Departament d'Arquitectura de Computadors

Facultat d' informàtica de Barcelona

Capítol 1

El paquet IP a les Xarxes de Computadors

1.1 Model de Xarxa Internet

1.2 Model arquitectònic de Internet

Book: Data and Computer Communications, Tenth Edition by William Stallings, (c) Pearson Education - Prentice Hall, 2014. Cap 1 I 2

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Book: Computer Networking: A Top Down Approach, Seventh Edition by KUROSE James F. and ROSS Keith W. , 2017 Cap. 1

Tecnologies de Xarxes de Computadors (TXC)

Consultar llibre Stallings capítol 1 i 2, llibre Kurose Cap. 1.5

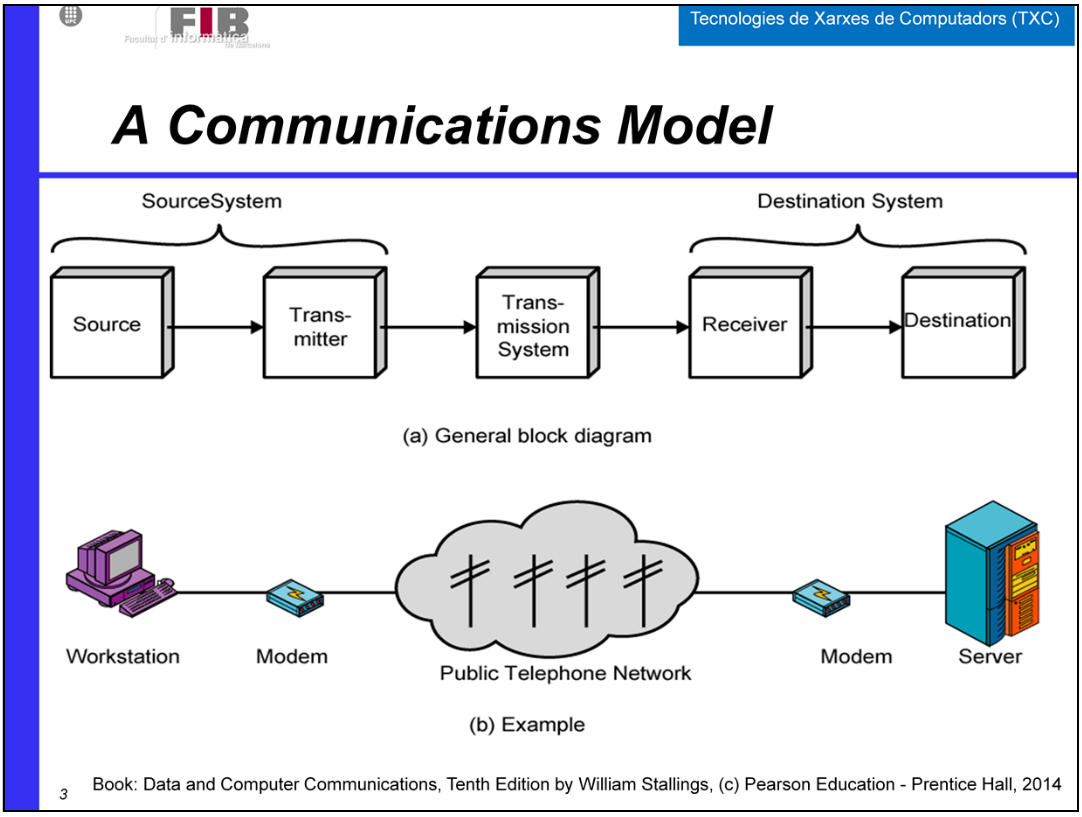
Departament d'Arquitectura de Computadors

1.1 Model de xarxa Internet

2

Tecnologies de Xarxes de Computadors (TXC)

Consultar llibre Stallings capítol 1, llibre Kurose Cap. 1.5



The fundamental purpose of a communications system is the exchange of data between two parties. Figure 1.3b presents one particular example, which is communication between a workstation and a server over a public telephone network. Another example is the exchange of voice signals between two telephones over the same network. The following are key elements of the model:

• Source: This device generates the data to be transmitted; examples are telephones and personal computers. • Transmitter: Usually, the data generated by a source system are not transmitted directly in the form in which they were generated. Rather, a transmitter transforms and encodes the information in such a way as to produce electromagnetic signals that can be transmitted across some sort of transmission system. For example, a modem takes a digital bit stream from an attached device such as a personal computer and transforms that bit stream into an analog signal that can be handled by the telephone network. • Receiver: The receiver accepts the signal from the transmission system and converts it into a form that can be handled by the destination device. For example, a modem will accept an analog signal coming from a network or transmission line and convert it into a digital bit stream. • Destination: Takes the incoming data from the receiver and • Transmission system: This can be a single transmission line or a complex network connecting source and destination.

