Internetworking

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Objectives

- The Open Systems Interconnection (OSI) model
- Cisco's three-layer hierarchical network model
- Different types of devices at different layers
- Different types of cables and connectors

Advantages in layered model

- Dividing the complex network operation into more manageable layers

Advantages in layered model

- Changing one layer without having to change all layers. This allows application developers to specialize in design and development.

Advantages in layered model

- Defining the standard interface for the “plug-and-play” multi vendor integration

OSI model

- OSI (Open Systems Interconnection) model was created by the International Organization for Standardization
- To help vendors create interoperable network devices

OSI model

- It describes how data and network information are communicated from applications on one computer, through the network media, to an application on another computer

OSI model

It also provides a framework for creating and implementing networking standards, devices, and internetworking schemes

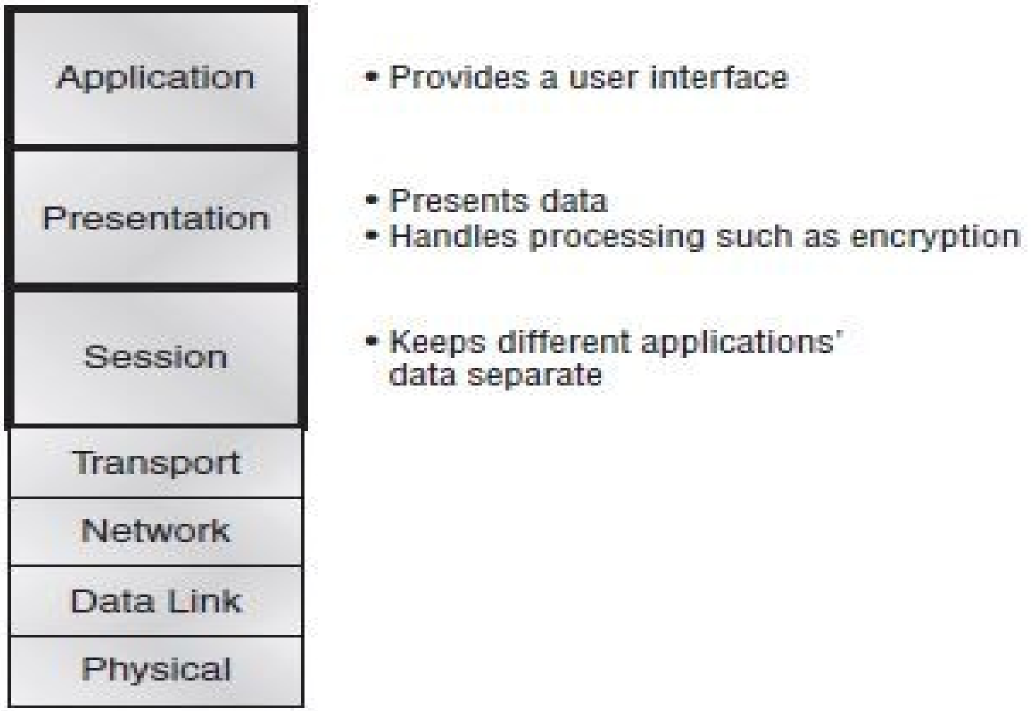
OSI model

- The OSI reference model breaks this approach in to layers.

The OSI Model

The OSI has seven different layers, which are divided into two groups.

The upper layers

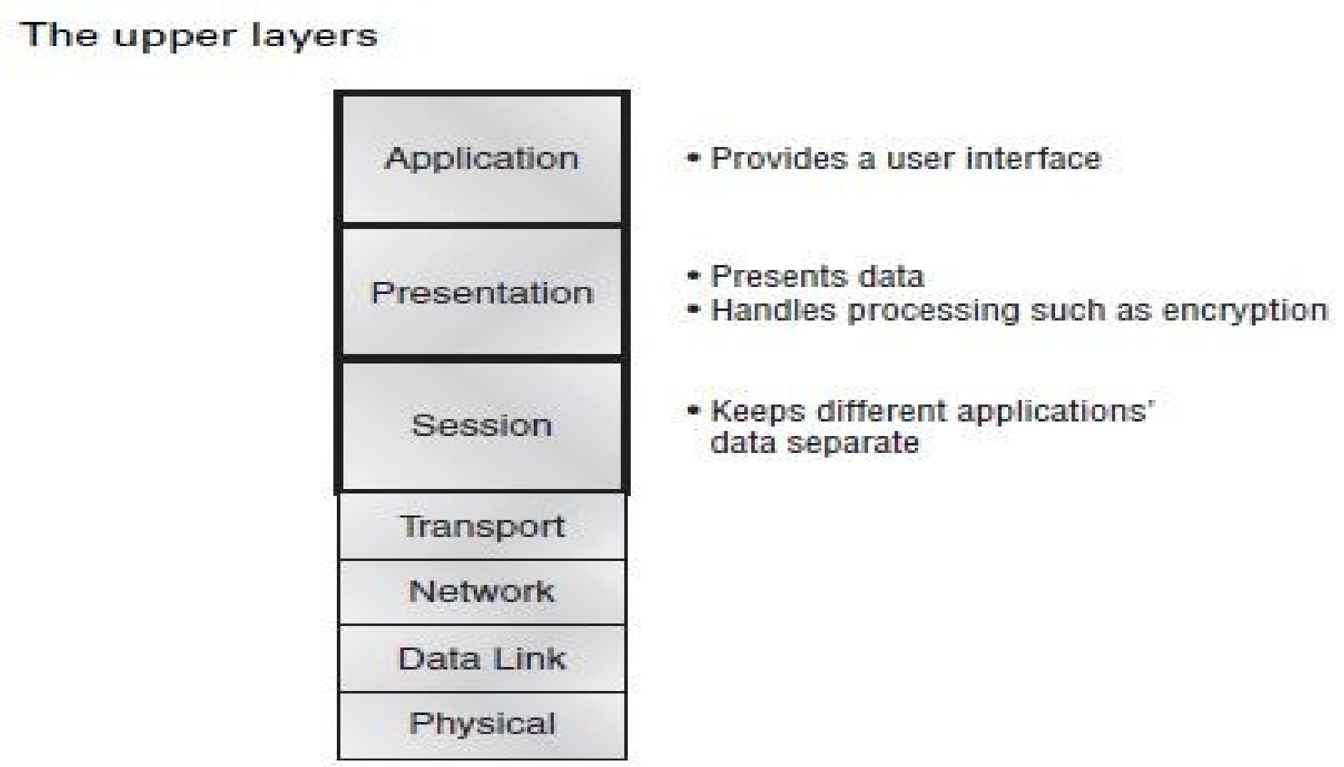


The OSI Model

The top three layers define how the applications within the end stations will communicate with each other and with users.

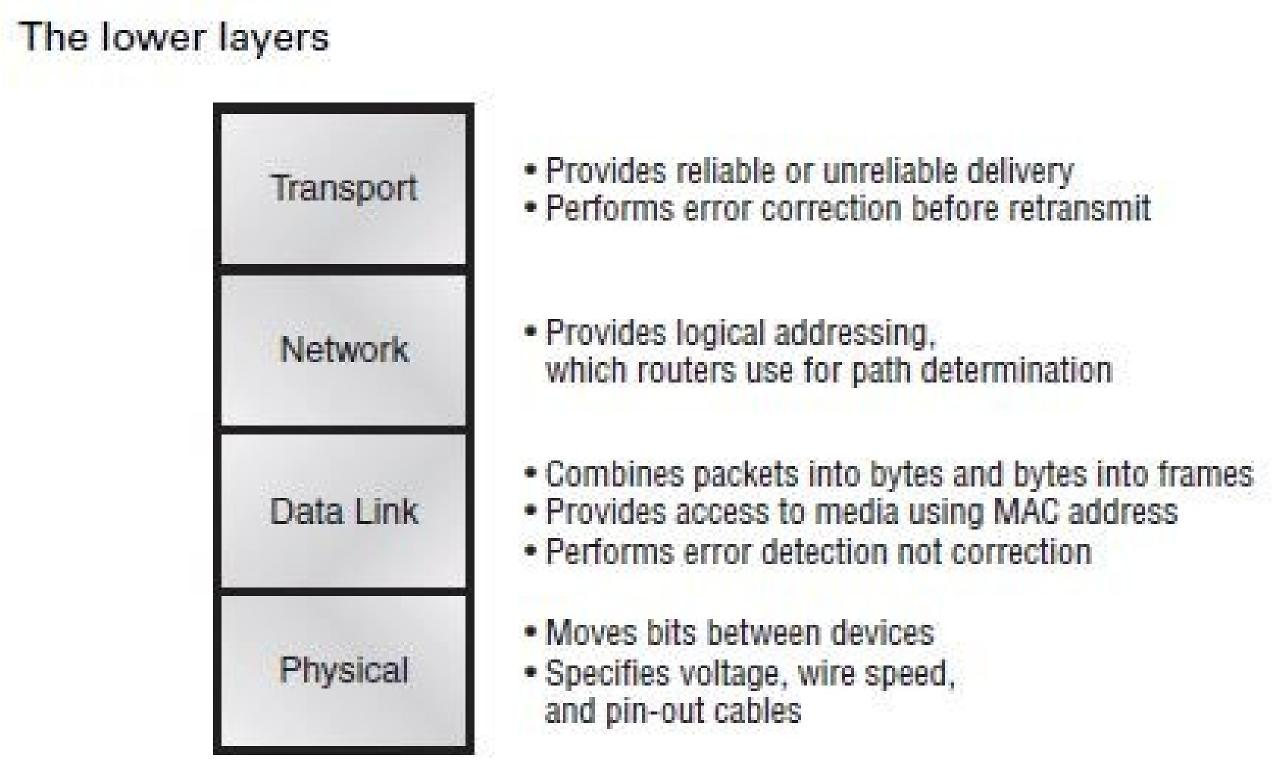
The bottom four layers define how data is transmitted end-to-end.

