Network Principles

Circuit Switching, Introduction ISDN
Packet Switching, Datagram versus Virtual Call
OSI Model, Introduction to ISDN, X.25, FR and ATM

Agenda

- **Introduction**
- **Circuit Switching**
- **Packet Switching**
  - Principles
  - Datagram Service
  - Virtual Call Service
- **OSI Reference Model**
- **Summary of Network Methods**
- **Short Introduction of**
  - IDSN
  - X.25, Frame Relay, ATM

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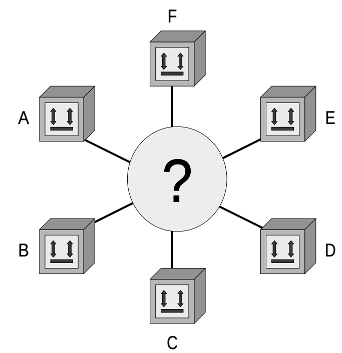
Introduction

- **chapters about line protocols and TDM techniques have explained**
  - how communication between two devices can be implemented over a point-to-point physical line using line protocol techniques
  - how TDM can be used to provide several communication channels between devices located on two locations
- **questions**
  - how should devices to be connected and how should communication between devices be organized, if there are many devices at different locations?

How To Connect All Locations?



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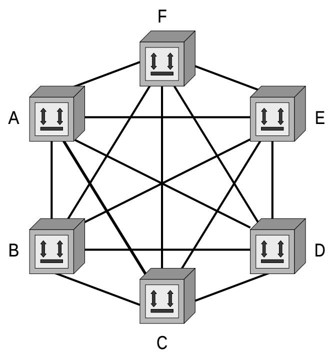
Any to Any Network Topology

- **easy solution**
  - any to any topology (fully meshed)
  - establish multiple point-to-point lines between devices
  - use line protocol techniques

Any-to-Any Topology?



Networking Techniques

- **any-to-any topology is very expensive**
  - many lines are required and hence large number of transmission equipment (like modems, DSUs, line repeaters, etc.) necessary
  - many physical communication ports are required in devices
  - scalability problem: N * (N-1) / 2
- **to reduce costs**
  - synchronous or asynchronous time division multiplexing principles can be used in a network environment
  - <u>circuit switching</u> based on synchronous TDM
  - <u>packet switching</u> based on asynchronous (statistical) TDM

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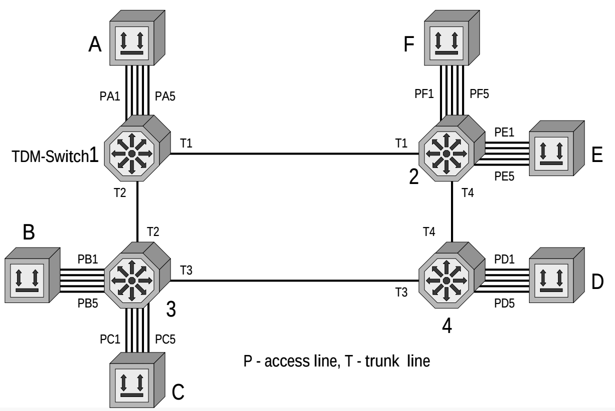
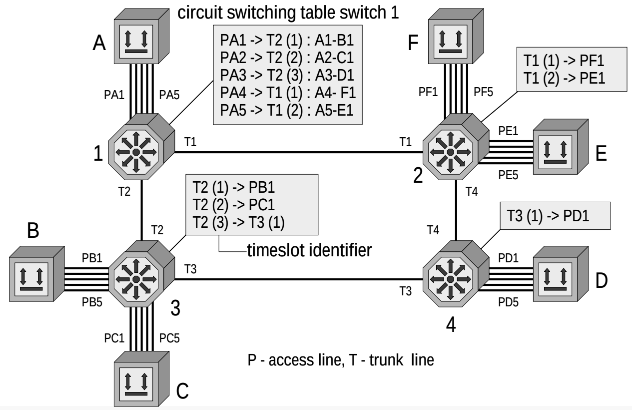
Circuit Switching

- **principle**
  - physical communication ports of devices are connected locally to synchronous TDM switches
  - trunk lines T between switches use synchronous time division multiplexing
    - e.g. standardized E1 (31 timeslots with 64kbit/s each)
  - each physical port is assigned a timeslot on an outgoing trunk for communication with remote device
  - switches map timeslots on incoming trunks either to local ports or to timeslots on outgoing trunks (transit switch)
  - mapping information
    - is stored in circuit switching tables

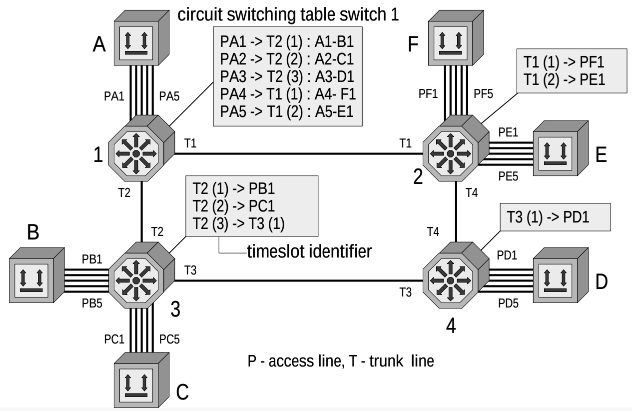
Circuit Switching



Connections of Device A



Connections of Device A
Circuit Path PA3 (A) - PD1 (D)



Circuit Switching Facts

- **circuit switching and synchronous TDM on trunk lines**
  - reduce the number of expensive wide area lines required in a fully meshed topology
  - switches form a synchronous TDM network
- **features of circuit switching are the same as for synchronous TDM**
  - minimal delay
  - high bit rate on trunk lines
  - idle pattern in timeslots if no data present
  - protocol transparent

Circuit Switching Facts

- **the path of a communication channel (circuit) between two devices**
  - is marked by corresponding entries in circuit switching tables
- **the number of local physical ports**
  - can be further reduced using synchronous TDM between a device and the local switch too
- **one physical device access line**
  - can carry many logical channels in corresponding timeslots and hence mapping between timeslots can be done in the same way as for trunk lines

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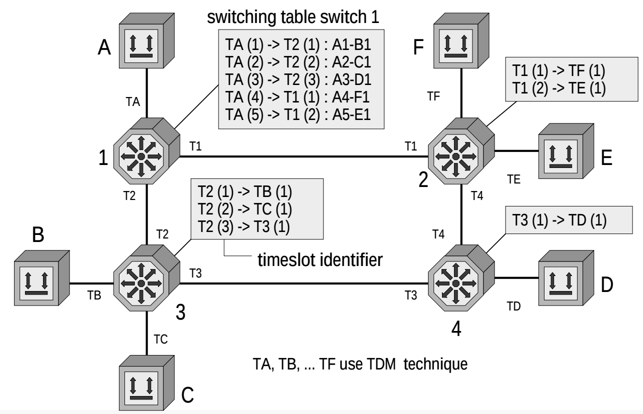
TDM lines to Devices



Services based on Circuit Switching

- **circuit switching table**
  - could be static
    - entries are configured by TDM network administrator
    - <u>permanent circuit service</u>
  - or dynamic (fail-safe)
    - entries are changed automatically by TDM network management protocol to switch over to a redundant path in case a trunk line breaks
    - <u>soft</u> permanent circuit service
  - or dynamic (on demand)
    - end-systems use <u>signaling protocol</u> to local TDM switch in order to transport setup or tear down requests
    - TDM switches establish path (corresponding entries in circuit switching tables) using their own signaling protocols
    - <u>switched circuit service</u>

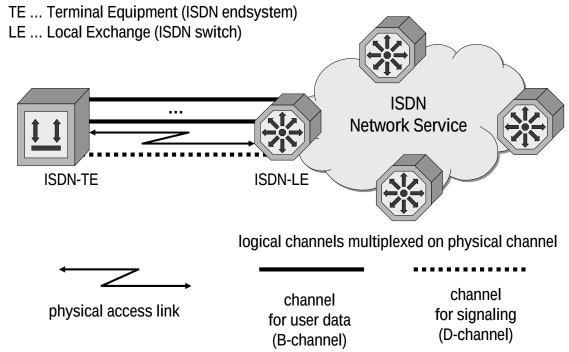
Circuit Switching Data Networks

- **network providers offer permanent circuit services**
  - based on redundant, synchronous TDM networks (PDH or SDH)
    - with permanent entries in circuit switching tables
    - automatic switchover in case of trunk failure
    - digital leased line
- **network provider offer switched circuit services**
  - based on ISDN
    - with dynamic entries in circuit switching tables generated on demand
    - outband signaling (D-channel) between ISDN endsystem (ISDN-TE) and local TDM switch
    - ISDN-LE (Local Exchange) instead of TDM switch
    - communication between ISDN-LEs based on Signaling System 7 (SS7)
- **base for both services**
  - underlying (PDH), SDH infrastructure for transporting channels over wide areas

ISDN

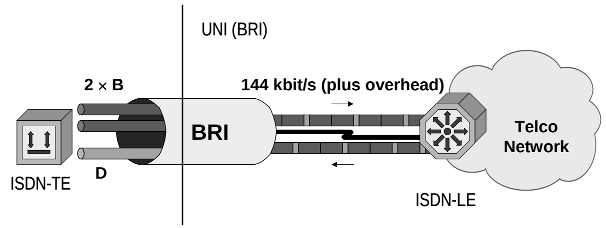
- **Integrated Services Digital Network (ISDN)**
  - offers transport of voice, video and data
  - all-digital interface at subscriber outlet
- **standardized user-to-network interface (UNI)**
  - BRI (Basic Rate Interface)
  - PRI (Primary Rate Interface)

ISDN User-to-Network Interface (UNI)



Basic Rate Interface (BRI)

- 2 B (bearer) channels with 64 kbit/s each
  - carrying digitized voice or data
- 1 D (data) channel with 16 kbit/s
  - for signaling purposes (e.g. Q.931 protocol)
- 2 B and D are synchronous TDM-multiplexed on physical access line



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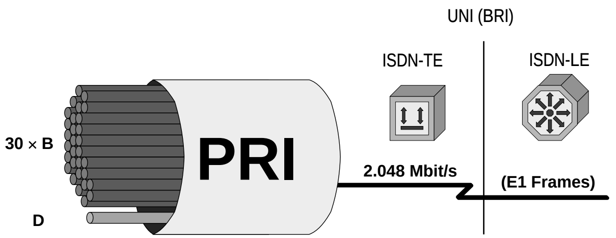
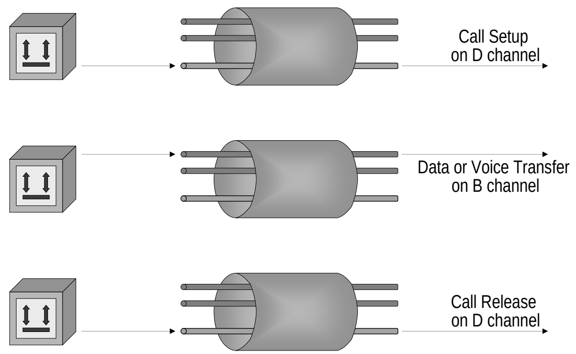
Primary Rate Interface (PRI)

- 30 B (Bearer) channels with 64 kbit/s each
- 1 D (Data) channel with 64 kbit/s
  - for signalling purposes (e.g. Q.931 protocol)
- 30 B and D are synchronous TDM-multiplexed on one physical access line



Procedures



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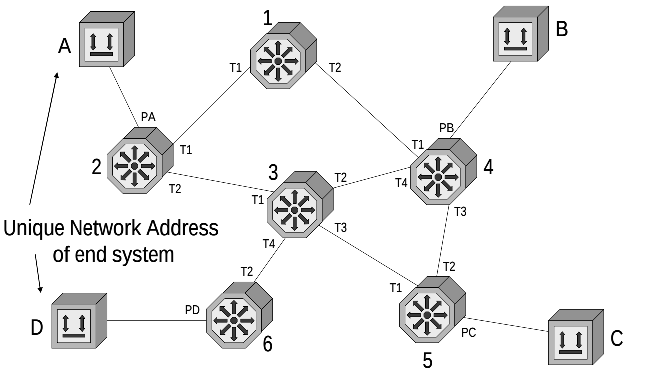
Packet Switching Principles 1

- **implementation of asynchronous, statistical TDM in a network environment**
- **network topology consists of**
  - packet switches
  - trunk lines to connect packet switches
  - access lines to connect devices
- **devices connected to packet switches**
  - end systems
- **packet switches**
  - intermediate systems

Packet Switching Principles 2

- **statistical TDM on trunks and access lines**
  - allows many end systems to communicate without reserving capacity on a trunk or access line
  - needs therefore explicit addressing information
    - source address
    - destination address
- **statistical TDM on trunks and access lines**
  - avoids large number of physical point-to-point lines required in a pure any-to-any topology
  - limits the bit rate necessary on trunk lines
    - bit rate will be calculated to carry the average traffic between end systems

Packet Switching Topology



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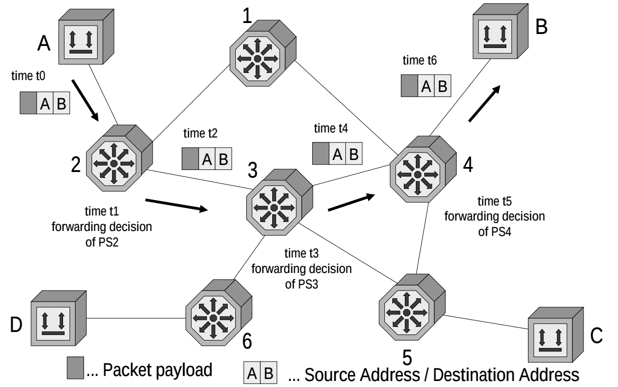
Packet Switching Principles 3

- **statistical TDM on access line**
  - requires a protocol between end systems and packet switches
    - addressing
    - optional flow control
  - is <u>not</u> protocol-transparent
  - hence end system must speak language of the packet switch
- **redundant trunk lines**
  - can provide redundant paths in case of failure
  - can be used for load sharing

Packet Switching Principles 4

- **end systems**
  - break information in small pieces called packets
  - deliver these packets to local packet switch
- **packets contain addressing information**
- **packet switches**
  - buffer incoming packets
  - use address information to decide where to forward them
  - put packets in outgoing queues after decision
  - transmit packets waiting in queues
- **store and forward technology**

Packet Forwarding Principle (Store and Forward)

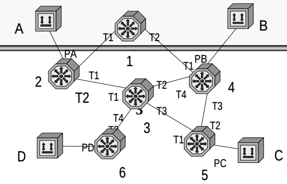


Principle of Packet Switching 5

- **forwarding of packets is based on tables**
  - switching tables
    - used for connection-oriented services
    - virtual call service
  - routing tables
    - used for connection-less services
    - datagram service
- **in these tables**
  - information how to reach certain destinations is stored
    - mapping between destination address or connection identifier and outgoing trunk or access port
  - "**signposts**"

Routing Table

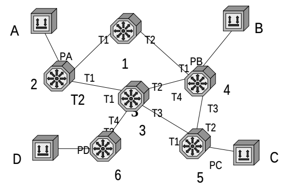
- **example of a static routing table of packet switch 3**



Address of destination	incoming line	outgoing line	next PS
B	T1	T2	PS 4
C	T1	T3	PS 5
D	T1	T4	PS 6
B	T2	kill	- - -
B	T3	kill	- - -
B	T4	T2	- - -
C	T2	T3	PS 5
C	T3	kill	- - -
.....	.....	.....	.....

