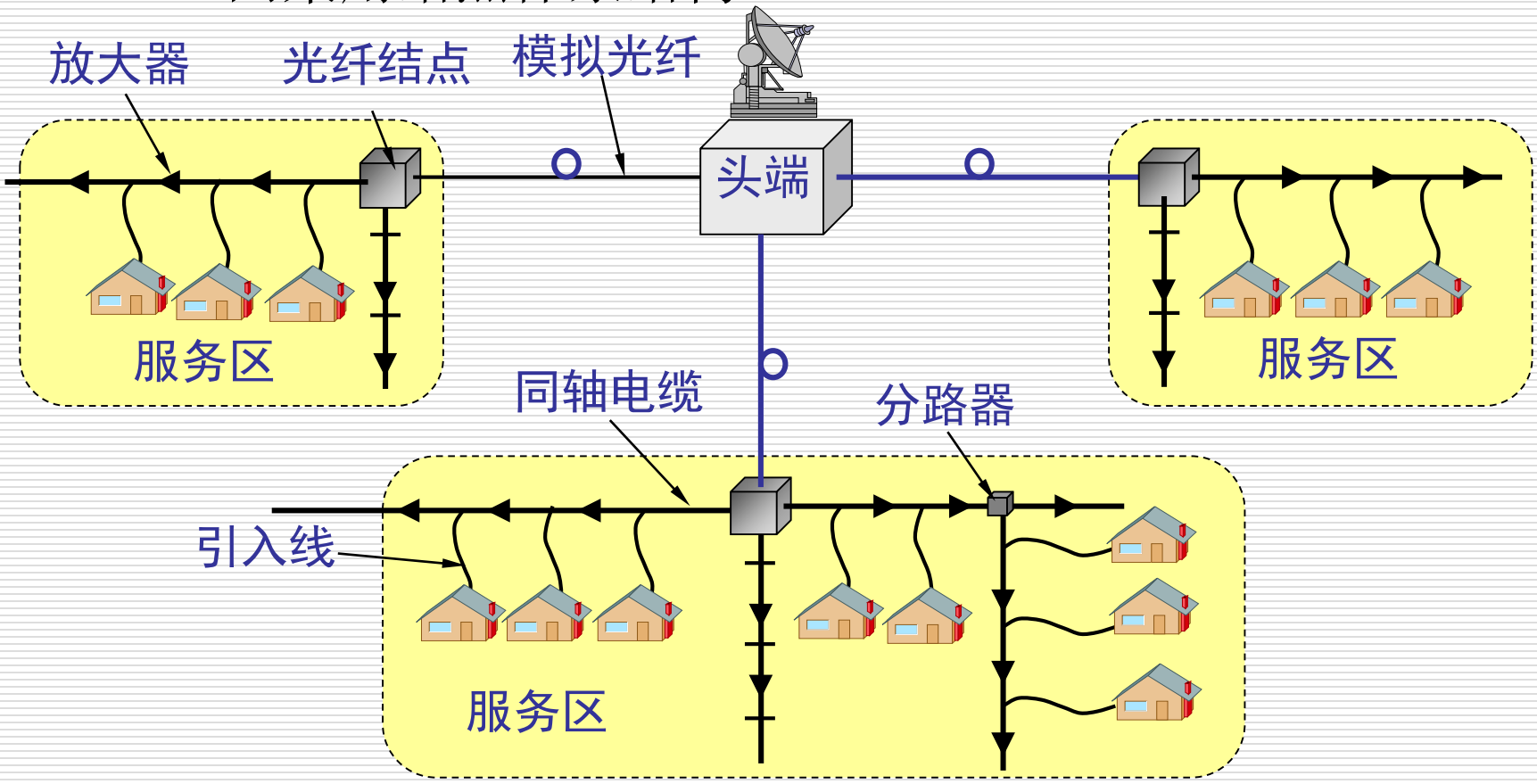
- HFC 网是在目前覆盖面很广的有线电视网 CATV 的基础上开发的一种居民宽带接入网。
- HFC 网除可传送 CATV 外，还提供电话、数据和其他宽带交互型业务。
- 现有的 CATV 网是树形拓扑结构的同轴电缆网络，它采用模拟技术的频分复用对电视节目进行单向传输。而 HFC 网则需要对 CATV 网进行改造，