Top Layers



The upper layers
Application
• Provides a user interface
Presentation
• Presents data
• Handles processing such as encryption
Session
• Keeps different applications' data separate
Transport
Network
Data Link
Physical

Bottom Layers



The Application Layer

The Application layer of the OSI model is where users communicate to the computer.

Is responsible for identifying and establishing the availability of the intended communication partner

Network applications like file transfers, e-mail, remote access, network management activities, client/server processes, and information location.

Applications

World Wide Web (WWW) - both accessing and viewing Web sites

E-mail gateways

Electronic Data Interchange (EDI)

Special interest bulletin boards

Financial transaction services

The Presentation Layer

It presents data to the Application layer.

It’s essentially a translator and provides coding and con- version functions.

The Presentation Layer

A successful data transfer technique is to adapt the data into a standard format before transmission.

Computers are configured to receive formatted data and then convert the data back into its native format

The Presentation Layer

Tasks like data compression, decompression, encryption, and decryption are associated with this layer.

Some Presentation layer standards are involved in multimedia operations.

The Session Layer

Responsible for setting up, managing, and then tearing down sessions between Presentation layer entities

The Session Layer

Also provides dialog control between devices, or nodes

Offering three different communication modes: ***simplex, half-duplex,*** and ***full-duplex***.

communication modes

Simplex – One way communication

Half-duplex - Two way communication, one at a time

Full-duplex - Two way communication, at a time

Session-layer protocols in Cisco Devices

Network File System (NFS)

Structured Query Language (SQL)

Remote Procedure Call (RPC)

X Window

AppleTalk Session Protocol (ASP)

Digital Network Architecture Session Control Protocol (DNA SCP)

Network File System (NFS)

Was developed by Sun Microsystems and used with TCP/IP and Unix workstations to allow transparent access to remote resources.

Structured Query Language (SQL)

Was developed by IBM to provide users with a simpler way to define their information requirements on both local and remote systems.

Remote Procedure Call (RPC)

Is a broad client/server redirection tool used for disparate service environments.

Its procedures are created on clients and performed on servers

X Window

Is widely used by intelligent terminals for communicating with remote Unix computers

AppleTalk Session Protocol (ASP)

Is another client/server mechanism, which both establishes and maintains sessions between AppleTalk client and server machines.

The Transport Layer

Services located in the Transport layer both segment and reassemble data from upper-layer applications and unite it onto the same data stream.

The Transport Layer

They provide end-to-end data transport services and can establish a logical connection between the sending host and destination host on an internetwork.

The Transport Layer

The Transport layer is responsible for providing mechanisms for multiplexing upper-layer application, session establishment.

Flow Control

Transport layer maintains flow control and allowing a reliable data transport between systems.

Flow Control..

Flow control prevents a sending host on one side of the connection from overflowing the buffers in the receiving host

How Flow Control ?

The segments delivered are acknowledged back to the sender upon their reception.

Any segments not acknowledged are retransmitted

How Flow Control ?

Segments are sequenced back into their proper order

A manageable data flow is maintained in order to avoid congestion, overloading, and data loss.

Connection-Oriented Communication

Step 1 – Establish end to end connection between sender and receiver

Step 2 – Negotiate on parameters

Step 3 – Data Transfer takes place

Step 4 – Terminate Connection

Cisco refers to this as a three-way handshake.

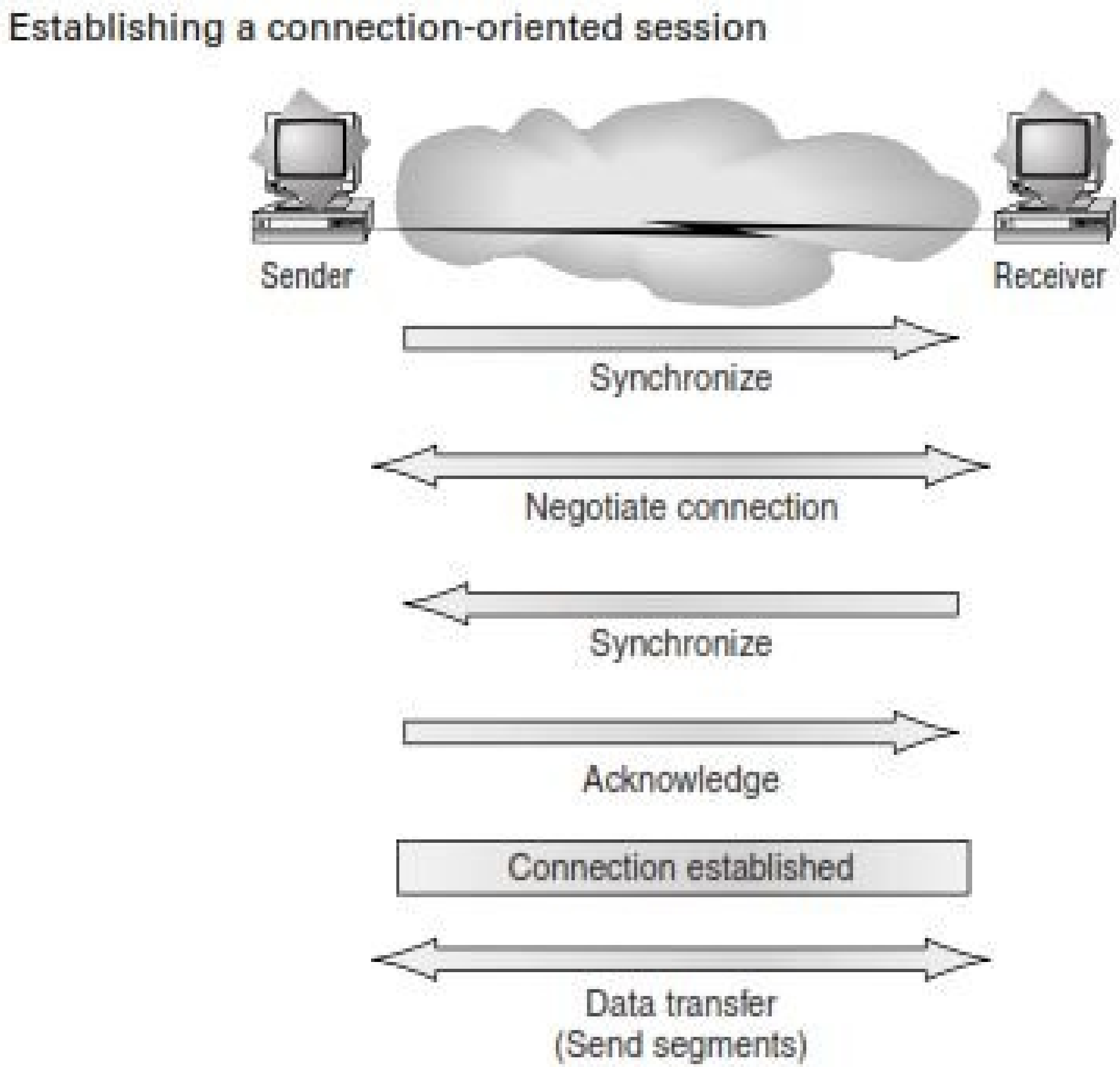
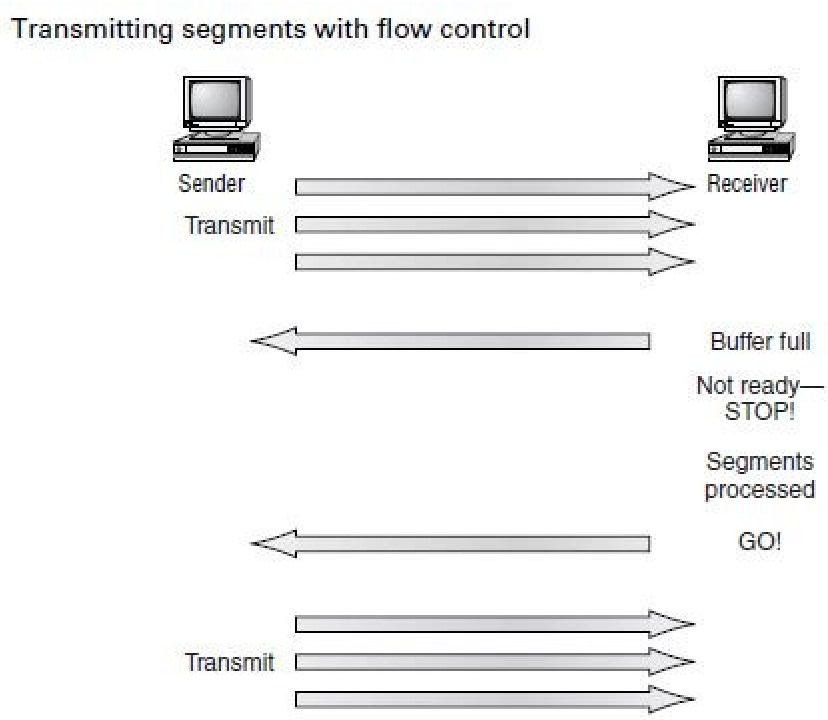