Routing Table

- **example of a static routing table of packet switch 2**



Address of destination	incoming line	outgoing line	next PS
B	PA	T2	PS 3
D	PA	T2	PS 3
C	PA	T2	PS 3
A	- - -	PA	local

Routing - Addressing

- **routing in packet switched networks**
  - process of path selection in order to forward a packet to a given destination
  - selection based on addresses
- **addresses specify the location of end system**
  - contain topology information
  - addresses must be unique within the network to enable routing
- **a protocol using unique <u>and</u> structured addresses**
  - is called <u>routed</u> or <u>routable protocol</u>

Static Routing

- **static routing**
  - based on preconfigured routing tables
    - done by network administrator
  - routing table entries are static
- **the basic problem of routing**
  - consistency of routing tables (distributed database)
  - static routing: task of network administrator
  - dynamic routing: task of routing protocol

Dynamic Routing

- **dynamic routing**
  - based on distributed routing processes
  - communication between processes (packet switches)
    - is done via routing protocol
  - <u>routing protocol</u> is used
    - to find out the network topology
    - to calculate all possible paths to a given location and select one path (best path) in case of redundancy
  - best paths are stored in the routing table
  - routing table entries are variable (dynamic)
    - caused by network topology changes

Routing Table Usage / Type of Service

- **routing tables are differently used**
  - depending on the type of service of the packet switching network
- **packet switched network based on**
  - <u>connection-oriented service (CO)</u>
    - routing tables are used to generate entries in switching tables
    - only needed for connection establishment
    - after connection establishment, switching tables are used to control the forwarding of data packets
  - <u>connection-less service (CL)</u>
    - routing tables are used to control the forwarding of each packet

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Datagram Service Principles

- **connection-less service**
  - packets can be sent without establishing a logical connection between end systems in advance
  - packets have no sequence numbers, are called datagrams
- **every incoming packet**
  - is processed independently by packet switches
- **the forwarding decision for incoming packets**
  - depends on the current state of the routing table
- **each packet contains**
  - complete address information (source and destination)

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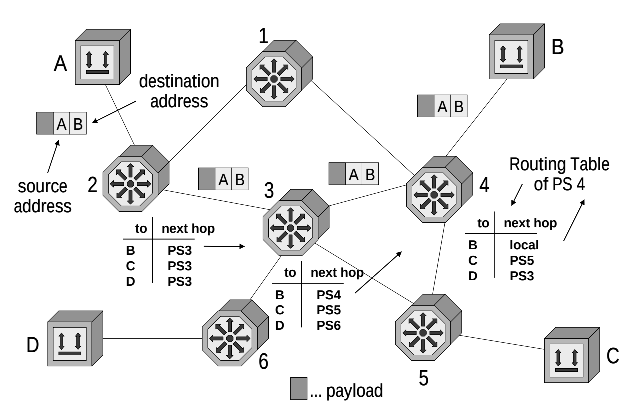
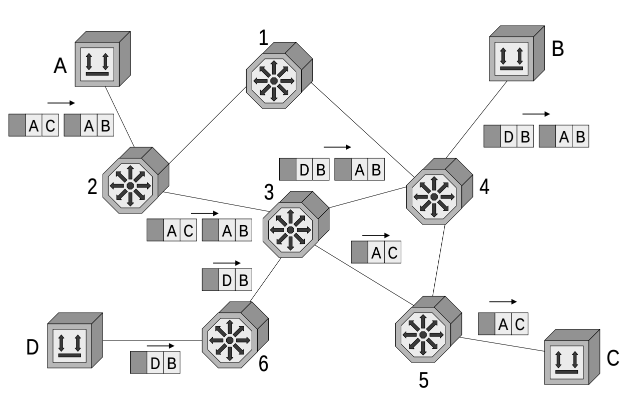
Packet forwarding (CL) is based on routing tables only
(Datagram Service, Best-Effort Service)



Datagrams are forwarded completely independent from each other based on current state of routing tables



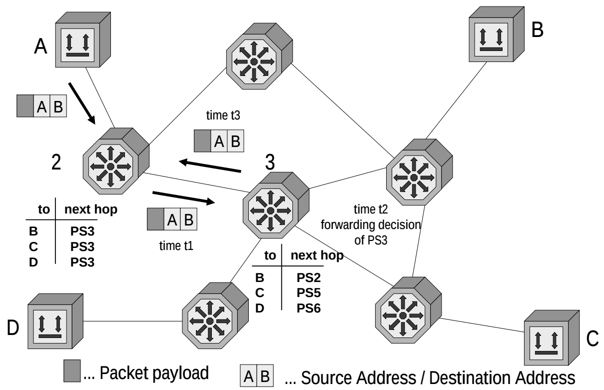
Datagram Service Facts 1

- **rerouting in case of topology changes or load balancing means**
  - packets with the same address information can take different paths to destination
  - packets may arrive out of sequence
- **packets may be discarded by packet switches**
  - in case of network congestion
  - in case of transmission errors
- **the end systems are responsible**
  - for error recovery (retransmission of dropped or corrupted packets)
  - for sequencing and handling of duplicates

Datagram Service Facts 2

- **connectionless behavior**
  - no reservation of resources is possible in advance
    - bandwidth on trunk line
    - buffer memory of packet switches
- **best effort service**
  - transport of packets depends on available resources
- **inconsistent routing tables**
  - could cause endless circulation of packets
    - endless circulation means blocking of buffer memory
    - special methods used for avoidance
    - maximum time to live, maximum hop count, etc.

Datagram forwarding needs a kill-mechanism to overcome inconsistent routing tables



Datagram Service

- **advantages**
  - small protocol overhead (easy to implement in end systems and packet switches)
  - fastest delivery of data between end systems because no connection must be established in advance
- **disadvantage**
  - delivery of packets is not guaranteed by the network, must be handled by end systems using higher layer protocol
  - proactive flow control is not possible

Network Technologies based on Datagram Method

- **IP**
  - packet is called datagram
  - end system is called IP host
  - packet switch is called router
- **IPX (Novell)**
- **XNS**
- **Appletalk**
- **Decnet Phase IV**
- **OSI CNLP**

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Virtual Call Principles

- **connection oriented service**
  - special control packets (call setup packets) establish a virtual point-to-point connection (virtual circuit) between end systems first
  - after connection is established, data packets can be transmitted across that virtual circuit
  - typically connection will be closed after data transfer is finished
- **different methods are possible**
  - to establish a virtual call service

Virtual Call Principles

- **one possible way**
  - call setup packets are transported across the network like datagrams
  - for path decisions routing tables are used
  - call setup packets contain
    - unique address information of source and destination endsystems
    - connection identifier to represent the requested connection
  - during proceeding of call setup packet
    - the connection identifier on an incoming line will be mapped to a connection identifier on the outgoing line
  - connection identifier has only local significance
    - meaning agreed between two directly connected devices
      - e.g. endsystem and local packet switch or packet switch to next packet switch and so on

Virtual Call Principles

- **one possible way (cont.)**
  - during call setup the information about
    - incoming connection identifier / Incoming port to outgoing connection identifier / outgoing port is stored in the switching table
  - path of call setup packet
    - is marked by corresponding switching table entries
  - if connection establishment is successful
    - each data or control packet using that connection will be transmitted along that established path
  - virtual point-to-point connection will be represented
    - by the local identifiers used between end systems and switches
    - by the sequence of local identifiers used on trunk lines

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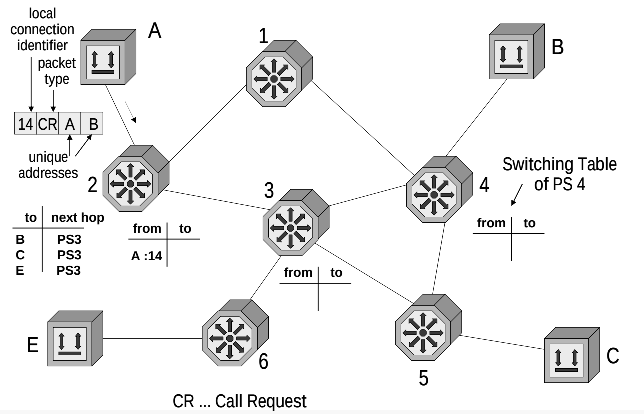
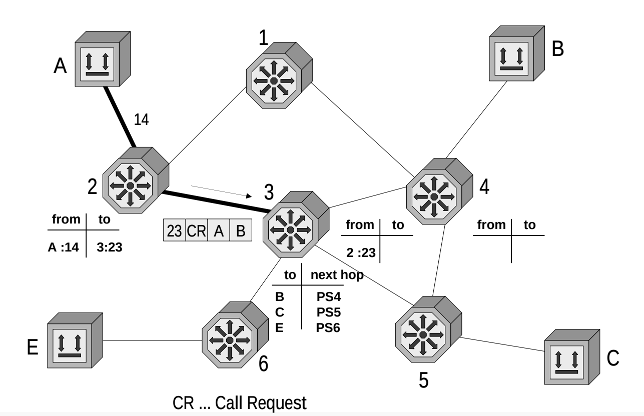
Packet forwarding (CO) is based on special switching tables but call-setup still uses conventional routing tables (Virtual Call Setup 1)



Virtual Call Setup 2



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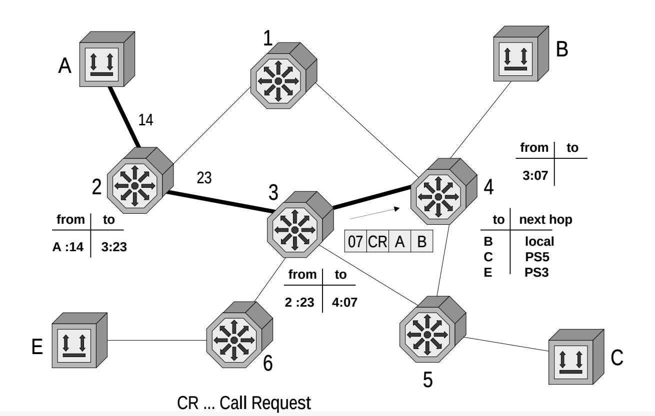
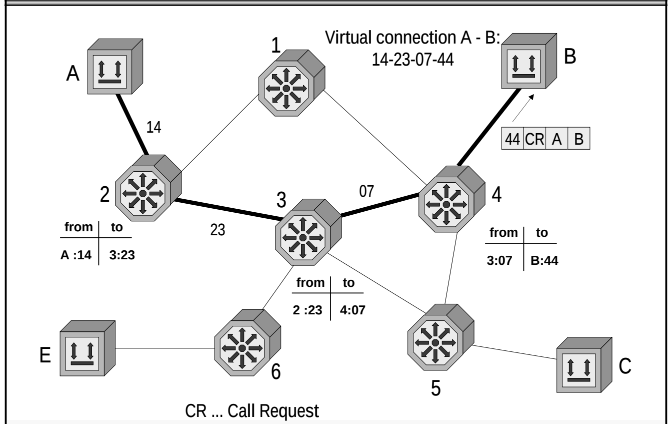
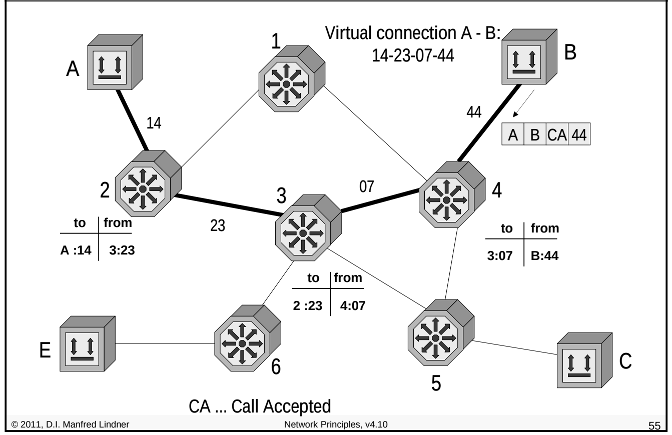
Virtual Call Setup 3



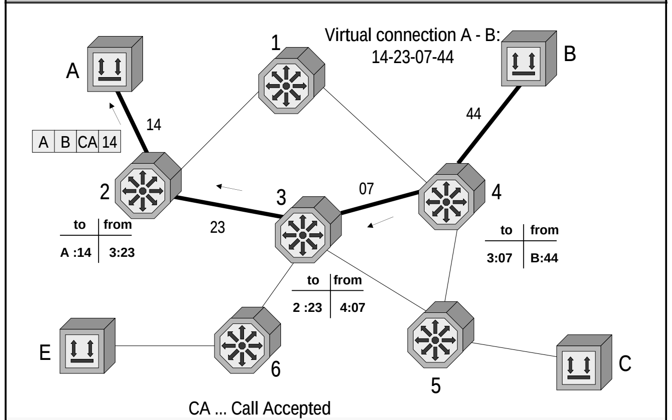
Virtual Call Setup 4



Virtual Call Setup 5



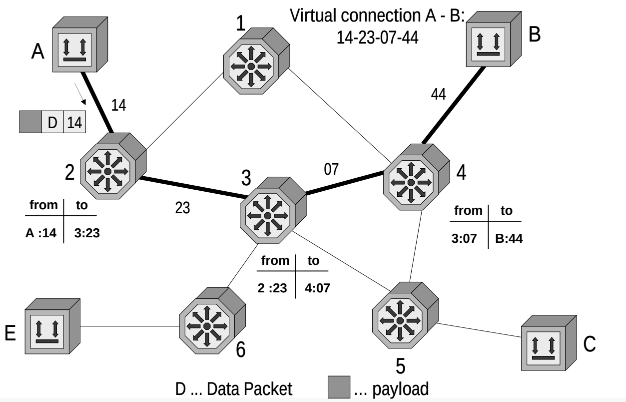
Virtual Call Setup 6



Forwarding Data

- **all data packets and control packets use local identifiers as address information only**
  - to indicate to which connection they belong
  - to which destination they should be delivered
- **unique source and destination addresses**
  - are not required during data transfer phase
- **mapping of incoming identifiers to outgoing identifiers**
  - is done by packet switches hop by hop by consulting the switching table only
- **forwarding decision based on switching table**
  - routing table not necessary in that phase