HFC 的主要特点

- HFC网的主干线路采用光纤
  - HFC 网将原 CATV 网中的同轴电缆主干部分改换为光纤，并使用模拟光纤技术。
  - 在模拟光纤中采用光的振幅调制 AM，这比使用数字光纤更为经济。
  - 模拟光纤从头端连接到光纤结点(fiber node)，即光分配结点 ODN (Optical Distribution Node)。在光纤结点光信号被转换为电信号。在光纤结点以下就是同轴电缆。

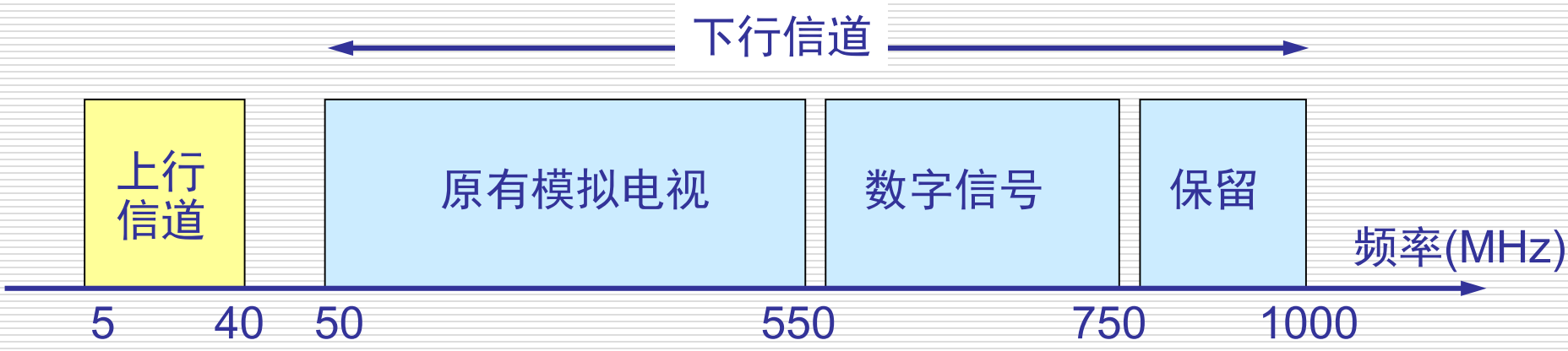
HFC 的主要特点

- HFC 网采用结点体系结构



HFC 的主要特点

- 具有比 CATV 网更宽的频谱，且具有双向传输功能



用户接口盒UIB (User Interface Box)

- 每个家庭要安装一个用户接口盒
- 用户接口盒 要提供三种连接，即：
  - 使用同轴电缆连接到机顶盒(set-top box)，然后再连接到用户的电视机。
  - 使用双绞线连接到用户的电话机。
  - 使用电缆调制解调器连接到用户的计算机。

电缆调制解调器(Cable Modem)

- 电缆调制解调器是为 HFC 网而使用的调制解调器。
- 电缆调制解调器最大的特点就是传输速率高。其下行速率一般在 3~10 Mb/s之间，最高可达 30 Mb/s，而上行速率一般为 0.2~2 Mb/s，最高可达 10 Mb/s。
- 电缆调制解调器比在普通电话线上使用的调制解调器要复杂得多，并且不是成对使用，而是只安装在用户端。

HFC 网的最大优点

- 具有很宽的频带，并且能够利用已经有相当大的覆盖面的有线电视网。
- 要将现有的 450 MHz 单向传输的有线电视网络改造为 750 MHz 双向传输的 HFC 网（还要将所有的用户服务区互连起来而不是一个个 HFC 网的孤岛），也需要相当的资金和时间。
- 在电信政策方面也有一些需要协调解决的问题。

FTTx 技术

- FTTx（光纤到……）也是一种实现宽带居民接入网的方案。这里字母 x 可代表不同意思。
  - 光纤到家 FTTH (Fiber To The Home)：光纤一直铺设到用户家庭可能是居民接入网最后的解决方法。
  - 光纤到大楼 FTTB (Fiber To The Building)：光纤进入大楼后就转换为电信号，然后用电缆或双绞线分配到各用户。
  - 光纤到路边 FTTC (Fiber To The Curb)：从路边到各用户可使用星形结构双绞线作为传输媒体。

谢 谢！