Establishing a connection-oriented session
Sender
Receiver
Synchronize
Negotiate connection
Synchronize
Acknowledge
Connection established
Data transfer
(Send segments)

Fig 1.5


Transmitting segments with flow control
Sender
Receiver
Transmit
Buffer full
Not ready—
STOP!
Segments
processed
GO!
Transmit

Windowing

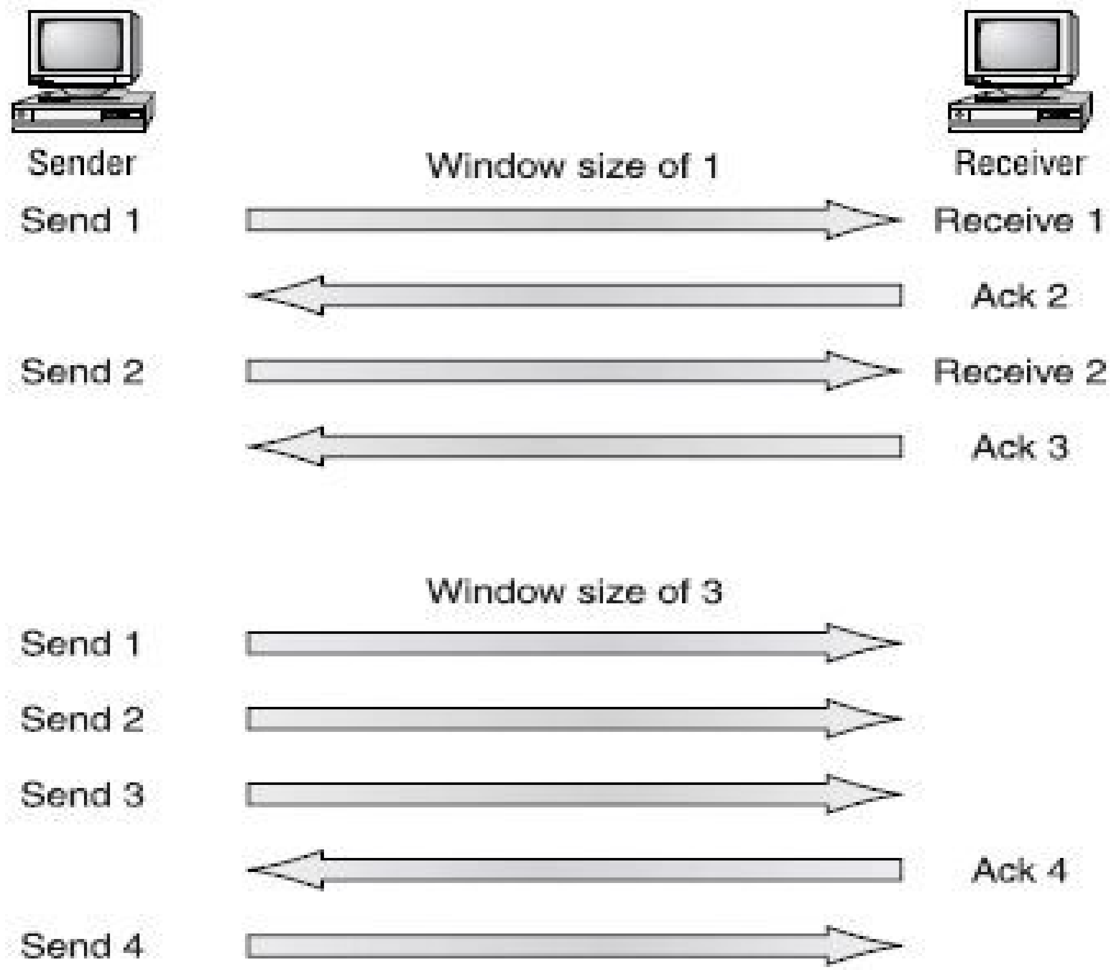
Data throughput would be low if the transmitting machine had to wait for an acknowledgment after sending each segment.

window

The quantity of data segments the transmitting machine is allowed to send without receiving an acknowledgment for them is called a window

If window size is 3, then sender is allowed to transmit three data segments before an acknowledgment is received.

Windowing


Sender
Receiver
Window size of 1
Send 1
Receive 1
Ack 2
Send 2
Receive 2
Ack 3
Window size of 3
Send 1
Send 2
Send 3
Ack 4
Send 4

Acknowledgments

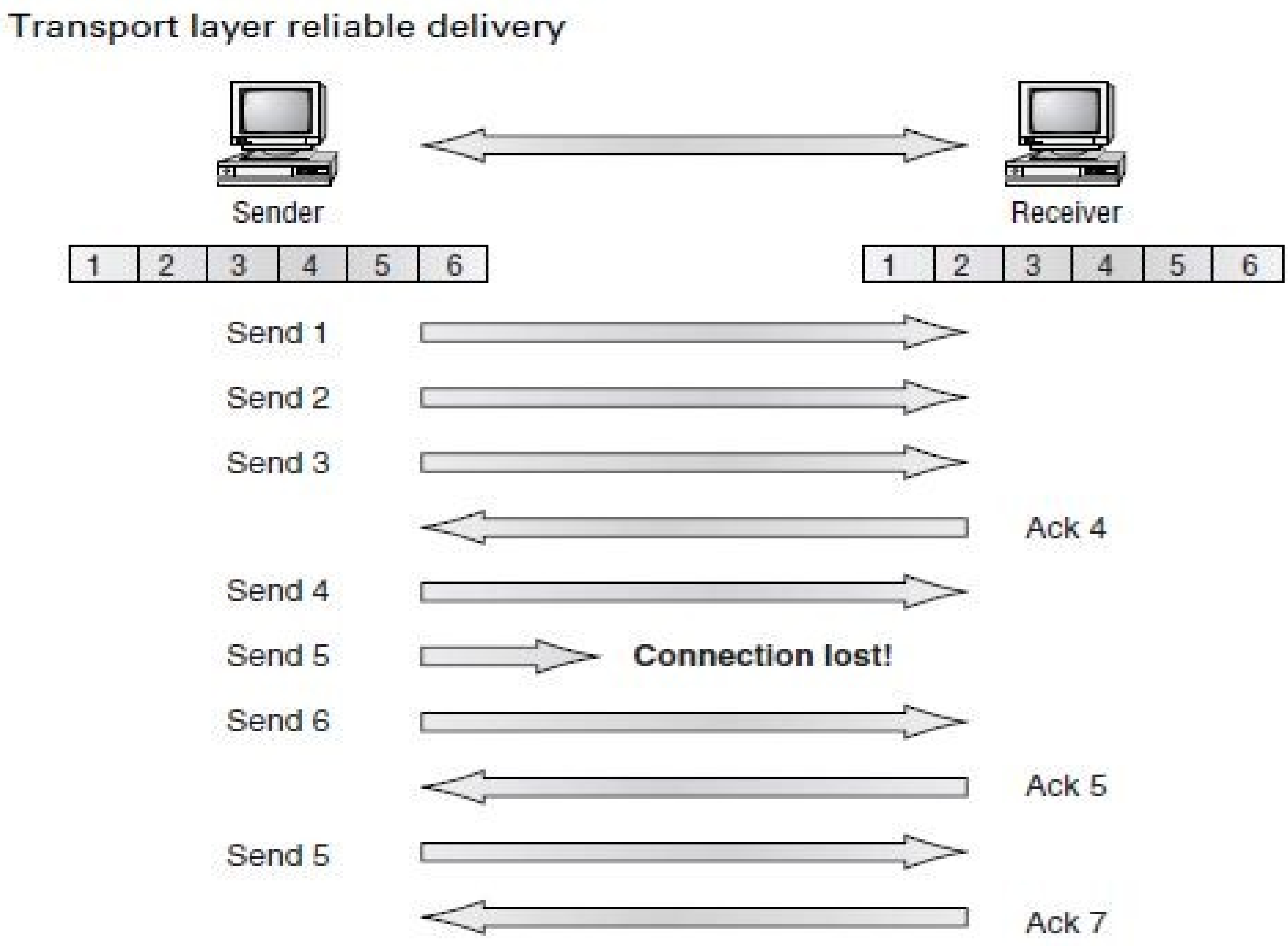
It guarantees the data won’t be duplicated or lost.

The method that achieves this is known as positive acknowledgment with retransmission.

This technique requires a receiving machine to communicate with the transmitting source by sending an acknowledgment message back to the sender when it receives data.

The sender documents each segment it sends and waits for this acknowledgment bfore sending the next segment

When it sends a segment, the transmitting machine starts a timer and retransmits if it expires before an acknowledgement is returned from the receiving end



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The Network Layer

The Network layer is responsible for routing and network addressing.

Routers, or other layer-3 devices, are specified at the Network layer and provide the routing services in an internetwork

Two types of packets are used at the network layer:

- Data packets
- Route updates packets.

Data packets

Are used to transport user data through the internetwork, and protocols used to support data traffic called routed protocols.