Data Transfer 1



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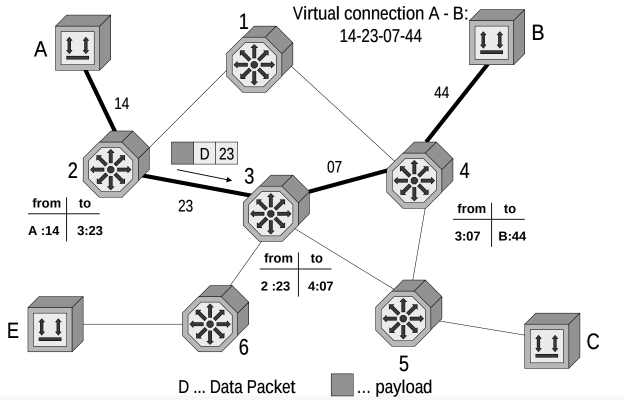
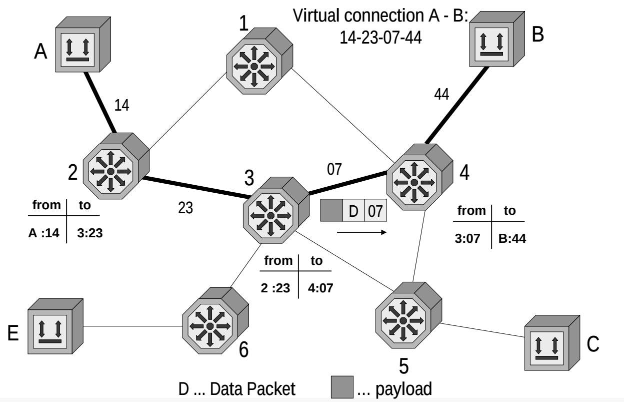
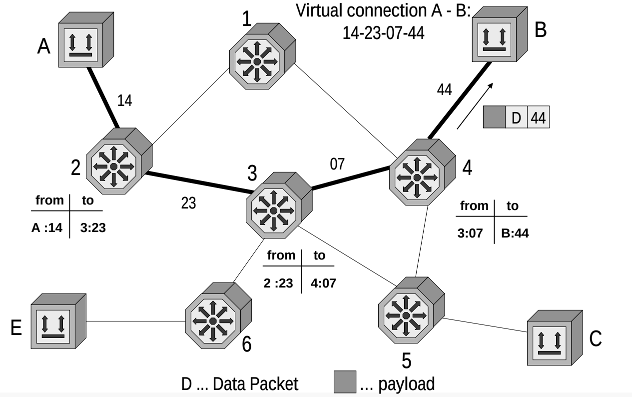
Data Transfer 2



Data Transfer 3



Data Transfer 4



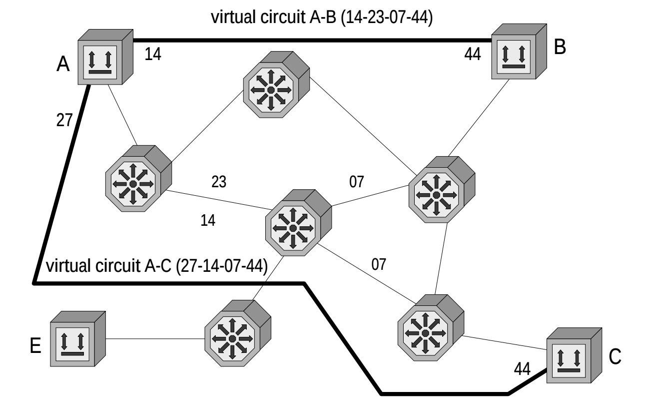
Virtual Call Service Facts

- **the sequence of data packets is guaranteed by the network**
  - packets can use the established path only
- **path selection is done during connection setup**
  - afterwards, entries of routing table are not used
- **in case of trunk line or packet switch failure**
  - virtual circuits will be closed and must be reestablished again by end systems using call setup packets
  - if there is at least one redundant path, packet switches can establish a new virtual circuit taking the redundant path

Multiplexing - Logical Channels

- **connection identifier are the base**
  - for maintaining several virtual circuits or logical channels on one physical link
- **therefore multiplexing**
  - several logical channels on the link between end system and local packet switch are possible
- **connection identifiers**
  - have in principle the same meaning as port identifiers used for asynchronous TDM on a point-to-point line
  - some examples
    - X.25 -> LCN (logical channel number)
    - Frame Relay -> DLCI (data link connection identifier)
    - ATM -> VPI/VCI (virtual path/channel identifier)

Example Virtual Circuits



Services based on Virtual Call Method

- **SVC service**
  - Switched Virtual Circuit
  - virtual circuits require establishing and clearing
- **PVC service**
  - Permanent Virtual Circuit
  - virtual circuits do not require establishing and clearing done by call setup and call release
  - circuits are permanently available for data transfer

Flow Control, QoS

- **connection-oriented packet switching**
  - allows flow control procedures between end system and packet switch because of connection-oriented approach
    - in connectionless packet switching networks flow control is not or only poorly implemented
  - flow control procedures can avoid buffer overflow and hence network congestion
  - allows reservation of resources
    - capacity, buffers, cpu time, etc.
  - can offer Quality of Service (QoS)
  - call setup can be denied by network if QoS can not be guaranteed

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Virtual Call Service

- **advantages**
  - required resources of packet switches can be reserved during call setup and hence QoS could be provided
  - end system view of the network
    - reliable point-to-point transport pipe based on network internal error recovery, flow control and sequencing procedures (X.25)
    - higher protocol layers can rely on network services (X.25)
  - readiness for receipt is tested in advance
    - call setup of SVC service
- **disadvantages**
  - call setup takes time
  - more complex protocols for end systems and packet switches than datagram service

Network Technologies based on Virtual Call Method

- **X.25**
  - reliable transport pipe because of protocol inherent error recovery and flow control
  - local identifier = LCN; in-band signaling
- **Frame Relay**
  - virtual circuit technique but no error recovery
  - congestion indication instead of flow control
  - local identifier = DLCI; out-band signaling
- **ATM**
  - same as Frame Relay but packets with fixed length
  - hence called cell switching
  - local identifier = VPI/VCI; out-band signaling

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Agenda

- **Introduction**
- **Circuit Switching**
- **Packet Switching**
  - Principles
  - Datagram Service
  - Virtual Call Service
- **<u>OSI Reference Model</u>**
- **Summary of Network Methods**
- **Short Introduction of**
  - IDSN
  - X.25, Frame Relay, ATM

Standards

- **We need networking standards**
  - Ensure interoperability
  - Large market, lower cost (mass production)
- **Vendors need standards**
  - Good for marketing
- **Vendors create standards**
  - Bad for competitors, hard to catch up
- **But:**
  - Slow standardization processes freeze technology...

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Who Defines Standards?

- ISO – Anything
  - International Standards Organization (ISO)
  - International agency for the development of standards in many areas, founded 1946, currently 89 member countries
- IETF – Internet
- ITU-T (former CCITT) – Telco Technologies
- CEPT - PTT Technologies
- ETSI - European Standards
- ANSI - North American Standards
- ATM-Forum, Frame Relay Forum, MPLS Forum
- IEEE – LAN Protocols
- DIN, ÖNORM, …. National Standards

Standards Types

- **De facto standards**
  - anyone can create them
  - e.g. Internet RFCs
- **De jure standards**
  - created by a standardization organization
  - e.g. ISO/OSI, ITU-T

Idea of Layering and Services

- **because communication between systems can be a very complex task**
  - divide task of communication in multiple sub-tasks
    - so called layers
  - hence every layer implements only a part of the overall communication systems
- **hierarchically organized**
  - each layer *receives* services from the layer below
  - each layer *serves* for the layer above
- **good for interoperability**
  - capsulated entities and interfaces
- **but increases complexity**

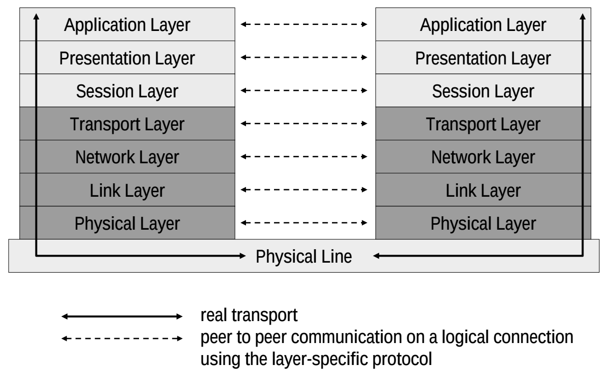
ISO/OSI Reference Model

- **where to define layers?**
  - group functions (services) together
  - when changes in technology occur
- **why to define layers**
  - to allow changes in protocol and HW
  - to utilize existing protocols and HW
- **layering of the ISO/OSI Reference Model**
  - **O**pen **S**ystems **I**nterconnection
  - defines tasks and interactions of seven layers
  - framework for development of communication standards
  - system-internal implementation is out of the scope
  - only external behavior of a system is defined by standards

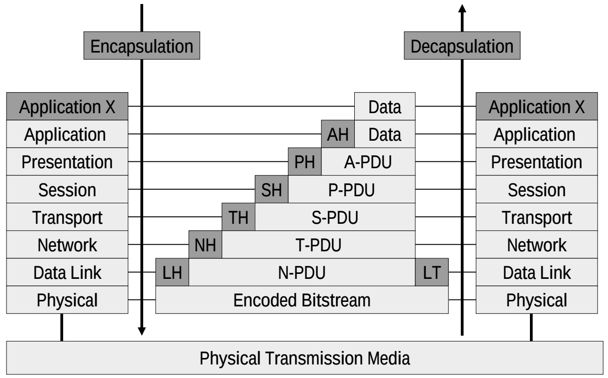
Basic Idea of the OSI Model

- **each layer depends on services of the layer below in order to provide its own services to the upper layer**
  - service specification standards
- **representation of a layer within a system**
  - is called entity (e.g. a particular task or subroutine)
- **in order to fulfill the task of a layer**
  - entities use their own system internal resources as well as peer-to-peer communication based on layer specific protocol
  - protocol specification standards

OSI 7 Layer Model



Frame Encapsulation and Decapsulation



OSI Speak (1)

- Entities
  - anything capable of sending or receiving information
- System
  - physically distinct object which contains one or more entities
- Protocol
  - set of rules governing the exchange of data between two entities
- Layer
  - a set of entities
- Interface
  - boundary between two layers
- Service Access Point (SAP)
  - virtual port where services are passed through
- Service Primitive
  - way to request a service from a lower layer or indicate the presence of an event to the upper layer

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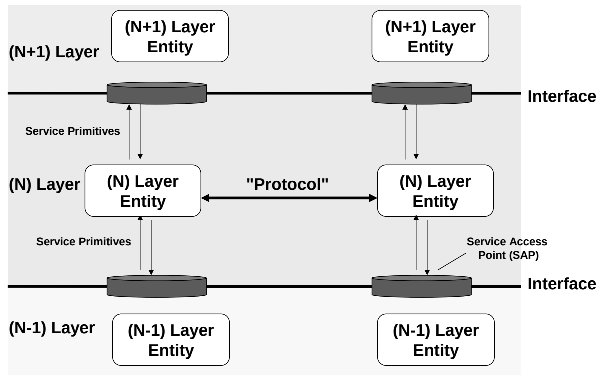
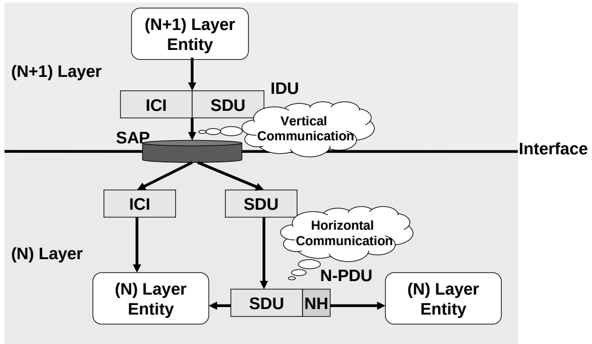
OSI Speak (2)



OSI Speak (3)

- Interface Data Unit (IDU)
  - data unit for vertical communication (between adjacent layers of same system)
- Protocol Data Unit (PDU)
  - data unit for horizontal communication (between same layers of peering systems)
- Interface Control Information (ICI)
  - part of IDU,
  - destined for entity in target-layer
- Service Data Unit (SDU)
  - Part of IDU,
  - destined for further communication
  - contains actual data

OSI Speak (4)



OSI Model Intermediate Systems

- **in end systems (ES)**
  - all seven layers must be implemented for communication between network applications of different computers
- **if two end systems are not directly connected via one physical link**
  - relay systems / intermediate systems are necessary
- **intermediate systems (IS)**
  - store and forward devices
  - packet switches
  - require routing / switching functionality
  - only lower layers (1-3) are necessary

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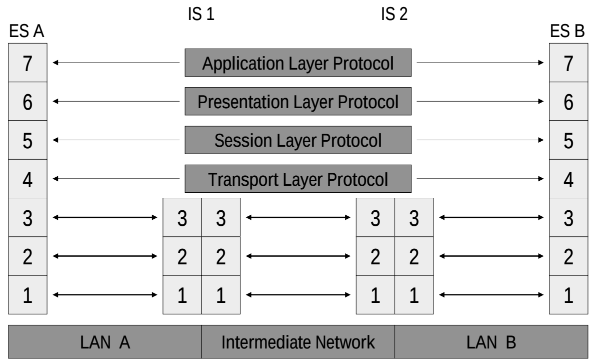
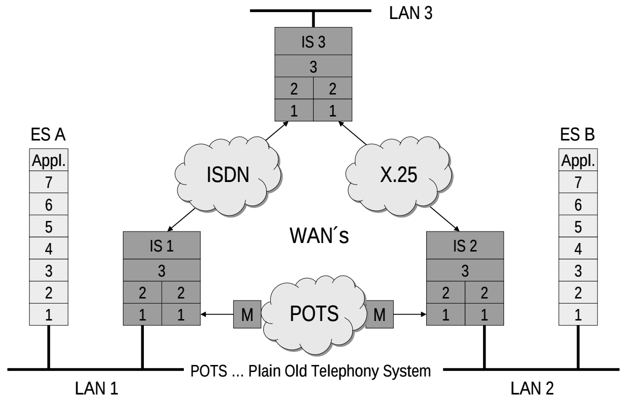
OSI Model with Intermediate Systems



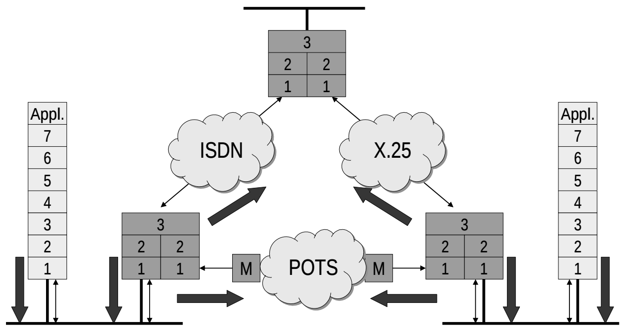
Example Topology with ES and IS



Tasks of the Physical Layer 1

- **access to physical medium**
- **transmission of bit streams**
- **electrical and mechanical interface specifications**
- **signal encoding, clock synchronization**
- **activation and deactivation of links between end systems (link management)**

Physical Layer 1



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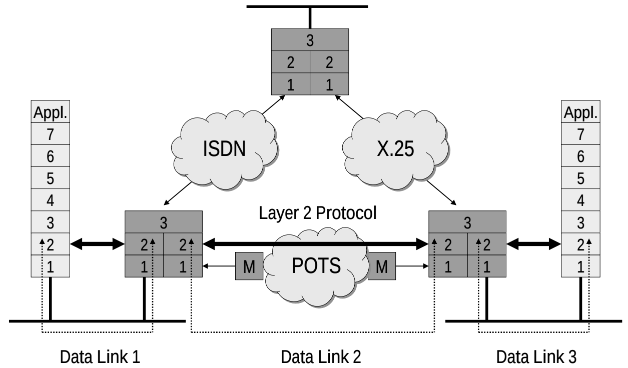
Physical Layer Standards

- **LANs**
  - 802.3 (Ethernet: 10Base5, 10Base2, 10BaseT, etc.)
  - Ethernet V2 (Physical Layer Part)
  - 802.5 (Token Ring: Physical Layer Part)
- **WANs**
  - V.24/V.28, RS 232C, V.10, V11
  - V.35, V.36, RS 449
  - X.21 - Public Switched Data Network
  - I.400 UNI ISDN
    - I.430 Basic Rate Access
    - I.431 Primary Rate Access

Tasks of the Data Link Layer 2

- **transport of frames across a physical link of the network**
  - frame synchronization (framing of packets)
  - frame checking
    - recognition of transmission errors on a physical link
  - addressing
    - MAC addresses (LAN)
    - HDLC addresses (Multipoint)
    - so called "physical address"
  - Media Access Control (LAN)
- **error recovery and flow control may be realized in connection-oriented mode**

Data Link Layer 2



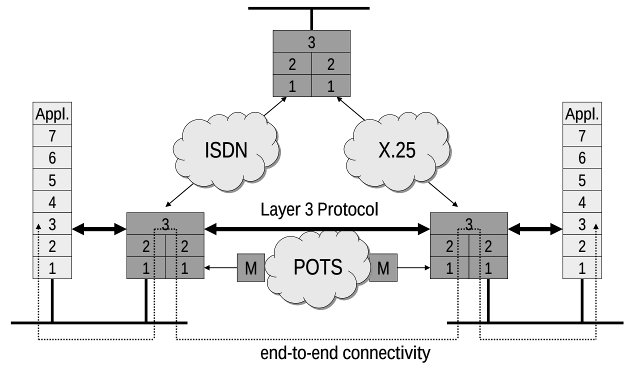
Data Link Layer Standards

- **LANs**
  - IEEE 802.2/ISO 8802.2 LLC Type 1
    - connection-less
  - IEEE 802.2/ISO 8802.2 LLC Type 2
    - connection-oriented
  - Ethernet V2 (connection-less, common standard)
  - IEEE 802.x/ISO 8802.x (MAC part for LANs)
- **WANs**
  - PPP (connection-less, common standard)
  - ISO 4335/7776/7809 HDLC, LAPB (X.25)
    - connection-oriented
  - Q.921/I.441 LAPD (ISDN - D channel)

Tasks of the Network Layer 3

- **transport of packets across a network based on intermediate systems**
- **unique addressing to identify the location of an end system**
  - NSAP (Network Service Access Point) addresses
  - these are the structured L3 addresses
- **path determination (routing) and forwarding (relaying/switching), if systems are not directly connected via physical links**
- **fragmentation/ reassembling**
- **multiplexing**

Network Layer 3



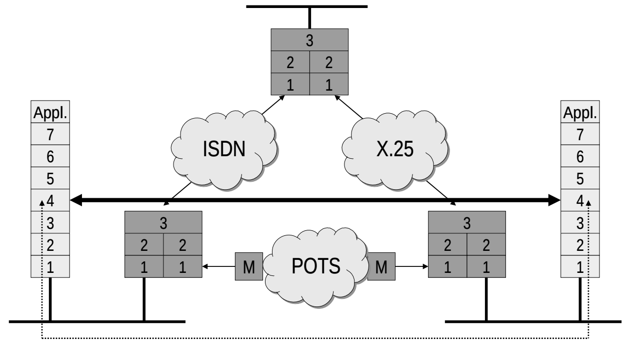
Network Layer Standards

- **LANs/Internetworking**
  - ISO 8473 CNLP
    - Connectionless Network Layer Protocol
  - ISO 8348 Network Services Definition
  - ISO 8880
    - Spec. of Protocols to Provide & Support OSI Network Service
  - IP (connection-less, common standard)
- **WANs**
  - CCITT X.25/ISO 8208 (connection-oriented)
  - Q.931/I.451 (ISDN signaling)
  - X.21(signaling)

Tasks of the Transport Layer 4

- **separates network aspects from application aspects**
- **addressing of processes inside the end system**
  - TSAP (Transport Service Access Point) addresses
- **implementing QoS requested by higher layers**
- **reliable transmission between end systems**
  - requires connection oriented mode
  - error recovery, sequencing
- **flow control between end systems**
  - requires connection oriented mode

Transport Layer 4



Transport Layer Standards

- **ISO 8072 Transport Service Definition**
- **ISO 8073 Transport Protocol**
  - 4 classes for different types of networks
  - connection-oriented
- **TCP**
  - connection-oriented, common standard
- **UDP**
  - connection-less, common standard

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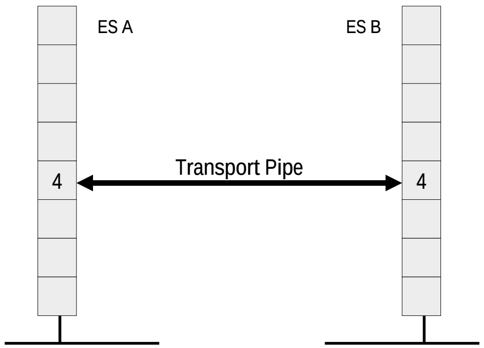
How Layer 5 sees the Network



Functions of Higher Layers

- **layer 5 (session layer)**
  - coordinates and controls dialogue between different end systems
- **layer 6 (presentation layer)**
  - responsible for common language between end systems (conversion, adaptation of data)
- **layer 7 (application layer)**
  - supports user with common network applications (e.g. file transfer, virtual terminal) or basic network procedures in order to implement distributed applications (e.g. transaction systems)

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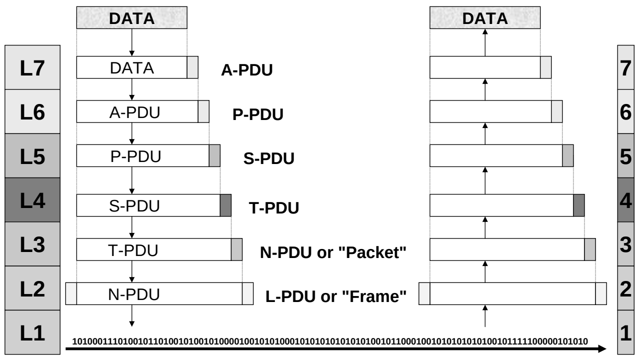
Standards for Layer 5 and 6

- **Session Layer (5)**
  - ISO 8326 Session Service Definition
  - ISO 8327 Session Protocol
  - RPC (Remote Procedure Call, Sun-Standard)
- **Presentation Layer (6)**
  - ISO 8822/8823 Service Definition/Presentation Protocol ISO: ASN.1 and BER
  - XDR (External Data Representation, Sun-Standard)
  - MIME (part of L7) and UUENCODING (part of L7)

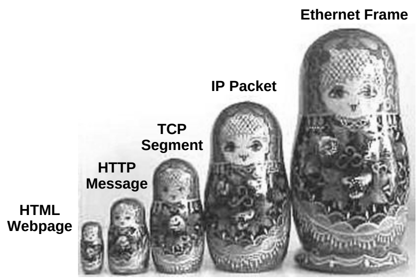
Standards for Layer 7

- **Application Layer (7)**
  - ISO 8571 FTAM File Transfer Access + Management
  - ISO 9040 VTAM Virtual Terminal
  - CCITT X.400 Message Handling System
  - NFS (Network File System, Sun-Standard)
  - CMIP (OSI Network Management)
  - SMTP, FTP, SNMP, HTTP, Telnet, DNS (Internet)

OSI Encapsulation Principle



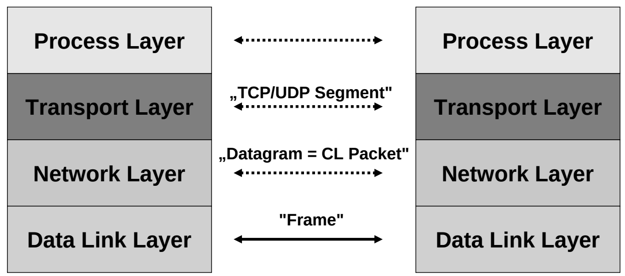
Practical Encapsulation



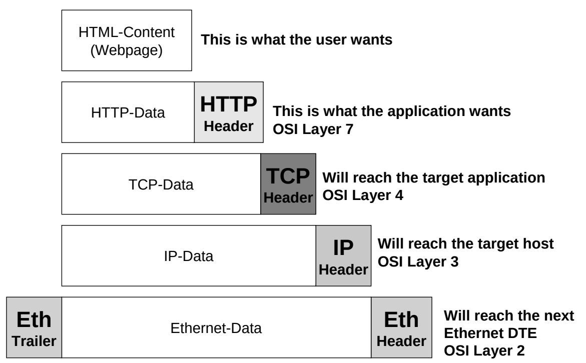
You Guess It...

Practical models typically employ a different number of layers.

DoD 4-Layer Model (Internet)



Internet Encapsulation



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  - X.25, Frame Relay, ATM

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Taxonomy of Network Technologies

Circuit Switching

- **Deterministic Multiplexing**
- **Low latency (delay)**
- **Designed for isochronous traffic**

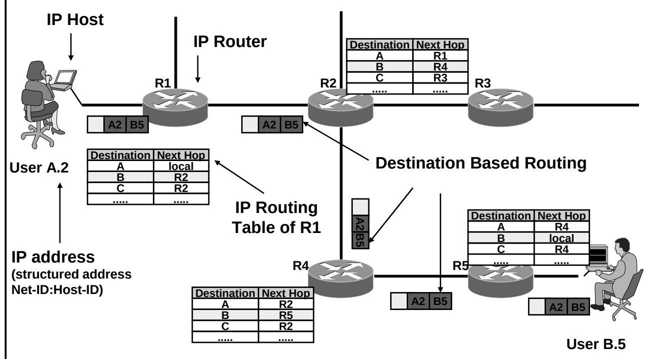
Dynamic Signalling	Static Configuration
Q.931, SS7, ...	Manual configuration
ISDN	PDH SONET/SDH

Packet Switching

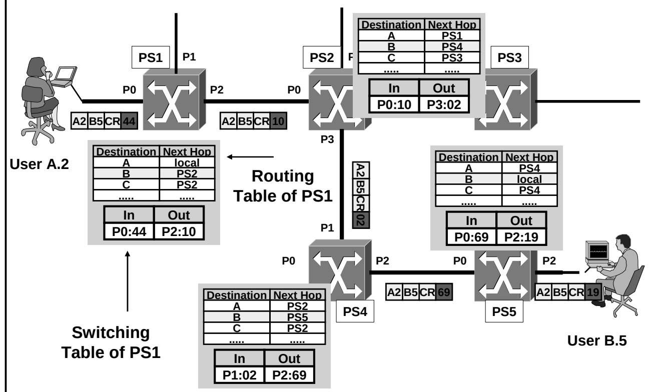
- **Statistical Multiplexing**
- **Store and forward (variable delay)**
- **Addressing necessary**
- **Designed for data traffic**

Datagram	Virtual Call
Connectionless	Connection-oriented
IP IPX AppleTalk	X.25 Frame Relay ATM

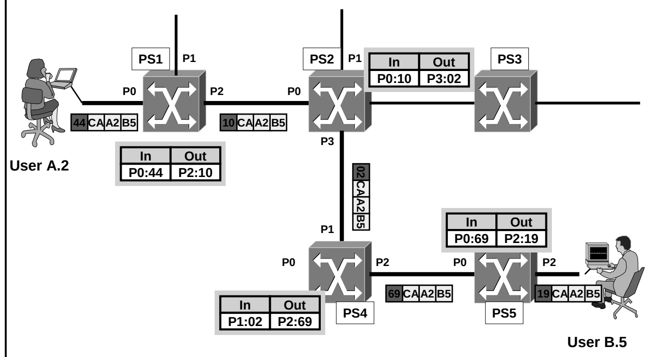
IP Datagram Service



Virtual Call – Call Request (CR)



Virtual Call – Call Accepted (CA)



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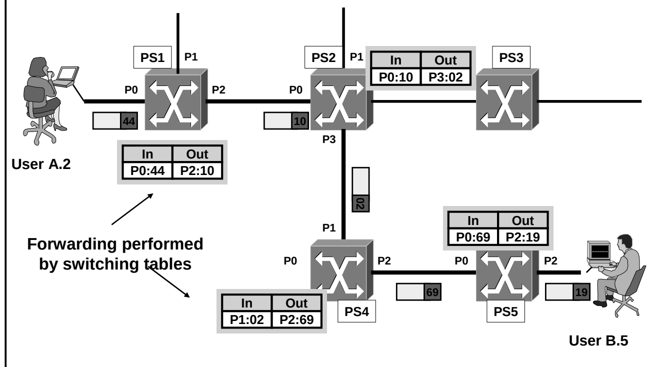
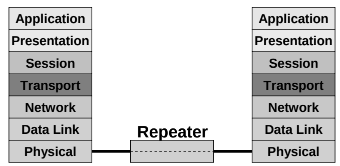
Virtual Call – Data Transfer



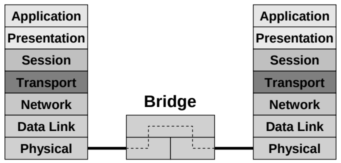
Layer 1 Devices

- **Adapts to different physical interfaces**
- **Amplifies and/or refreshes the physical signal**
- **Repeater, Hub (Multiport Repeater), ISDN NT1, PDH/SDH Muxes**



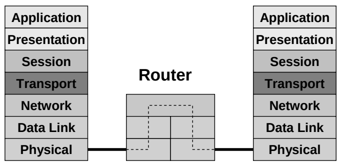
Layer 2 Devices

- **Filter/Forwards frames according Data Link Layer Address**
  - based on packet switching principle
- **Incorporates Layer 1-2**
- **LAN-Bridge ("Ethernet Switch", L2-Switch)**