Examples of routed protocols are IP and IPX

Route update packets

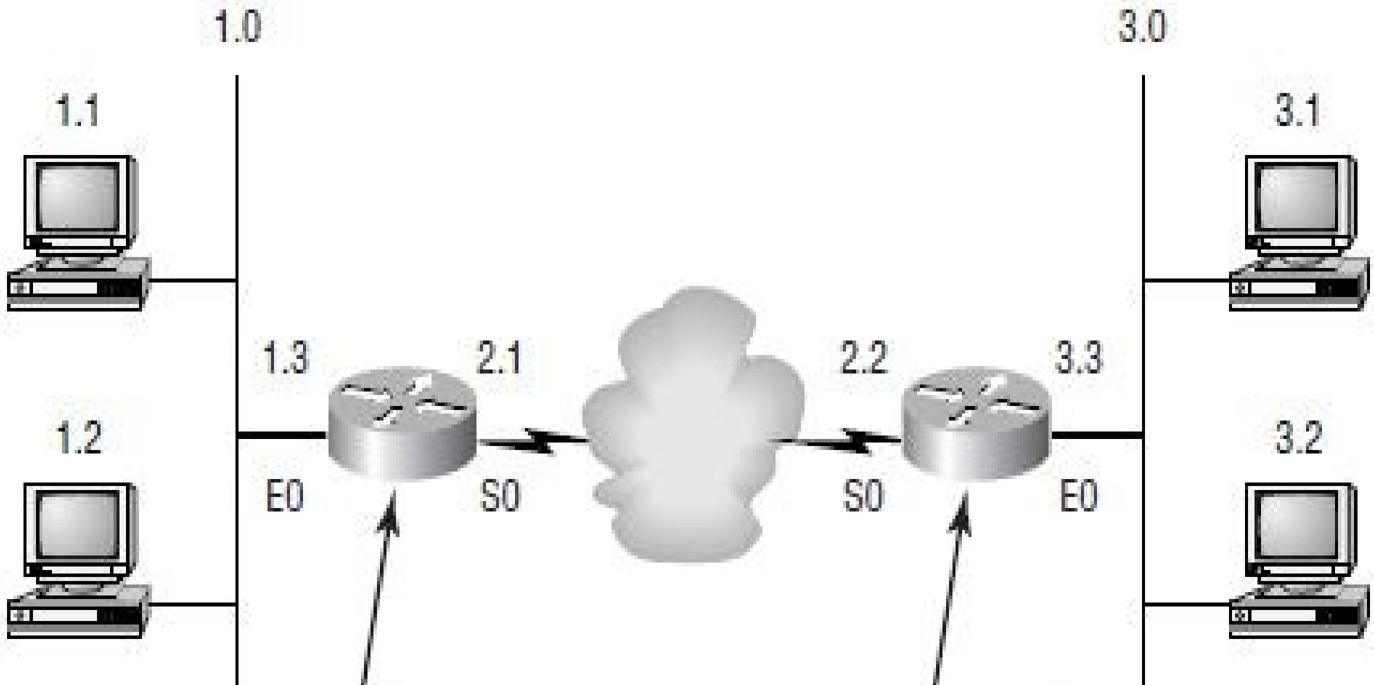
Are used to update neighbour routers about networks connected to routers in the internetwork.

Protocols that send route update packets are called routing protocols

Examples for routing protocols are RIP, IGRP, EIGRP, and OSPF.

Routing update packets are used to build and maintain routing tables on each router

Routing table used in a router



Routing Table		
NET	INT	Metric
1	E0	0
2	S0	0
3	S0	1

Routing Table		
NET	INT	Metric
1	S0	1
2	S0	0
3	E0	0

The Data Link Layer

The Data Link layer ensures that messages are delivered to the proper device and translates messages from the Network layer into bits for the Physical layer to transmit.

The Data Link Layer..

It formats the message into data frames and adds a customized header containing the hardware destination and source address.

The Data Link Layer..

The Data Link layer is responsible for uniquely identifying each device on a local network by hardware addressing.

The framing of the packet continues for each hop until the packet is finally delivered to the receiving host

The IEEE Ethernet Data Link layer has two sublayers:

- Media Access Control (MAC) 802.3
- Logical Link Control (LLC) 802.2

Media Access Control (MAC)

This defines how packets are placed on the media.

There are three types of media access methods:

- contention (Ethernet),
- token passing (Token Ring and FDDI),
- polling (IBM Mainframes).

Media Access Control (MAC)

Physical addressing is defined here, as well as logical topologies.

Logical topology is the signal path through a physical topology.

Media Access Control (MAC)

Line discipline, error notification (not correction), ordered delivery of frames, and optional flow control can also be used at this sublayer.

Logical Link Control (LLC) 802.2

This sublayer is responsible for identifying Network layer protocols and then encapsulating them.

An LLC header tells the Data Link layer what to do with a packet once a frame is received.

Logical Link Control (LLC) 802.2

The LLC can also provide flow control and sequencing of control bits

Switches & Bridges

Both Work at the Data Link Layer

Filter the network using hardware (MAC) addresses

Switches & Bridges..

Bridges and switches read each frame as it passes through the network.

Then puts the source hardware address in a filter table and keeps track of which port it was received on

After a filter table is built on the layer-2 device, the device will only forward frames to the segment where the destination hardware address is located

Switches & Bridges..

If the destination device is on the same segment as the frame, the layer-2 device will block the frame from going to any other segments.

Switches & Bridges..

If the destination is on another segment, the frame is only transmitted to that segment.

This is called transparent bridging.

Benefit of Switch against Hub

Each switch port has its own collision domain, whereas a hub creates one large collision domain

Benefit of Switch against Hub

Each device on every segment plugged into a switch can transmit simultaneously because each segment is its own collision domain

Hubs allow only one device per network to communicate at a time

However, switches and bridges do not break up broadcast domains, instead forwarding all broadcasts

Switches cannot translate between different media types

One would need a router to provide the translation services.

The Physical Layer

The Physical layer communicates directly with the various types of actual communication media

Different kinds of media represent these bit values in different ways

The Physical Layer

Physical layer specifications specify the electrical, mechanical, procedural, and functional requirements for activating, maintaining, and deactivating a physical link between end systems.

The Physical Layer

Specific protocols are needed for each type of media to describe the proper bit patterns to be used,how data is encoded into media signals, and the various qualities of the physical media's attachment interface.

The Physical Layer

At the Physical layer, the interface between the Data Terminal Equipment, or DTE, and the Data Circuit-Terminating Equipment, or DCE, is identified.

The Physical Layer

The services available to the DTE are most often accessed via a modem or Channel Service Unit/Data Service Unit (CSU/DSU)

The Physical Layer

The Physical layer's connectors and different physical topologies are defined by the OSI as standards

Hubs at the Physical Layer

Hub is a multiple port repeaters

A repeater receives a digital signal and re-amplifies it or regenerates the digital signal, then forwards the digital signal out all active ports without looking at any data

Any digital signal received from a segment on a hub port is regenerated or re-amplified and transmitted out all ports on the hub

All devices plugged into a hub are in the same collision domain as well as in the same broadcast domain

Broadcast Domain

A broadcast domain is defined as all devices on a network segment that hear all broadcasts sent on that segment

Hubs create a physical star network where the hub is a central device and cables extend in all directions, creating the physical star effect

However, Ethernet networks use a logical bus topology

Ethernet Networking

Ethernet is a contention media access method that allows all hosts on a network to share the same bandwidth of a link

Ethernet Networking

Ethernet uses the Data Link and Physical layer specifications

Ethernet Networking

Ethernet networking uses Carrier Sense Multiple Access with Collision Detect (CSMA/CD) protocol

Ethernet Networking

when a node transmits in a CSMA/CD network, all the other nodes on the network receive and examine that transmission

Ethernet Networking

Only bridges and routers effectively prevent a transmission from propagating through the entire network

CSMA/CD protocol working

When a host wants to transmit over the network, it first checks for the presence of a digital signal on the wire.

If all is clear (no other host is transmitting), the host will then proceed with its transmission

CSMA/CD protocol working..

The transmitting host constantly monitors the wire to make sure no other hosts begin transmitting

CSMA/CD protocol working..

If the host detects another signal on the wire, it sends out an extended jam signal that causes all nodes on the segment to stop sending data

CSMA/CD protocol working..

The nodes respond to that jam signal by waiting a while before attempting to transmit again

Half- Duplex Ethernet

Half-duplex Ethernet is defined in the original 802.3 Ethernet and uses only one wire pair with a digital signal running in both directions on the wire

Full-duplex Ethernet

Full-duplex Ethernet uses two pairs of wires

Uses a point-to-point connection between the transmitter of the transmitting device and the receiver of the receiving device

Full-duplex Ethernet

Full Duplex Ethernet is supposed to offer 100 percent efficiency in both directions.