Layer 3 Devices

- **"Packet Switch" or "Intermediate System"**
- **Forwards packets to other networks according structured address**
- **Terminates Data Links**
- **Router, WAN-Switch**



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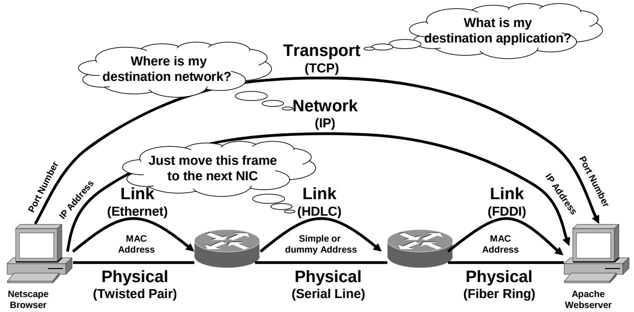
A Practical Example



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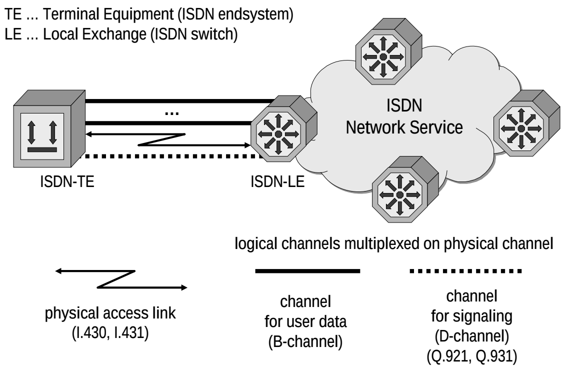
ISDN

- **Integrated Services Digital Network (ISDN)**
  - offers transport of voice, video and data
  - all-digital interface at subscriber outlet
- **standardized user-to-network interface (UNI)**
  - BRI (Basic Rate Interface)
  - PRI (Primary Rate Interface)
- **implementation of a circuit switching**
  - synchronous TDM
  - constant delay and constant capacity
  - channels created on demand (switched)

ISDN User-to-Network Interface (UNI)



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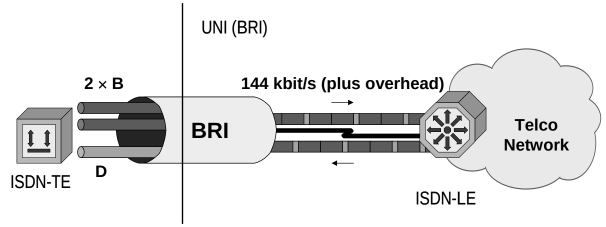
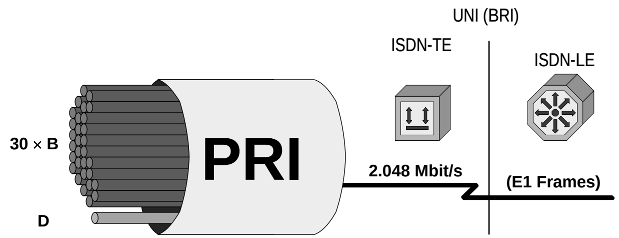
Basic Rate Interface (BRI)

- 2 B (bearer) channels with 64 kbit/s each
  - carrying digitized voice or data
- 1 D (data) channel with 16 kbit/s
  - for signalling purposes (e.g. Q.931 protocol)
- 2 B and D are synchronous TDM-multiplexed on physical access line

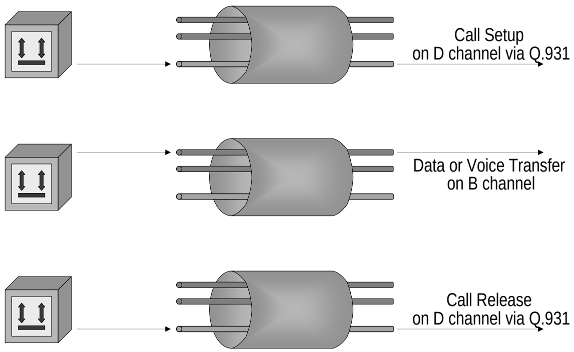


Primary Rate Interface (PRI)

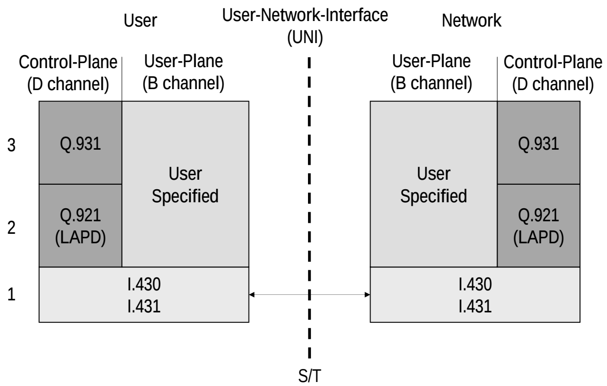
- 30 B (Bearer) channels with 64 kbit/s each
- 1 D (Data) channel with 64 kbit/s
  - for signalling purposes (e.g. Q.931 protocol)
- 30 B and D are synchronous TDM-multiplexed on one physical access line



Procedures



ITU-T ISDN Layers ("Protocol Stack")



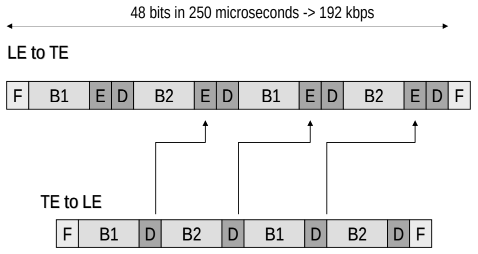
BRI (I.430)

- **basic rate interface (S_0/T interface)**
  - four wires with terminating resistor (100 ohm)
  - RJ45 connector with 8 leads
    - 2 transmit + 2 receive with power source 1 via phantom circuit
    - 4 optional power feeds for power source 2 and 3
  - modified AMI code (zero causes alternate pulses)
    - positive or negative pulse of 750mV + -10%
    - bitstuffing prevent long sequences of ones on D-channel
  - frame synchronization based on code violations
  - frame of 48 bit is transmitted in a period of 250 usec
  - 192 kbps total speed
    - 2 B channels at 64 kbps, 1 D channel at 16 kbps
    - 48 kbps for framing, DC balancing and D-channel mirroring

BRI (I.430)

- **basic rate interface (cont.)**
  - allows either a point-to-point or multipoint configuration
  - point-to-point
    - maximum distance between TE and NT is 1000 meters
  - for multipoint, physical connection is a passive bus
    - up to eight TE´s can share a bus
    - maximum distance between TE and NT is 200 meters (short bus) or 500 meters (extended bus)
  - multipoint operation
    - B channels are dynamically assigned to TE´s for exclusive usage only
    - D channel must be shared by all TE´s in order to request usage of a B channel
    - contention mode on D channel

Simplified Frame Structure I.430



F ... Starting Delimiter SD for frame synchronization
D ... D-channel bit
E ... Echo-channel bit

B1 ... 8 B1-channel bits
B2 ... 8 B2-channel bits

D - Channel Access Control

- **D - channel**
  - must be shared by different TEs in a multipoint configuration
  - control of access to D channel is necessary
- **control is done via E - bits**
  - TEs use D - bits for transmission to NT
  - E contains echo (sent by NT) of D bit received by NT
  - note:
    - encoding gives transmitted zeros higher priority than ones (zeros produce signal changes (pulses) but ones do not)
    - if TEs send at the same time on D channel, only TE with the most zeros transmitted will see its message on E again

D - Channel Access Control

- **before TE can use D channel**
  - at least eight ones (no signal activity) in sequence must be received (carrier sense, monitor state)
- **when TE starts transmitting on D channel**
  - E bits are used for comparison transmitted information with received information
  - if unequal (collision detect) TE will stop transmission (collision resolution) and will listen for next eight ones in sequence

D - Channel Access Control

- **once the D channel was successfully occupied**
  - bitstuffing will prevent sequence of eight ones for the rest of the message and TE can finish its transmission without disturbance
- **to give other TEs fair chance to access the D channel**
  - TE must release D channel after message was sent
  - TE waits then for a sequence of nine ones before access is tried again
  - this allows other waiting TEs access to the D channel
    - round-robin among all TEs in worst case

PRI (I.431)

- **primary rate interface**
  - allows point-to-point configuration only
  - based on E1 or T1 specifications
  - E1 (HDB3 encoding)
    - 2.048 Mbps total speed
    - timeslot 0 used for synchronization
    - timeslot 16 used for D channel information
    - timeslots 1-15 and 17-31 for 30 B-channels

ISDN Data Link Layer Q.921 for Signaling

- **only used on the D channel**
- **uses LAPD**
  - Link Access Procedure D-Channel
  - based on HDLC
  - 2 byte address field
  - may use extended sequence numbering (0-127)
- **ISDN level 3 signaling**
  - travels in the information field of the LAPD I-frame
- **LAPD may also be used to support user traffic**
  - D channel is not fully utilized by signaling messages
  - e.g. X.25 over D-channel

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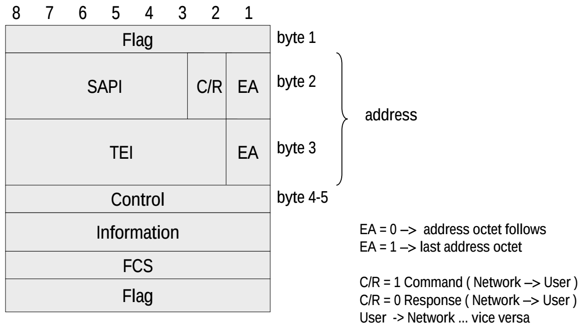
LAPD Frame Format



EA Address Field Extension Bit
C/R Command/Response Bit
SAPI Service Access Point Identifier
TEI Terminal Endpoint Identifier

SAPI + TEI: Data Link Connection Identifier (DLCI)

SAPI and TEI

- **SAPI - Service Access Point Identifier**
  - identifies the entity where data link layer services are provided to the layer above
  - protocol type field
  - examples
    - 0 signaling information (s-type)
    - 16 packet data (p-type)
    - 63 management information
- **TEI - Terminal Endpoint Identifier**
  - identifies an endpoint within a service access point
  - "address field" of HDLC
  - possible values
    - 0 - 127

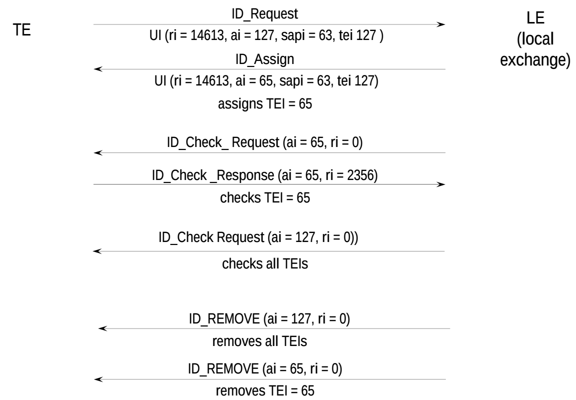
TEI Management

- **before a LAPD connection can be established**
  - either a TEI value is assigned automatically between TE and network
    - TEI value range 64-126
    - TEI assignment procedure
  - or a preconfigured value may be used
    - TEI value range 0-63
    - TEI verification procedure for checking duplicates
- **TEI = 127**
  - broadcasting, means all
- **on PRI**
  - TEI always 0

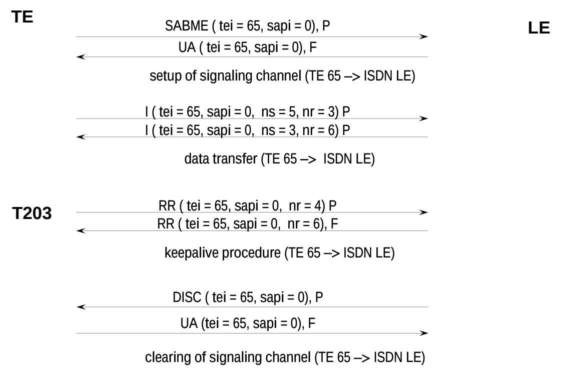
TEI Management Messages

- **always UI frames with SAPI = 63 and TEI 127**
- **information field of UI contains**
  - reference indicator (RI)
    - correlation of request and responses
  - action indicator (AI)
    - contains TEI number to be requested, assigned or checked
    - AI = 127 asks for assignment of any TEI or checks all TEs
  - message type
    - user to network (TE to NT)
      - ID_Request, ID_Check Response, ID_Verify
    - network to user (NT to TE)
      - ID_Assigned, ID_Denied, ID_Check Request (ri always 0), ID_Remove (ri always 0)

TEI Assignment, Checking, Removal



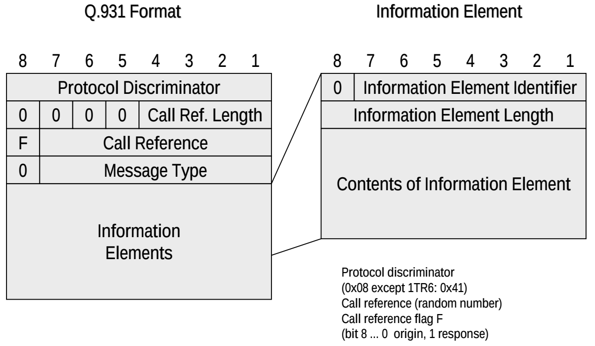
Signaling Channel Active



ISDN Network Layer Q.931 for Signaling

- **not used on B channels**
- **Q.931 is used on D channels for call control**
  - used between TE and local ISDN switch
  - not used end-to-end
- **Signaling System 7 (SS#7) is used inside the network between ISDN-LEs**
- **several flavors exist on the market**
  - be careful to select the correct version of the protocol

Q.931 Protocol Format



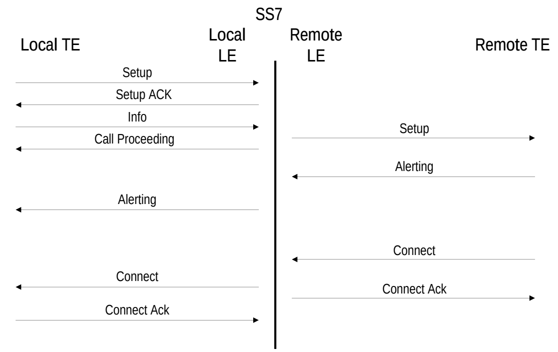
Layer 3 Messages

- **Call Establishment**
  - ALERTing
  - CALL PROCeeding
  - CONNect
    - CONNect ACKnowledge
  - SETUP
    - SETUP ACKnowledge
- **Call Information Phase**
  - RESume
    - RESume ACKnowlegde
    - RESume REJect
  - SUSPend
    - SUSPend ACKnowledge
    - SUSPend REJect
  - USER INFOrmation
- **Call Clearing**
  - DETatch
    - DETach ACKnowledge
  - DISConnect
  - RELease
    - RELease COMplete
  - REStart
    - REStart ACKnowledge
- **Miscellaneous**
  - CANCel, - Ack, - Reject
  - CONgestion CONtrol
  - FACility, - Ack, - Reject
  - INFOrmation
  - REGister. - Ack, - Reject
  - STATUS

Some Information Elements

- 0x04 Bearer Capability (eg. 0x8890 .. dig. 64kb/s Circuit)
- 0x08 Cause (reason codes for call disconnect)
- 0x18 Channel Identification
- 0x1E Progress Indicator
- 0x2C Keypad
- 0x6C Calling Party Number
- 0x6D Calling Party Subaddress
- 0x70 Called Party Number
- 0x71 Called Party Subaddress
- 0x7C Low-Layer Compatibility
- 0x7D High-Layer Compatibility

Call Establishment



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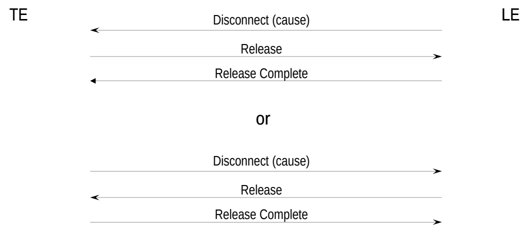
Call Release



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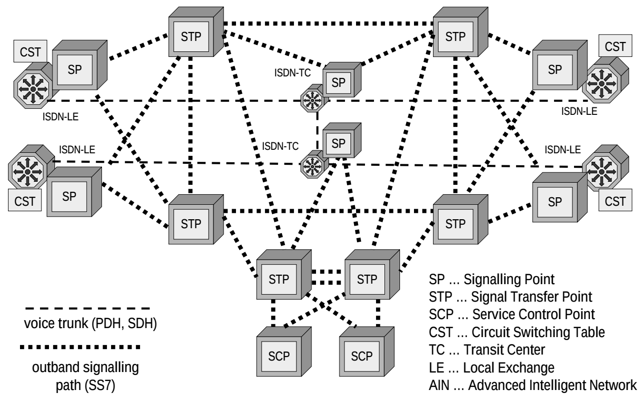
ISDN Network Service Internals (AIN, SS7)



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ISDN Detail Information

- **For a detailed description of ISDN see the corresponding chapters of section WAN technologies**

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Agenda

- **Introduction**
- **Circuit Switching**
- **Packet Switching**
  - Principles
  - Datagram Service
  - Virtual Call Service
- **OSI Reference Model**
- **Summary of Network Methods**
- **<u>Short Introduction of</u>**
  - IDSN
  - <u>X.25, Frame Relay, ATM</u>

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What is X.25?

- **packet switching technology**
  - based on store-and-forward of packets
  - connection oriented
- **interface definition between user and network equipment**
  - X.25 - DTE (e.g. router) <–> X.25 - DCE (packet switch)
- **wide area network service**
  - based on virtual circuit technique
- **operation within X.25 network cloud**
  - switch to switch communication not standardized
  - vendor specific implementation

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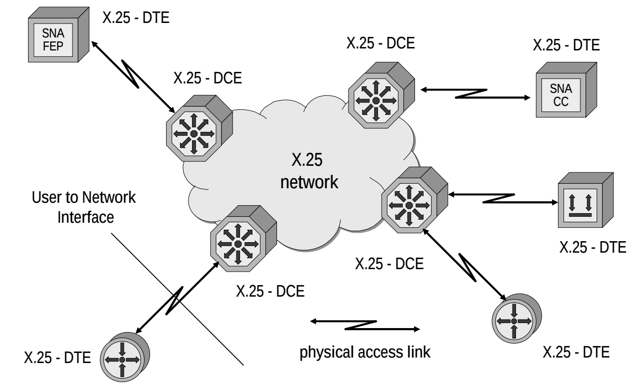
X.25 Topology



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X.25 Virtual Circuits/LCN

- **virtual circuit technique**
  - for statistically multiplexing many logical data conversations over a single physical transmission link
  - end systems (X.25-DTE) use virtual circuits for delivering data to the X.25 network and vice versa
  - virtual circuits appear to end systems as transparent transport pipes (logical point-to-point connections)
- **virtual circuits (VCs) are identified using LCN numbers**
  - logical channel number (LCN)
  - LCN are of local significance only

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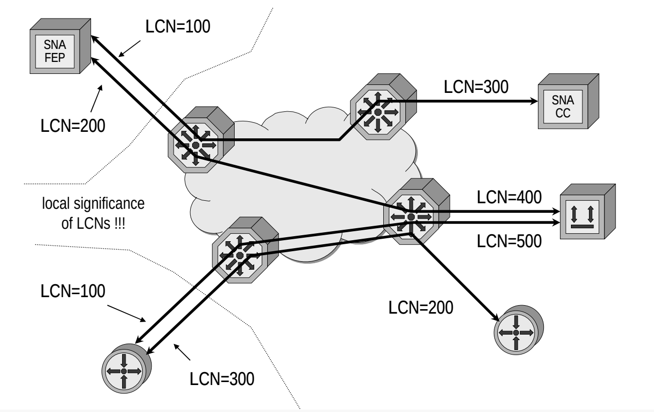
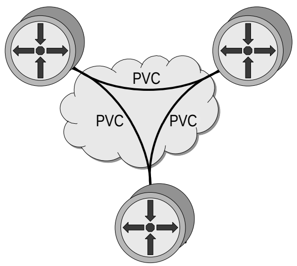
Logical Channel Number (LCN)



Permanent Virtual Circuit (PVC)

- **static connection between two end devices**
- **functionally equivalent to dedicated leased lines**
- **but remember**
  - store and forward technology
  - variable delays



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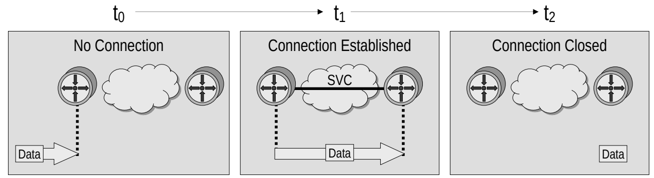
Switched Virtual Circuit (SVC)

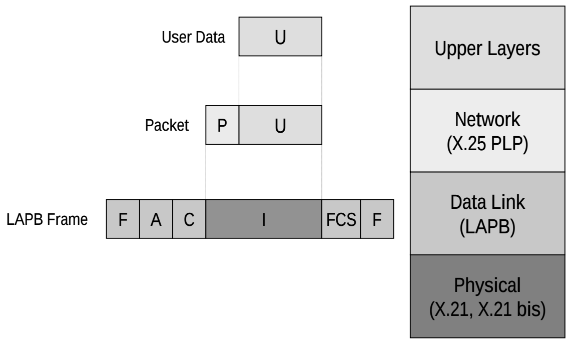


- **dynamic connection setup and tear down between two end devices**
- **similar to dial up circuits in that they provide bandwidth on demand**

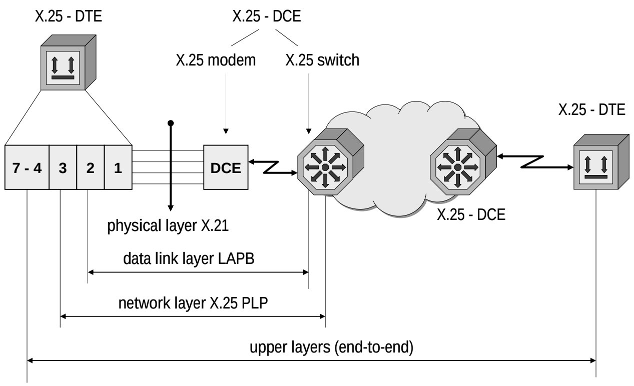
Roots of X.25

- **originally defined by CCITT**
  - as an interface between user equipment and public switched data network
  - three layers covered
    - X.21 (physical layer)
    - LAPB (data link layer); a member of the HDLC layer
    - X.25 (network layer)
  - different versions:
    - four years cycle
    - 1980 (yellow books), 1984 (red books), 1988 (blue book), ...
- **X.25 definitions were expanded by ISO**
  - for provisioning the Connection Mode Network Service (layer 3) in OSI based networks

X.25 Layers (CCITT)



X.25 Interface (CCITT)



X.25 Facts

- **remember:**
  - X.25 standards defines communication between DTE and DCE only
  - operation (e.g. routing) within network not defined
  - only sequencing must be guaranteed
  - X.25 uses statistical multiplexing
- **X.25 technology was developed for low quality, low speed lines**
  - use error recovery and flow control on layer 2 to control transmission of frames over physical line
  - use flow control and optionally error recovery on layer 3 to control transmission of packets over a virtual circuit

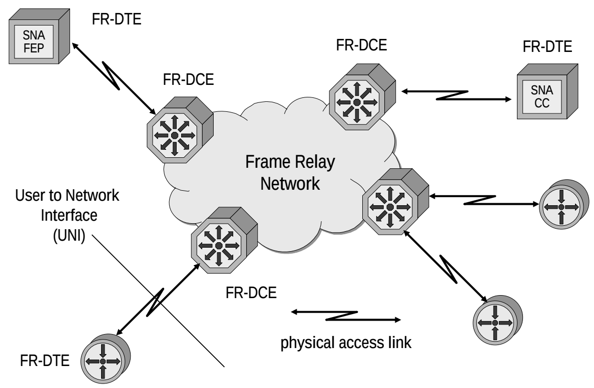
X.25 Detail Information

- **For a detailed description of X.25 see the corresponding chapters of section WAN technologies**

What is Frame Relay?

- **packet switching technology**
  - based on store-and-forward of packets
  - connection oriented
- **interface definition between user and network equipment**
  - FR-DTE (e.g. router) <–> FR-DCE (frame relay switch)
  - UNI (User to Network Interface)
- **wide area network service**
  - based on virtual circuit technique
- **operation within FR network cloud**
  - switch to switch communication not standardized
  - vendor specific implementation

Frame Relay Basic Topology



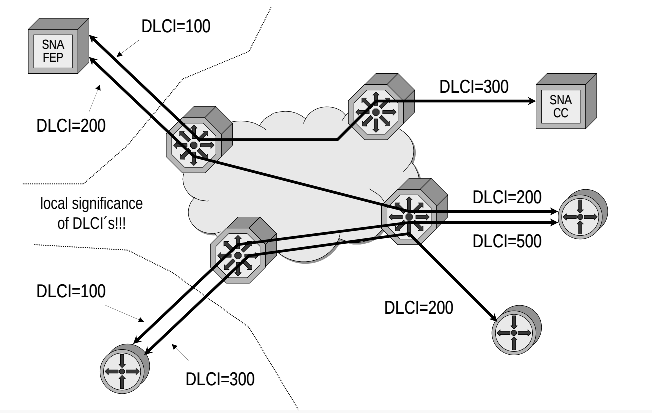
Frame Relay Virtual Circuits

- **virtual circuit technique used**
  - for statistically multiplexing many logical data conversations over a single physical transmission link
- **end systems (FR-DTE) use virtual circuits for delivering data to the FR network and vice versa**
- **virtual circuits appear to end systems as transparent transport pipes (logical point-to-point connections)**

Frame Relay DLCI

- **virtual circuits (VCs) are identified using DLCI numbers**
  - data link connection identifier (DLCI), locally significant
- **some implementations support global addressing**
  - still locally significant
  - but number of user ports limited
- **two kinds of virtual circuits**
  - permanent virtual circuits (PVC) established in advance by service provider
  - switched virtual circuits (SVC) established on demand by user through signaling procedure

Data Link Connection Identifier (DLCI)



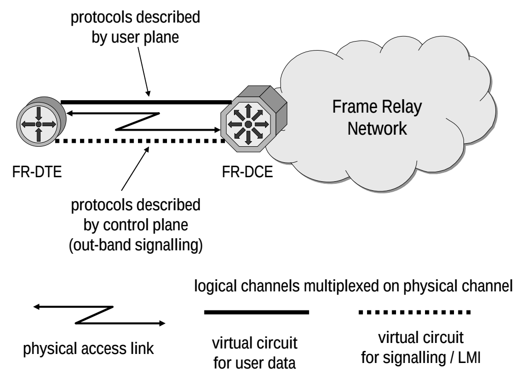
Frame Relay versus X.25

- **protocols like X.25 have been developed for low quality, low speed lines**
  - use error recovery and flow control on layer 2 and 3
- **those protocols are an overkill for high speed lines providing very low error rates**
- **frame relay has been designed to overcome these problems**
  - use only part of layer 2
  - error recovery moved to the end system
  - congestion control instead of flow control
  - therefore simpler link operation and hence higher speed and throughput then X.25 is possible

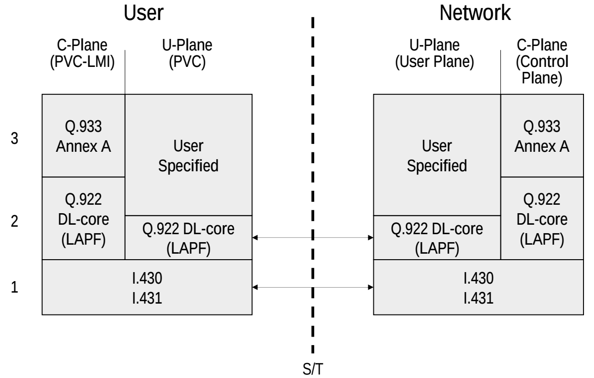
Roots of Frame Relay

- **originally defined by ITU-T as a network service within ISDN**
  - I.122 specifies the framework for additional packet mode bearer services, one of these services is frame relay
  - initial requirement was for ISDN primary rate access
- **frame relay is based upon ISDN data link layer procedures for the D channel**
  - D channel is used for ISDN signaling and ISDN data transfer in packet switching mode
  - I.440/I.441 ISDN user-network interface data link layer
  - Q.920/Q.921 link access procedures on the D channel (LAPD)

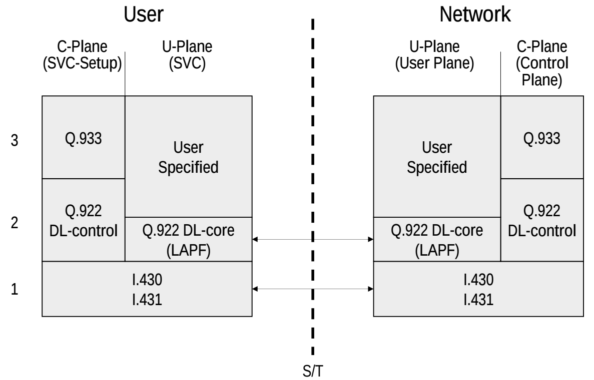
Control Plane <-> User Plane



ITU-T Frame Relay Protocol Architecture



ITU-T Frame Relay Protocol Architecture



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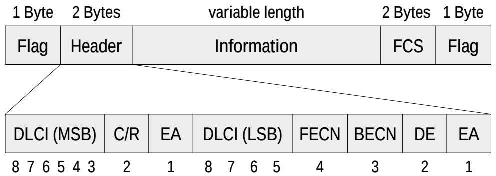
L05 - Network Principles