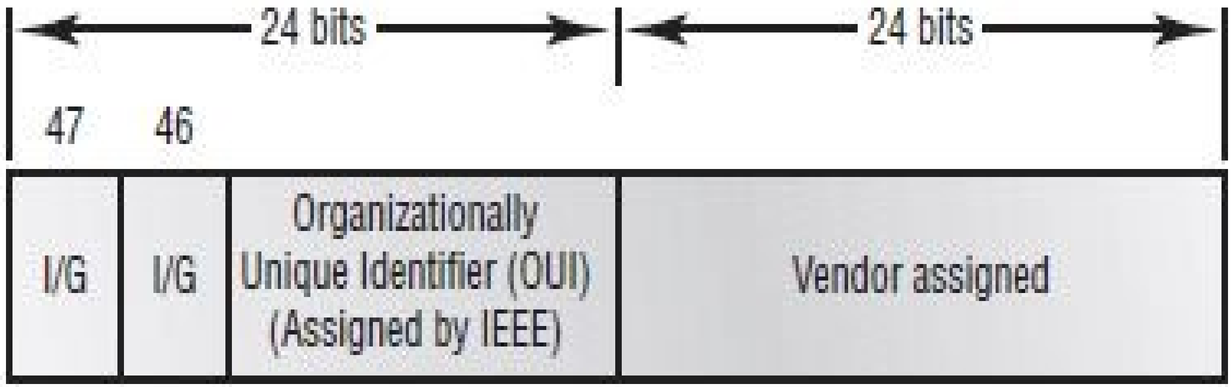
This means that you can get 20Mbps with a 10Mbps Ethernet running full duplex

Ethernet Addressing

Ethernet addressing uses the Media Access Control (MAC) address burned into each and every Ethernet Network Interface Card (NIC)

The MAC address, sometimes referred to as a hardware address, is a 48-bit address.

Ethernet addressing using MAC addresses



Ethernet Addressing

The Organizationally Unique Identifier (OUI) is assigned by the IEEE to an organization (24 bits or 3 bytes)

Ethernet Frames

The Data Link layer is responsible for combining bits into bytes and bytes into frames

Ethernet Frames

Frames are used at the Data Link layer to encapsulate packets handed down from the Network layer for transmission on a type of media access

802.3 and Ethernet frame formats

Ethernet_II

Preamble 8 bytes	DA 6 bytes	SA 6 bytes	Type 2 bytes	Data	FCS 4 bytes

802.3_Ethernet

Preamble 8 bytes	DA 6 bytes	SA 6 bytes	Length 2 bytes	Data	FCS

Preamble

An 8 Bytes alternating 1,0 pattern.

Provides a 5MHz clock at the start of each packet, which allows the receiving devices to lock the incoming bit stream.

Destination Address (DA)

DA is used by receiving stations to determine if an incoming packet is addressed to a particular node

6 Bytes size

The destination address can be an individual address, or a broadcast or multicast MAC address

Source Address (SA)

SA is a 48-bit MAC address supplied by the trans mitting device

Length or Type field

Ethernet frame uses a type field to identify the Network layer protocol

Data

This is a packet sent down to the Data Link layer from the Network layer.

The size can vary from 46–1500 Bytes

Frame Check Sequence (FCS)

FCS is a field at the end of the frame that is used to store the cyclic redundancy check (CRC)

Ethernet at the Physical Layer

Ethernet uses a bus topology which means that whenever a device transmits, the signal must run from one end of the segment to the other

Ethernet also defined baseband technology, which means that when a station does transmit, it will use the entire bandwidth on the wire and will not share it

IEEE 802.3 standards

10Base2

10Base5

10BaseT

10Base2

10Mbps, baseband technology, up to 185 meters in length.

Known as ***thinnet*** and can support up to 30 workstations on a single segment.

10Base5

- 10Mbps, baseband technology, up to 500 meters in length.
- Known as ***thicknet***

10BaseT

10Mbps using category-3 twisted-pair wiring.

Each device must connect into a hub or switch, and you can only have one host per segment or wire.

Each of the 802.3 standards defines an Attachment Unit Interface (AUI)

It allows a one-bit-at-a-time transfer to the Physical layer from the Data Link media access method

AUI interface cannot support 100Mbps Ethernet because of the high frequencies involved

Media Independent Interface (MII) provides 100Mbps throughput for 100BaseT.

The MII uses a nibble, which is defined as four bits

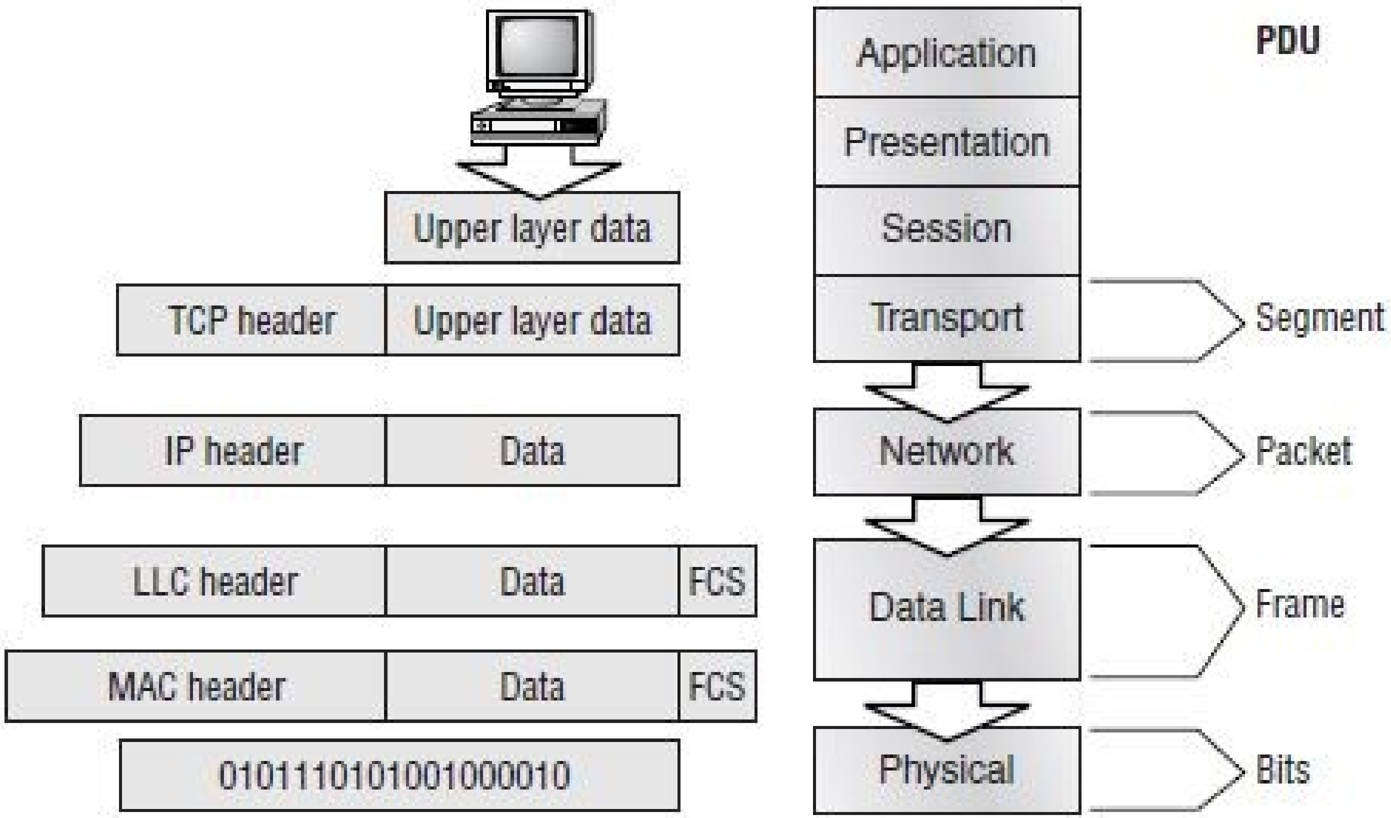
Gigabit Ethernet uses a Gigabit Media Independent Interface (GMII), which is eight bits at a time

Data Encapsulation

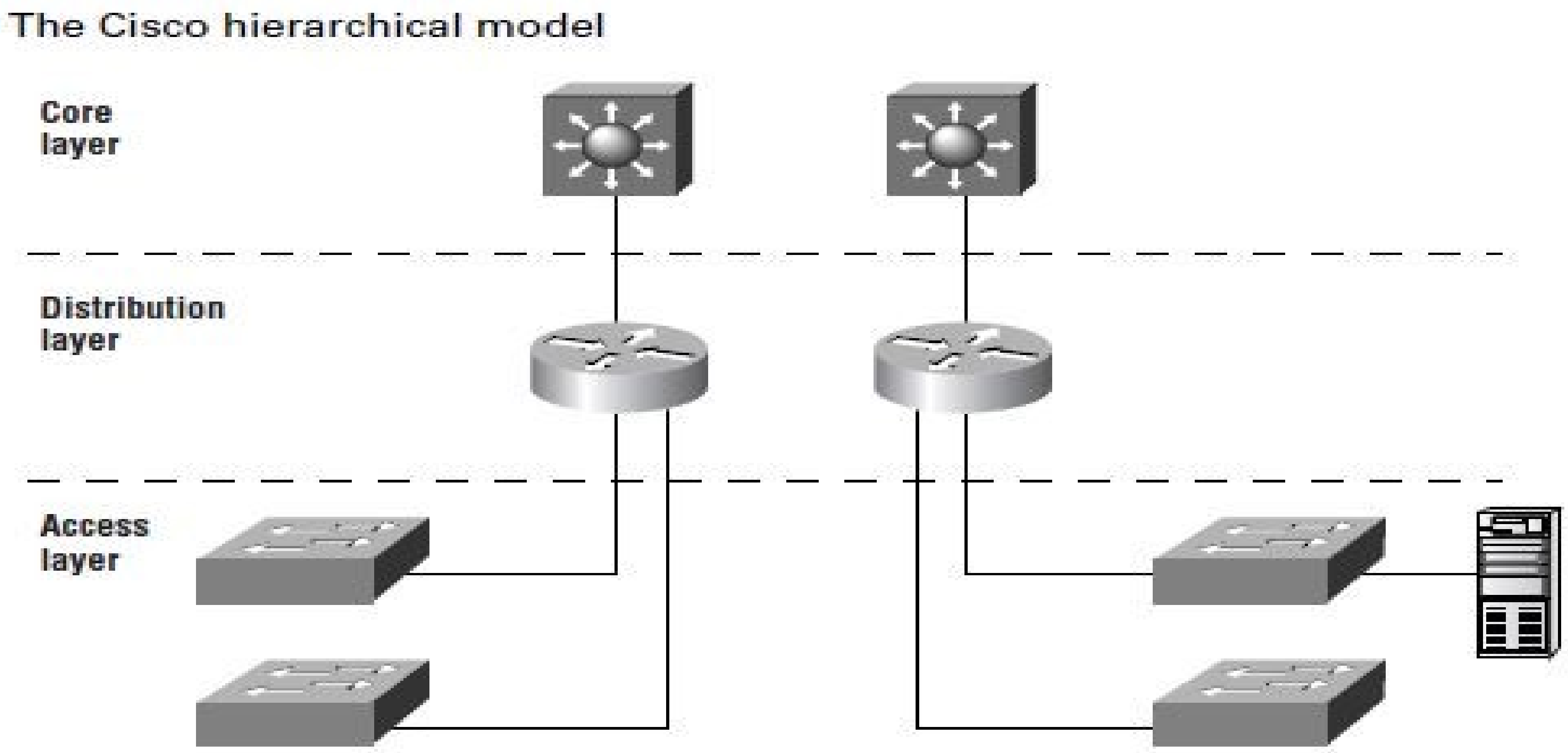
To communicate and exchange information, each layer uses what are called Protocol Data Units (PDUs).