Frame Relay Layer 2 for Data Transfer

- **data link layer (2) defined in Q.922 Annex A (LAPF) or T1.618 specifies**
  - frame alignment and delimiting (HDLC Flag)
  - zero bit insertion and extraction (bit stuffing)
  - error detection but no correction
  - verification that frame fulfill minimum size, maximum agreed size, integral number of octets
  - frame multiplexing/demultiplexing using an address field (DLCI number)
  - congestion control
- **all remaining upper layers are transparent to the frame relay user plane**

Frame Format (Q.922 Annex A, T1.618)



DLCI	Data Link Connection Identifier	FECN	Forward Explicit Congestion Notification
C/R	Command/Response Bit	BECN	Backward Explicit Congestion Notification
EA	Address Extension Bits	DE	Discard Eligibility

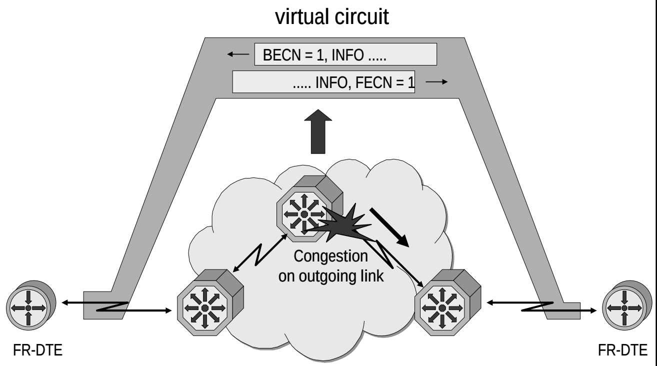
Frame Format

- **DLCI address**
  - uniquely identifies a virtual circuit through the network to a specific destination
  - in most cases 10 bit length (value range 0 - 1023)
  - could be expanded with additional octets using EA bits
  - FRF, GOF specifies only two octets DLCI address
- **DLCI reserved values (10 bit DLCI)**
  - for signaling, management and future aspects
    - 0 -15
    - 992 - 1023 (ANSI, ITU-T, FRF)
    - 1008 - 1023 (GOF)

Frame Format

- **Forward Explicit Congestion Notification (FECN)**
  - may be set by a frame relay network to notify the user that congestion was experienced for traffic in the direction of the frame carrying FECN indication
- **Backward Explicit Congestion Notification (BECN)**
  - may be set by a frame relay network to notify the user that congestion was experienced by traffic in the opposite direction of the frame carrying BECN indication
- **DE Discard Eligibility**
  - may be set by the user or the network to indicate that this frame should be discarded in preference to other frames (without the DE bit set) in case of congestion

FECN/BECN



FR Data Link Layer Service

- **LAPF/T1.618 does not provide any error recovery or flow control procedures**
- **although frame relay is connection oriented**
  - only a best effort service is offered to end systems
- **only delivering frames in sequence is offered to end systems**
  - basic transport service
- **principle rule:**
  - a frame relay network tries to guarantee delivering frames which are inside the traffic contract with high probability

FR Data Link Layer Service

- **if a frame error is detected by a frame relay switch**
  - the corresponding frame will be discarded
- **if a congestion situation is experienced by a frame relay switch (buffer overflow)**
  - frames will be discarded
- **error recovery must be done by end systems**
  - end systems must detect missing frames using their own higher layer sequence numbers
  - discarded frames must be retransmitted by end systems

Frame Relay Detail Information

- **For a detailed description of Frame Relay see the corresponding chapters of section WAN technologies**

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L05 - Network Principles

What is ATM?

- **ATM**
  - Asynchronous Transfer Mode
  - Based on asynchronous TDM
    - hence buffering and address information is necessary
- **Cell switching technology**
  - based on store-and-forward of cells
  - connection oriented type of service
- **ATM cell**
  - small packet with constant length
  - 53 bytes long
    - 5 bytes header + 48 bytes data

What is Asynchronous Transfer Mode?

Synchronous TDM

(+) Constant delay (good for voice)

(+) Protocol transparent

(–) Fixed channel assignment (might be uneconomic)

(–) Trunk bandwidth = sum of channel speeds (expensive)

Asynchronous TDM

(–) Variable delay (variable frame sizes)

(+/–) Fairly protocol transparent

(+) Flexible channel assignment (using addresses)

(+) Trunk bandwidth = average of channel speeds

Asynchronous Transfer Mode (ATM)

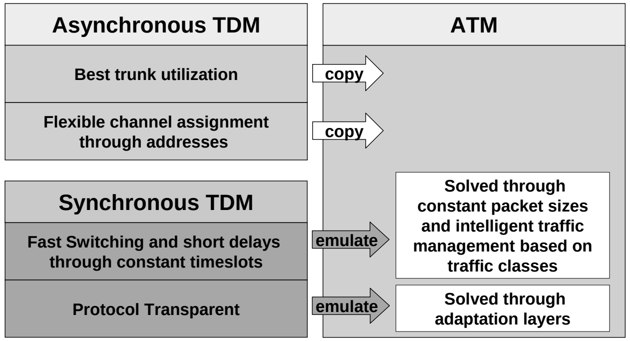
(+) Bounded delay through fixed cell sizes (53 bytes)

(+) Protocol transparent through higher layers (CPCS and SAR)

(+) Flexible channel assignment using addresses (VPI/VCI)

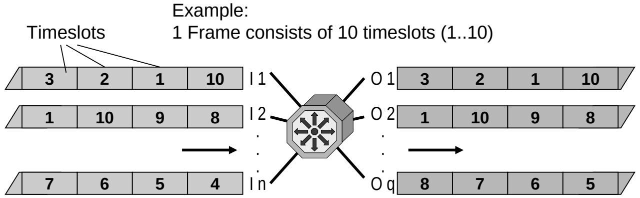
(+) Trunk bandwidth according average channel speeds (different traffic classes)

Design Ideas



Synchronous Transfer Mode

Example:
1 Frame consists of 10 timeslots (1..10)

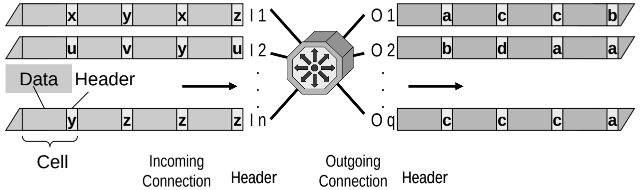


Incoming Connection	Timeslot	Outgoing Connection	Timeslot
I1	1	O2	8
	2	O7	3
	3	O1	3
	4	O4	5
....		....	

Fixed timeslot allocation !

Asynchronous Transfer Mode

Cell header: addressing information for routing and dynamic bandwidth allocation

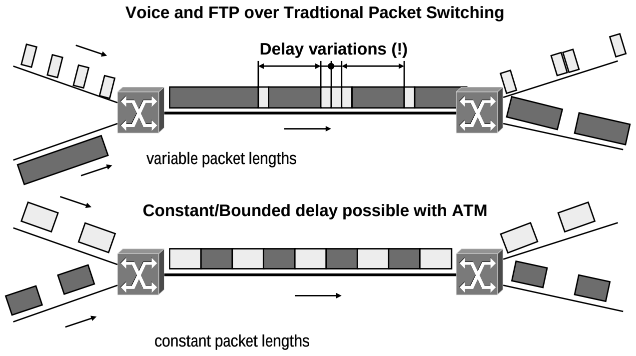


Incoming Connection	Header	Outgoing Connection	Header
I1	v	O2	a
	w	O7	b
	x	O1	c
	y	O4	d
....		....	

Why Cells?

- **Cell switching technology allows**
  - Forwarding of cells in hardware
    - Hence very fast
  - Predictable and bounded delay for a given cell
    - Still variable !
  - Quality of Service (QoS) guarantees
    - With specific strategies like admission control, QOS routing, traffic shaping, traffic policing, cell scheduling
  - Integration of voice, video and data
    - Real-time traffic and non real-time traffic on the same network infrastructure

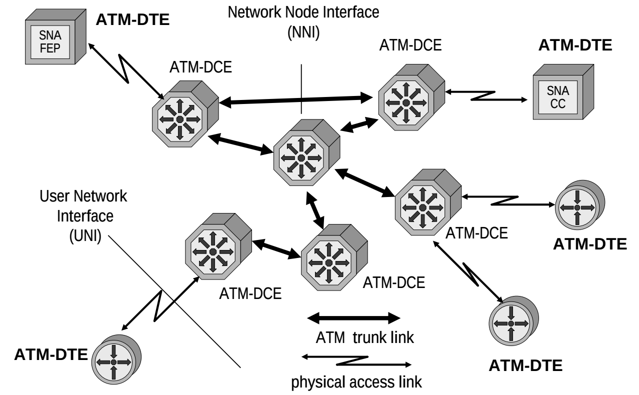
Cell Switching and Jitter



ATM Technology

- **WAN service and campus area network service**
  - Based on virtual circuit technique
  - Connection oriented, enables charging for carriers and providers
  - Sequencing of cell stream is guaranteed but no error recovery is done for damaged cells
  - One single technology to cover both WAN and LAN (MAN) aspects
- **Standardized interface definitions**
  - User Network Interface (UNI)
    - between ATM-DTE and ATM-DCE
  - Network Node Interface (NNI)
    - between ATM-DCE and ATM-DCE

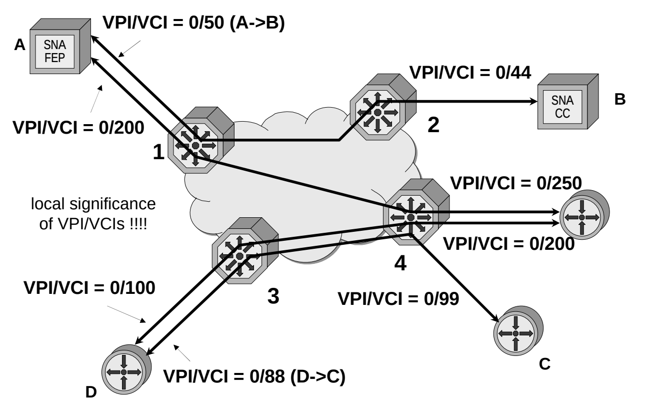
ATM Basic Topology



ATM VPI / VCI

- **Virtual circuits (VCs) are identified using VPI / VCI numbers**
  - Virtual Path Identifier / Virtual Channel Identifier
  - Only locally significant
- **Two kinds of virtual circuits**
  - Permanent virtual circuits (ATM-PVC) established in advance by service provider
  - Switched virtual circuits (ATM-SVC) established on demand by user through signaling procedure

VPI / VCI



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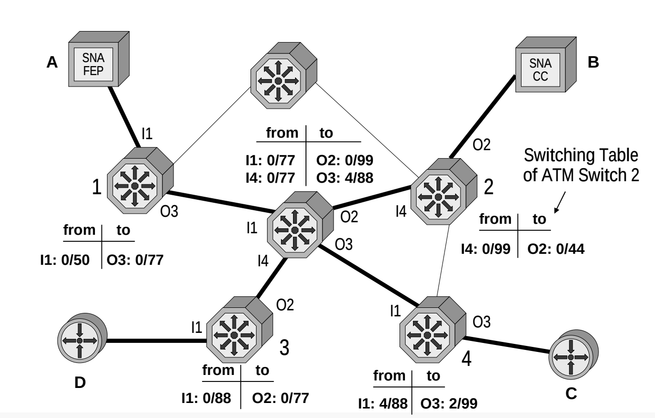
ATM Switching Tables



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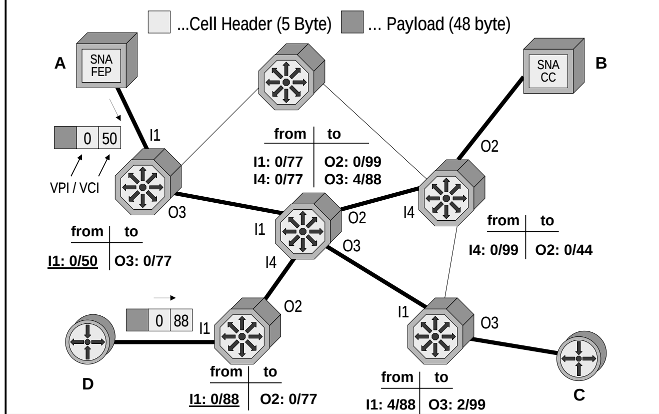
Cell Forwarding / Label Swapping 1



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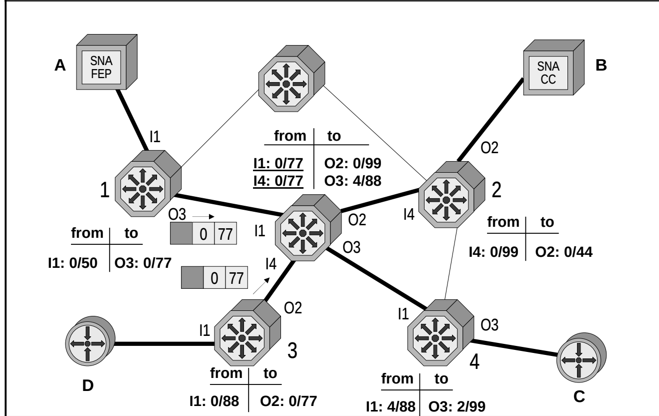
Cell Forwarding / Label Swapping 2



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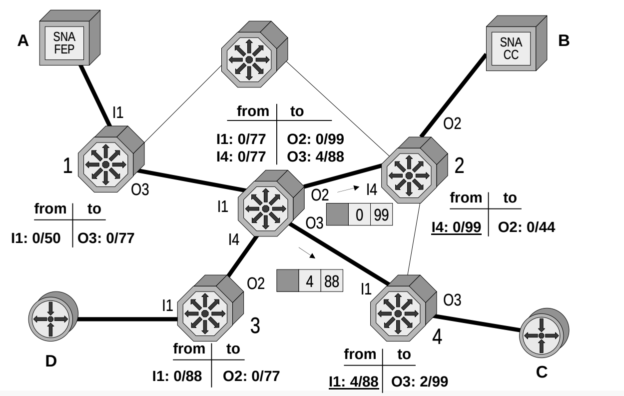
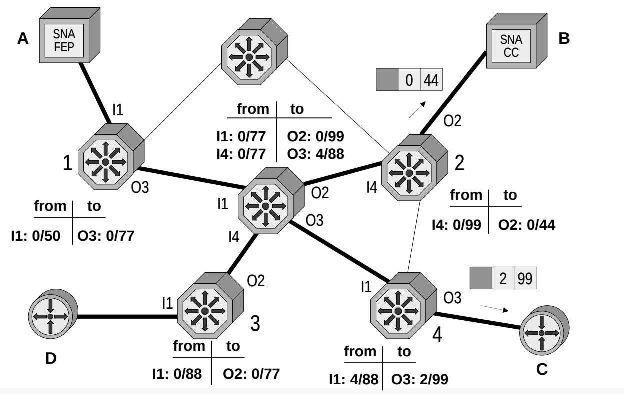
Cell Forwarding / Label Swapping 3

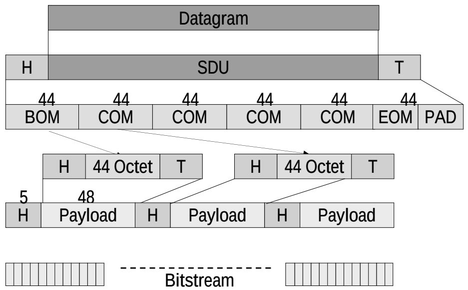


Cell Forwarding / Label Swapping 4



Segmentation Principle

- **Cells are much smaller than data packets**
  - Segmentation and Reassembly is necessary in ATM DTEs (!!!)
  - ATM DCEs are not involved in that



ATM Usage

- **Public and private networks**
  - LAN, MAN, WAN
- **Backbone high-speed networks**
  - Public (Telco's) or private
- **Original goal: World-wide ATM network**
  - But Internet technology and state-of-the art Ethernet are more attractive today
- **New importance as backbone technology for mobile applications**
  - Cellular networks for GSM, GPRS, UMTS, ...