PDU hold the control information attached to the data at each layer of the model

Data encapsulation



Cisco Three-Layer Hierarchical Model



Three layers

The Core layer

The Distribution layer

The Access layer

The Core layer

At the top of the hierarchy, the core layer is responsible for transporting large amounts of traffic both reliably and quickly.

The Core layer

The traffic transported across the core is common to a majority of users

User data is processed at the distribution layer, and forwards the requests to the core only if needed

If there is a failure in the core, every single user can be affected

The core is likely to see large volumes of traffic, so speed and latency are driving concerns here

things we don’t want to do at core

Using access lists, routing between virtual local area networks (VLANs), and packet filtering.

things we don’t want to do at core

Don’t support workgroup access here.

Avoid expanding the core when the internetwork grows (i.e., adding routers)

things that we want to do at core

Design the core for high reliability.

Consider data-link technologies that facilitate both speed and redundancy, such as FDDI, Fast Ether- net (with redundant links), or even ATM.

Design with speed in mind. The core should have very little latency

Select routing protocols with lower convergence times

The Distribution Layer

The distribution layer is sometimes referred to as the workgroup layer and is the communication point between the access layer and the core.

Distribution Layer

The primary function of the distribution layer is to provide routing, filtering, and WAN access

Also to determine how packets can access the core, if needed

Distribution Layer

The distribution layer must determine the fastest way that network service requests are handled

For example, how a file request is forwarded to a server

Distribution Layer

After the distribution layer determines the best path, it forwards the request to the core layer.

The core layer then quickly transports the request to the correct service

Distribution Layer

The distribution layer is the place to implement policies for the network

should be done at distribution layer

Implementation of tools such as access lists, of packet filtering, and of queuing

Implementation of security and network policies, including address translation and firewalls

should be done at distribution layer

Redistribution between routing protocols, including static routing

Routing between VLANs and other workgroup support functions

Definitions of broadcast and multicast domains

The Access Layer

The access layer controls user and workgroup access to internetwork resources

The network resources most users need will be available locally.

The distribution layer handles any traffic for remote services.

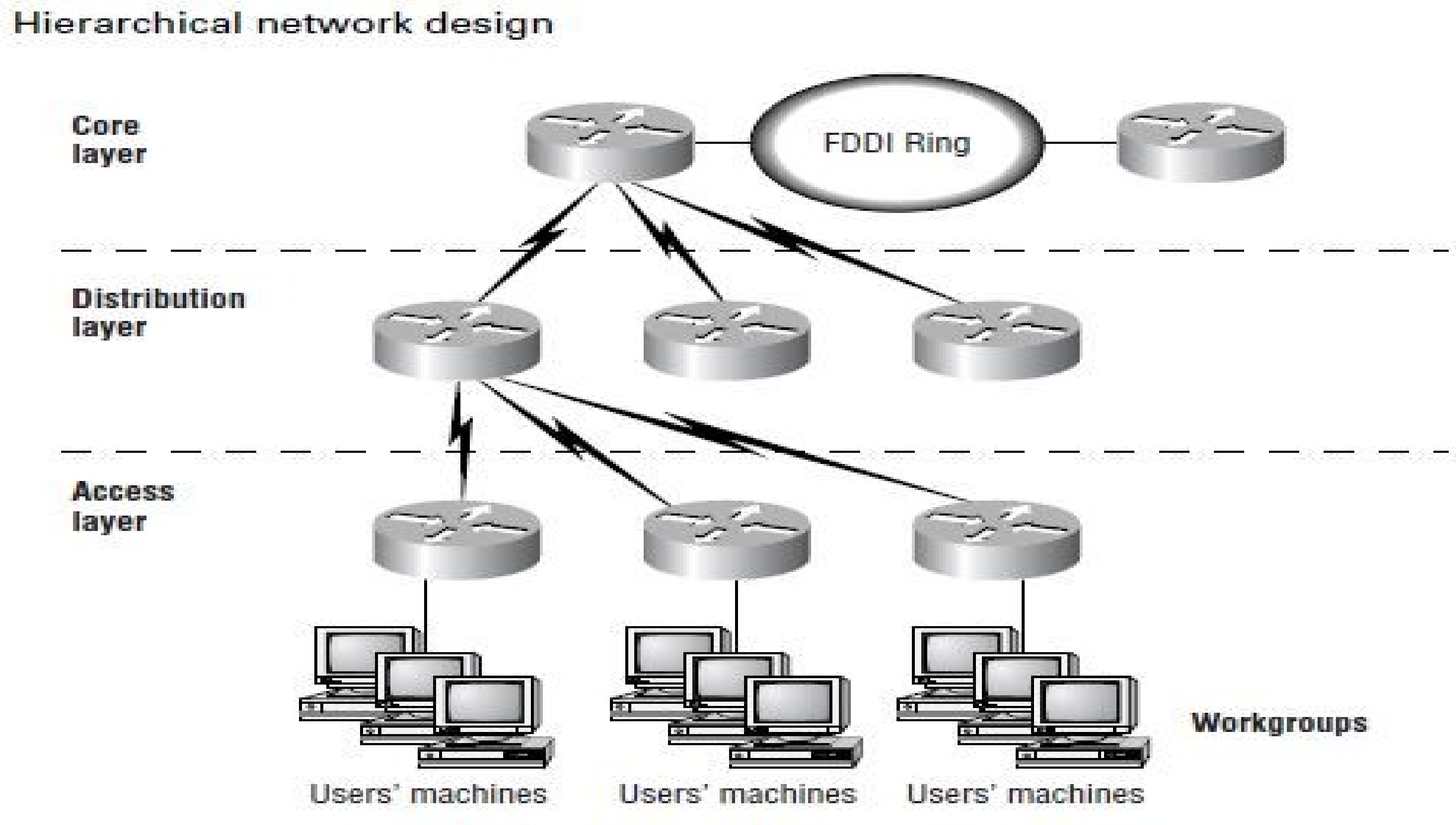
functions at access layer

Continued (from distribution layer) access control and policies

Creation of separate collision domains (segmentation)

Workgroup connectivity into the distribution layer

Technologies such as DDR and Ethernet switching are frequently seen in the access layer


Hierarchical network design
Core layer
FDDI Ring
Distribution layer
Access layer
Workgroups
Users' machines
Users' machines
Users' machines

Assembling and Cabling Cisco Devices

Use 10Mbps switches at the access layer to provide good performance at a low price.

100Mbps links can be used for high-bandwidth consuming clients or servers

Use FastEthernet between access layer and distribution layer switches.

10Mbps links would create a bottleneck

Use FastEthernet (or Gigabit if applicable) between distribution layer switches and the core

Dual links between distribution and core switches are recommended for redundancy and load balancing.

Ethernet Media and Connector

Ethernet was first implemented by a group called DIX

Ethernet use a registered jack (RJ) connector with a 4 5 wiring sequence on unshielded twisted-pair (UTP) cabling (RJ-45)

different Ethernet media

10Base2 50-ohm coax, called thinnet. Up to 185 meters and 30 hosts per segment

10Base5 50-ohm coax called thicknet. Up to 500 meters and 208 users per segment

10BaseT - using two-pair unshielded twisted-pair (UTP) wiring. One user per segment; up to 100 meters long.

Uses an RJ-45 connector with a physical star topology and a logical bus

100BaseTX - UTP two-pair wiring. One user per segment; up to 100 meters long.

Uses an RJ-45 connector with a physical star topology and a logical bus.

100BaseFX - Uses fiber cabling, multimode fiber. Point-to-point topology; up to 400 meters long.

Uses an ST or SC connector, which are duplex media-interface connectors

1000BaseCX - Copper shielded twisted-pair that can only run up to 25 meters.