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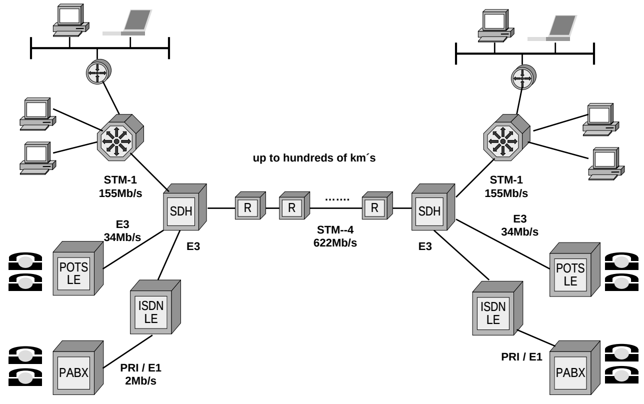
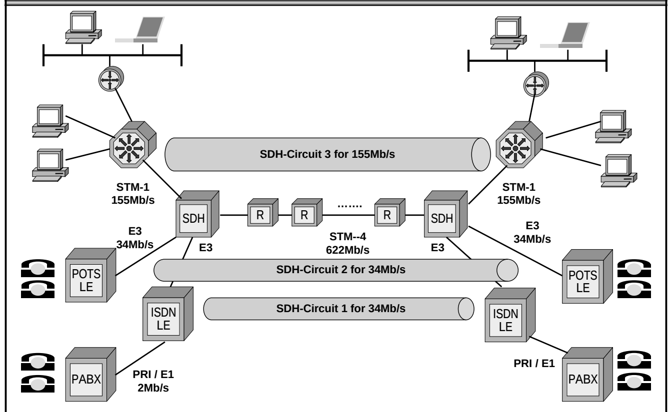
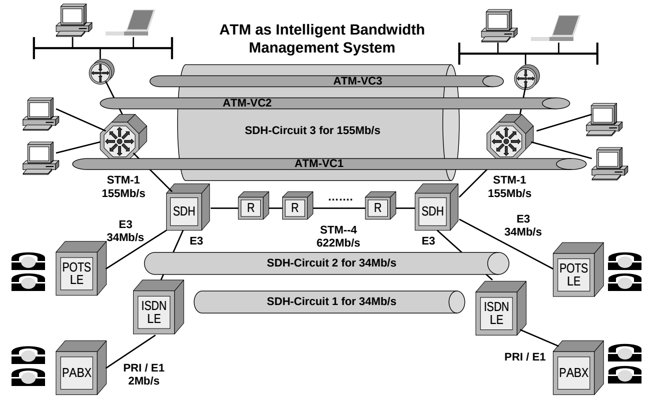
ATM as WAN Technology based on SDH



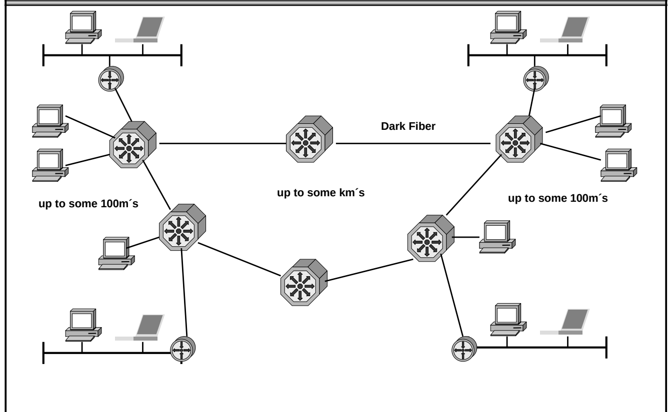
SDH Circuits (Timeslots of S-TDM)



ATM-VC´s inside SDH-Circuit



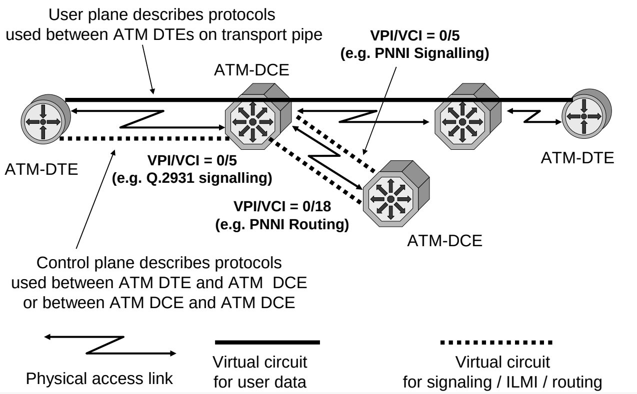
ATM as LAN/ MAN Technology based on Dark Fiber



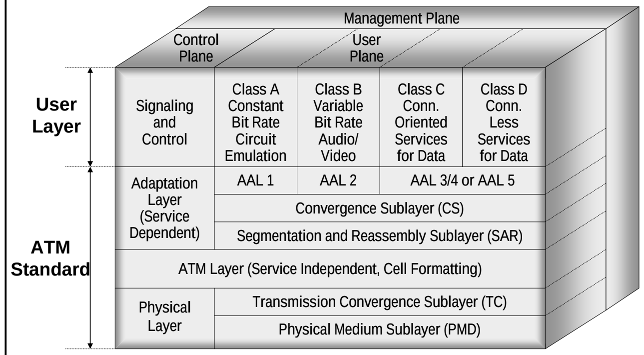
ATM Reference Model

- **User Plane**
  - Provides for transfer of information
- **Control Plane**
  - Call control, connection control, PVC management, interim local management interface (e.g. ILMI)
- **Management Plane**
  - Layer management
    - e.g. meta-signaling, layer specific Operation and Maintenance (OAM) information flow
  - Plane management
    - Management functions related to the whole system
    - Coordination between all planes

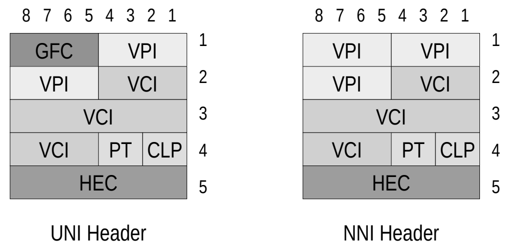
Control Plane <-> User Plane



ATM Reference Model

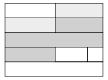


Cell Format



- **Two slightly different formats**
  - UNI … 8 bits for VPI
  - NNI … 12 bits for VPI

Cell Format



- **Cell Size**
  - 53 byte
  - 5 byte header and 48 byte payload
- **VPI and VCI**
  - VPI - Virtual Path Identifier
  - VCI - Virtual Channel Identifier
  - VPI/VCI identifies the virtual connection
    - Similar function as the X.25 logical channel identifier or the Frame Relay DLCI
  - Reserved values used for
    - Signaling
    - Operation and maintenance
    - Resource management

Reserved VPI/VCI Values

VPI	VCI	Function
0	0- 15	ITU-T
0	16 - 31	ATM Forum
0	0	Idle Cell
0	3	Segment OAM Cell (F4)
0	4	End-to-End OAM Cell (F4)
0	5	Signaling
0	16	ILMI
0	17	LANE
0	18	PNNI

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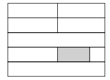
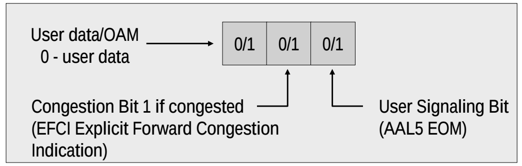
Cell Format



- **Payload Type (3 bits)**
  - Used by AAL5 to flag end of block
  - Used to signal congestion

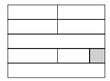


Value	OAM Type
100	OAM link associated cell
101	OAM end-to-end cell
110	Resource management cell
111	Reserved

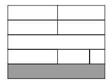
(OAM = Operation, Admin, Management)

RM cell (Flow control in ABR)

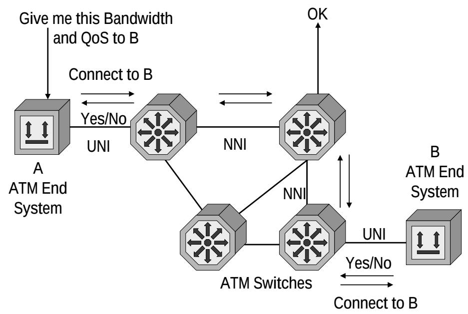
Cell Format



- **Cell Loss Priority (CLP)**
  - Similar to the DE-bit in Frame Relay
  - Normal transmission: CLP = 0
  - Low priority, might be discarded: CLP = 1
- **Header Error Check (HEC)**
  - Allows the correction of single-bit errors in the cell header or
  - Allows the detection of most multi-bit errors
  - Also used for determining cell boundaries on some types of physical link connection



ATM Goal: Bandwidth on Demand with QoS Guarantees



ATM Traffic Management Basics

- **The ATM network establishes**
  - a separate traffic contract with the user for each VC
- **The elements for a traffic contract are**
  - ATM service class
    - framework that defines which of the following parameters are relevant for a certain traffic class
  - ATM traffic parameters
    - specify characteristics of the traffic (cell flow) which is generated by an ATM end system
  - ATM QoS parameter
    - performance parameters expected by an ATM end system from the ATM network when generated traffic is within the contracted parameters; some of these parameters are negotiated (ptp CDV, maxCDT, CLR)

Traffic and QoS Parameters

- **ATM traffic parameters**
  - Peak Cell Rate (PCR)
  - Cell Delay Variation Tolerance (CDTV)
  - Sustainable Cell Rate (SCR)
  - Maximum Burst Size (MBS)
  - Minimum Cell Rate (MCR)
- **ATM QoS parameters**
  - Cell Transfer Delay (CTD)
  - Cell Delay Variation (CDV)
  - Cell Loss Ratio (CLR)
  - Cell Error Rate (CER)

Service Classes

Guaranteed Service "Bandwidth on Demand"	CBR	Constant Bit Rate Circuit Emulation, Voice
	VBR	Variable Bit Rate Full Traffic Characterization Real-Time VBR and Non Real-Time VBR
"Best Effort" Service	UBR	Unspecified Bit Rate No Guarantees, "Send and Pray"
	ABR	Available Bit Rate No Quantitative Guarantees, but Congestion Control Feedback assures low cell loss

Service Classes

- **CBR Service**
  - Used for very strict bandwidth traffic
  - Minimal delay, minimal delay variation, minimal loss
  - Traffic parameter is peak cell rate (PCR)
  - For example digital leased line emulation
- **VBR Service**
  - Variable bandwidth traffic
  - Useful for video and compressed voice applications
  - Traffic parameters are sustainable (average) cell rate (SCR), PCR, and maximum burst size (MBS)
  - Guaranteed service if source conforms to parameters

Service Classes

- **ABR Service**
  - Useful for computer applications
  - Variable bandwidth traffic
  - Traffic parameter is minimum cell rate (MCR)
  - Includes feedback control
- **UBR Service**
  - “Best effort” service
    - No real guarantees
  - Useful for computer applications
  - Variable bandwidth traffic
  - No traffic parameters

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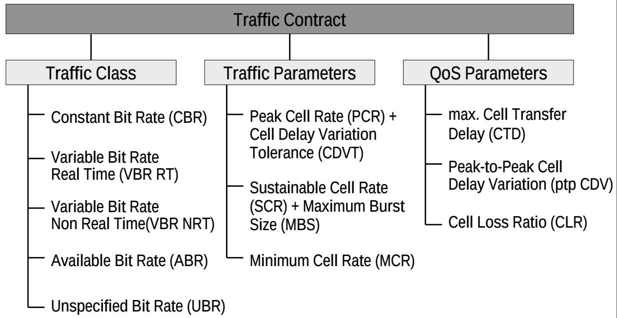
Traffic Contract



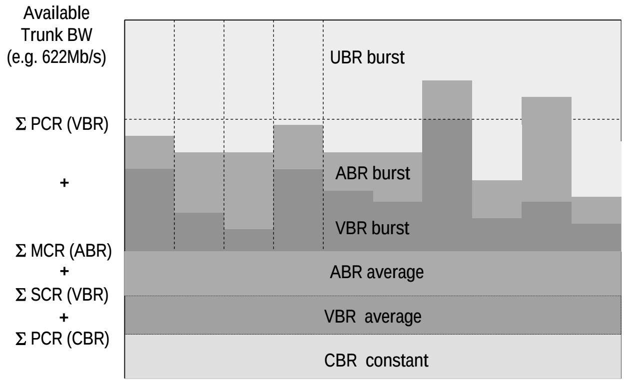
Traffic Contract per Service Class

- **Specified for each service class**

ATTRIBUTE	CBR	rt-VBR	nrt-VBR	ABR	UBR
PCR & CDVT	Specified			Specified	
SCR, MBS, CDVT	n/a	Specified		n/a	
MCR	n/a			Specified	n/a
max CTD & ptp CDV	Specified		Unspecified	Unspecified	
CLR	Specified			Optional	Unspecified

CLR = Cell Loss Ratio
CTD = Cell Transfer Delay
CDV = Cell Delay Variation
MBS = Maximum Burst Size
PCR = Peak Cell Rate
CDVT = CDV Tolerance
SCR = Sustainable CR
MCR = Minimum CR

ATM as an Intelligent Bandwidth Management System



ATM Detail Information

- **For a detailed description of ATM see the corresponding chapters of section WAN technologies**
  - Note: If you are a newcomer start with ATM PNNI Routing after you got familiar with IP OSPF routing covered later in this course