1000BaseT - Category 5, four-pair UTP wiring up to 100 meters long

UTP Connections (RJ-45)

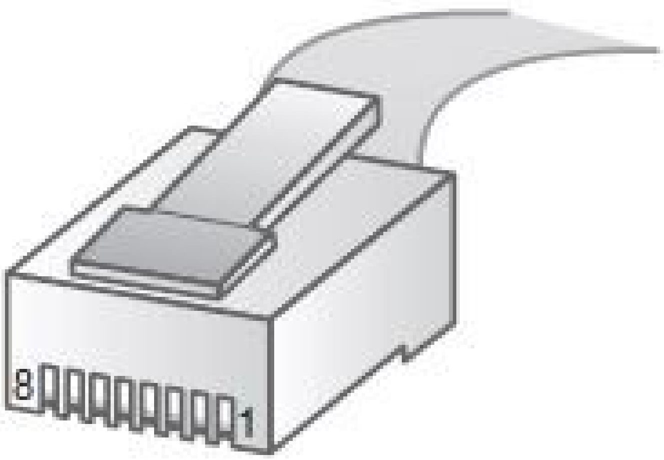
These wires are twisted into four pairs.

Four wires (two pairs) carry the voltage and are considered tip.

The other four wires are grounded and are called ring

UTP wire with an RJ-45 connector attached

Pin	Wire Pair (T Is Tip; R Is Ring)
1	Pair 2 T2
2	Pair 2 R2
3	Pair 3 T3
4	Pair 1 R1
5	Pair 1 T1
6	Pair 3 R3
7	Pair 4 T4
8	Pair 4 R4



RJ-45 connector

Different types of wiring

- Straight-Through
- Crossover

Straight-Through

In a UTP implementation of a straight-through cable, the wires on both cable ends are in the same order.

UTP straight-through pinouts

Hub/Switch

Server/Router

Pin	Label		Pin	Label
1	RD+	←	1	TD+
2	RD–	←	2	TD–
3	TD+	→	3	RD+
4	NC		4	NC
5	NC		5	NC
6	TD–	→	6	RD–
7	NC		7	NC
8	NC		8	NC

use of straight-through cable

Connecting a router to a hub or switch

Connecting a server to a hub or switch

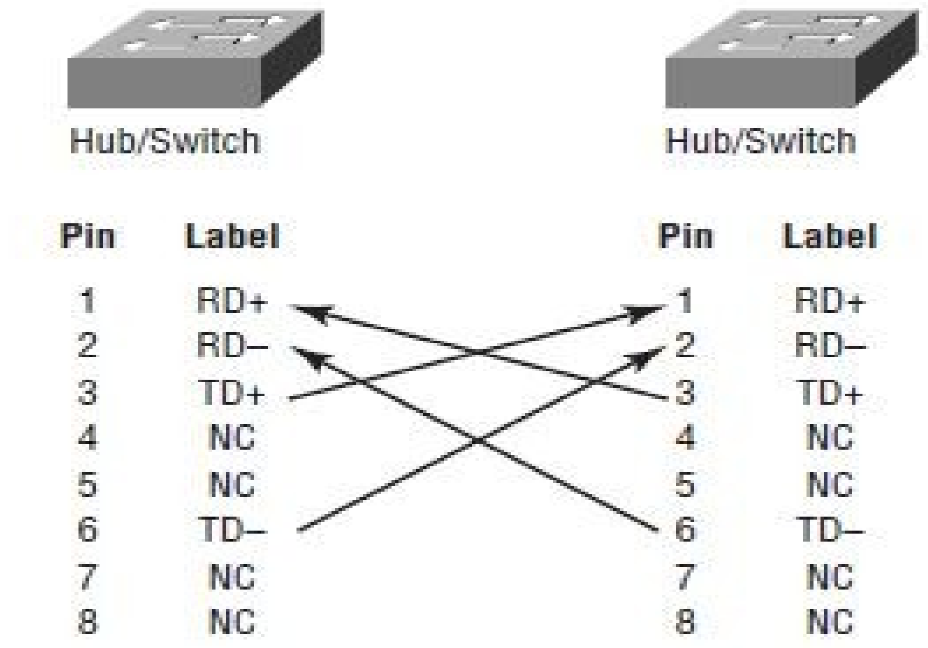
Connecting workstations to a hub or switch

Crossover

Wires on each end of the cable are crossed.

Transmit to Receive and Receive to Transmit on each side, for both tip and ring.

UTP crossover implementation



use a crossover cable for

Connecting uplinks between switches

Connecting hubs to switches

Connecting a hub to another hub

Connecting a router interface to another router interface

Connecting two PCs together without a hub or switch

Cabling the Wide Area Network

Cisco serial connections support almost any type of WAN service.

The typical WAN connections are dedicated leased lines using High-Level Data Link Control (HDLC), Point-to-Point Protocol (PPP), Integrated Services Digital Network (ISDN), and Frame Relay

Serial Transmission

WAN serial connectors use serial transmission, which is one bit at a time, over a single channel.

Parallel transmission can pass at least 8 bits at a time

Cisco routers use a proprietary 60-pin serial connector, which you must buy from Cisco or a provider of Cisco equipment

Serial links are described in frequency or cycles-per-second (hertz).

The amount of data that can be carried within these frequencies is called bandwidth

Bandwidth is the amount of data in bits-per-second that the serial channel can carry

DTE & DCE

- Data Terminal Equipment
- Data Communication Equipment

Router interfaces are, by default, Data Terminal Equipment (DTE) and connect into Data Communication Equipment (DCE), for example, a Channel Service Unit/Data Service Unit (CSU/DSU).

The idea behind a WAN is to be able to connect two DTE networks together through a DCE network.

The DCE network includes the CSU/DSU, through the provider’s wiring and switches, all the way to the CSU/DSU at the other end.

Console Connections

All Cisco devices are shipped with console cables and connectors, which allow you to connect to a device and configure, verify, and monitor it.

The cable used to connect between a PC is a rollover cable with RJ-45 connectors

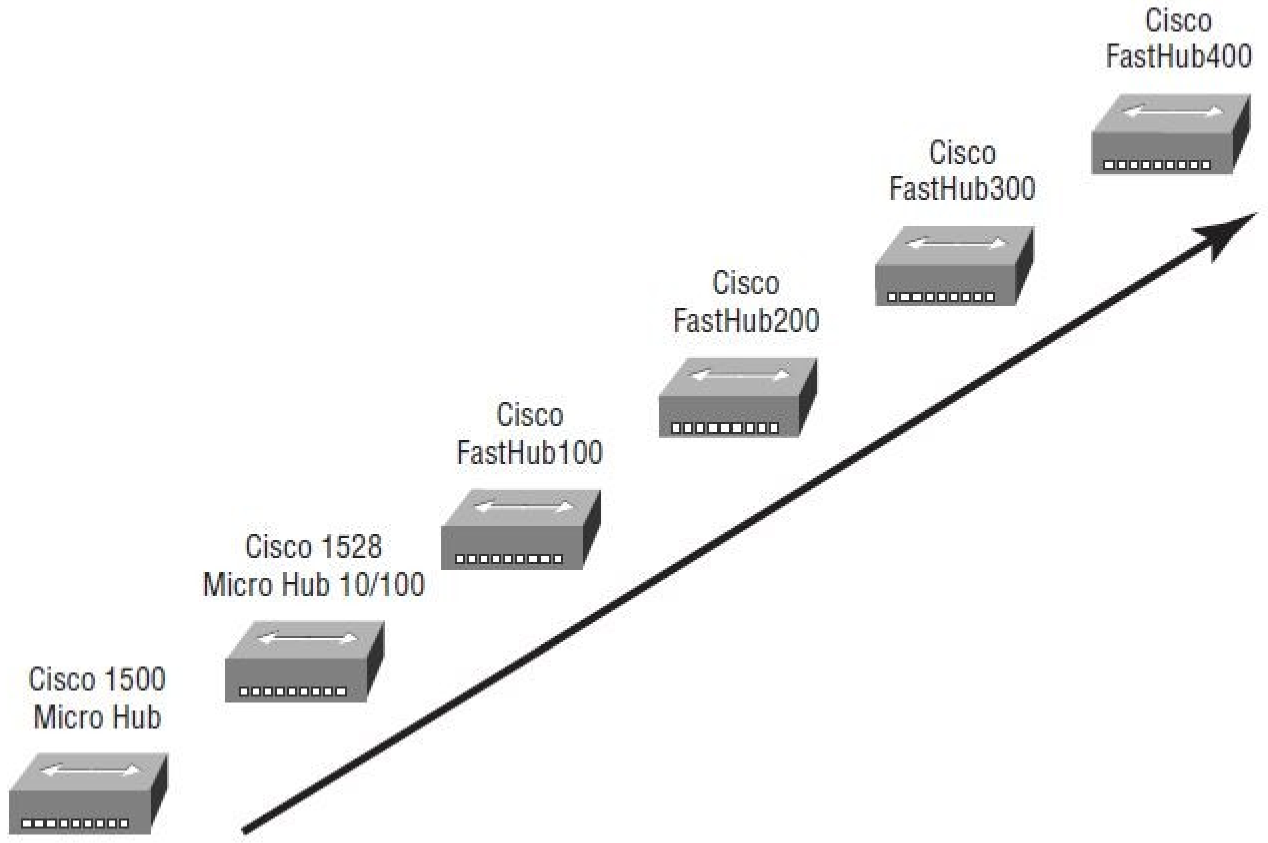
Cisco Products

Cisco Hubs

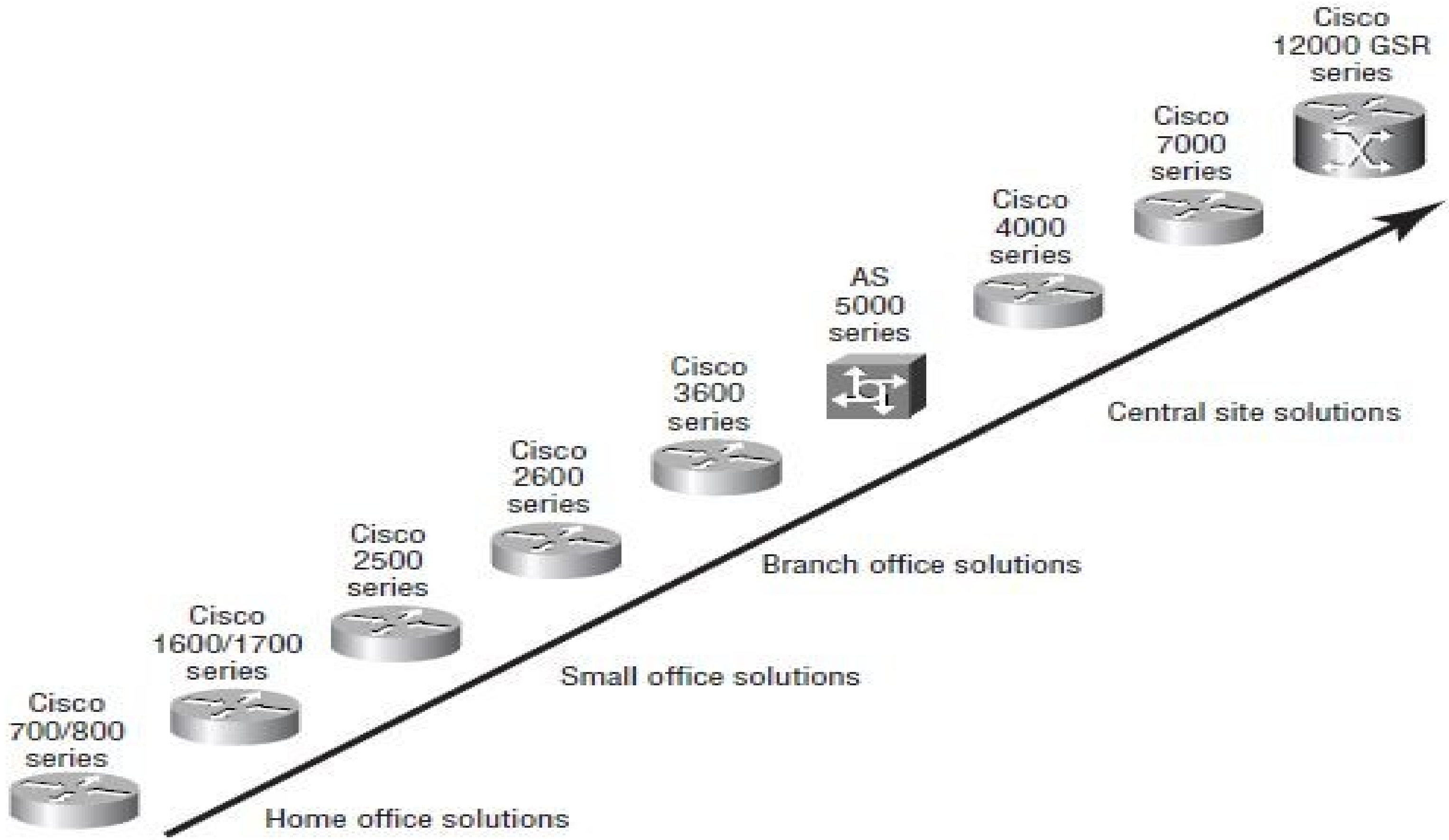
Cisco Routers

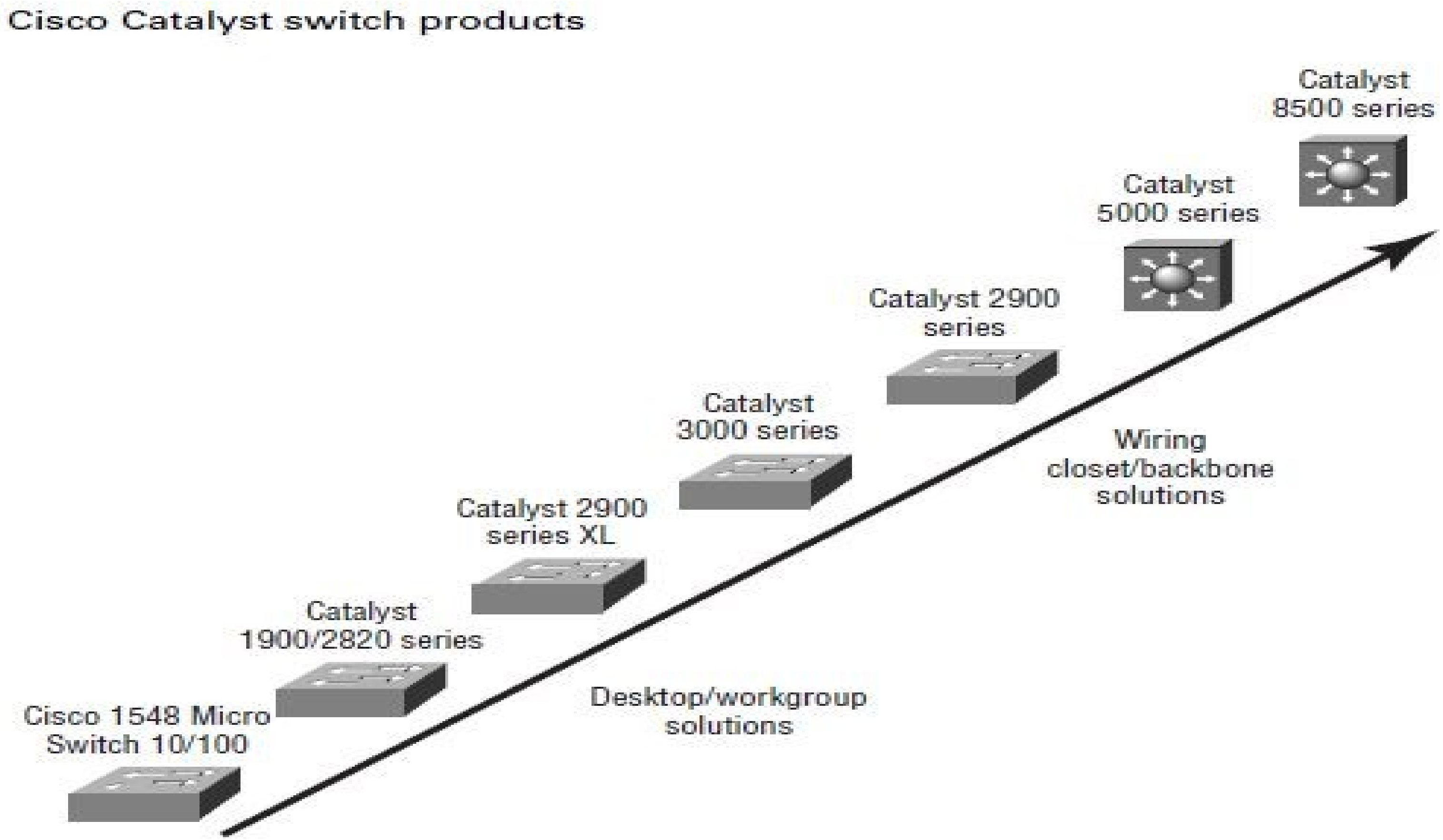
Cisco Switches

Cisco hub products



Cisco router products




Cisco Catalyst switch products
Catalyst 8500 series
Catalyst 5000 series
Catalyst 2900 series
Catalyst 3000 series
Catalyst 2900 series XL
Catalyst 1900/2820 series
Cisco 1548 Micro Switch 10/100
Wiring closet/backbone solutions
Desktop/workgroup solutions

Key Terms

Before taking the exam, be sure you're familiar with the following terms.

- *access layer*
- *Application layer*
- *Application-Specific Integrated Circuits (ASICs)*
- *Basic Rate Interface (BRI)*
- *bridges*
- *broadcast domain*
- *buffer*
- *Carrier Sense Multiple Access with Collision Detect (CSMA/CD)*
- *Channel Service Unit/Data Service Unit (CSU/DSU)*
- *core layer*
- *Data Communication Equipment (DCE)*
- *data frame*
- *Data Link layer*
- *Data Terminal Equipment (DTE)*
- *distribution layer*
- *encapsulation*
- *Ethernet*
- *flow control*

frame

full duplex

half duplex

hierarchical addressing

hubs

Integrated Services Digital Network (ISDN)

layered architecture

Media Access Control (MAC) address

Network layer

Organizationally Unique Identifier (OUI)

OSI (Open Systems Interconnection) model

Physical layer

Presentation layer

Protocol Data Units (PDUs)

registered jack (RJ) connector

router

Session layer

simplex

state transitions

switch

thicknet

thinnet

Transport layer

unshielded twisted-pair (UTP)

wide area network (WAN)

windowing

Assignments