Data Communications Model

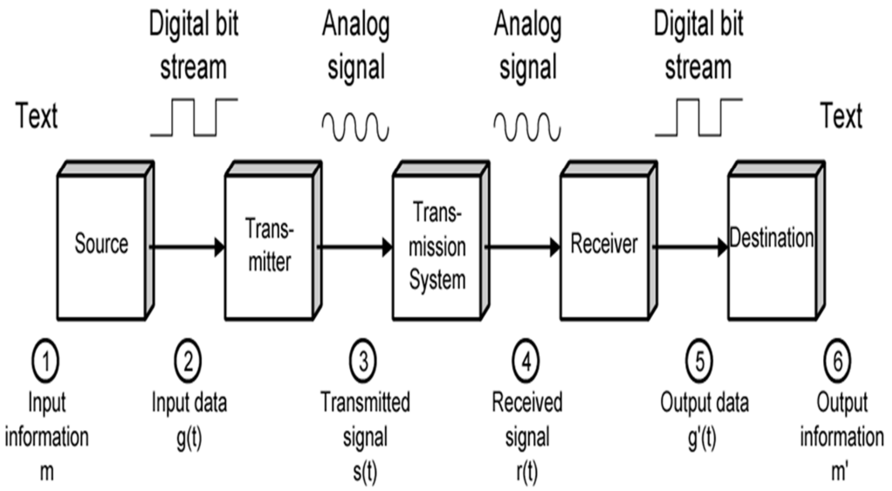


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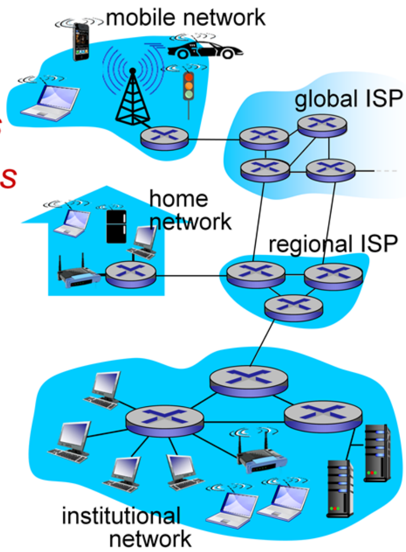
Figure 1.4 provides a new perspective on the communications model of Figure 1.3a. We trace the details of this figure using electronic mail as an example.

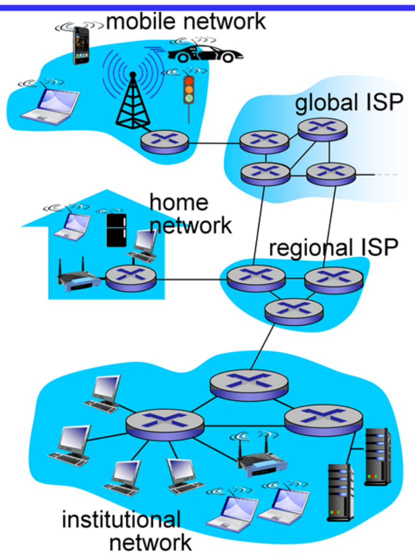
What's the Internet: "nuts and bolts" view

- billions of connected computing devices:
  - *hosts* = *end systems*
  - running *network apps*
- *communication links*
  - fiber, copper, radio, satellite
  - transmission rate: *bandwidth*
- *packet switches:* forward packets (chunks of data)
  - *routers* and *switches*



What's the Internet: "nuts and bolts" view

- *Internet:* "network of networks"
  - Interconnected ISPs
- *protocols* control sending, receiving of messages
  - e.g., TCP, IP, HTTP, Skype, 802.11
- *Internet standards*
  - RFC: Request for comments
  - IETF: Internet Engineering Task Force



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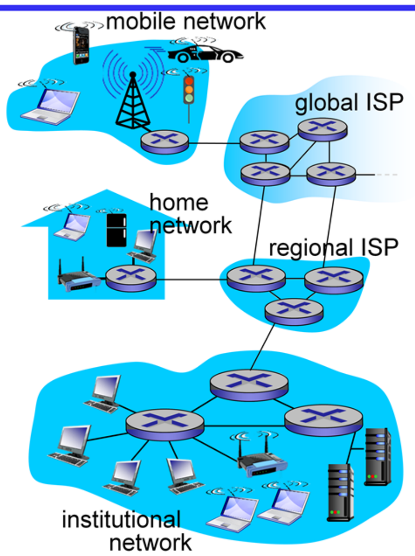
What's the Internet: a service view

- *infrastructure that provides services to applications:*
  - Web, VoIP, email, games, e-commerce, social nets, …
- *provides programming interface to apps*
  - hooks that allow sending and receiving app programs to "connect" to Internet
  - provides service options, analogous to postal service



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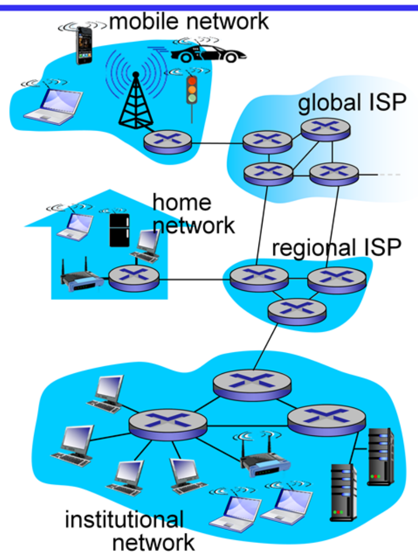
A closer look at network structure:

- *network edge:*
  - hosts: clients and servers
  - servers often in data centers
- *access networks, physical media:* wired, wireless communication links
- *network core:*
  - interconnected routers
  - network of networks



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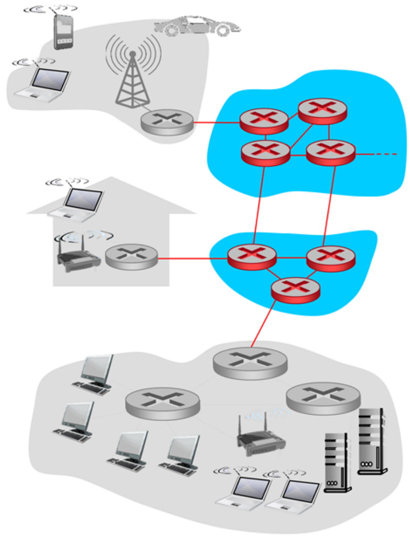
The network core

- mesh of interconnected routers
- packet-switching: hosts break application-layer messages into *packets*
  - forward packets from one router to the next, across links on path from source to destination
  - each packet transmitted at full link capacity



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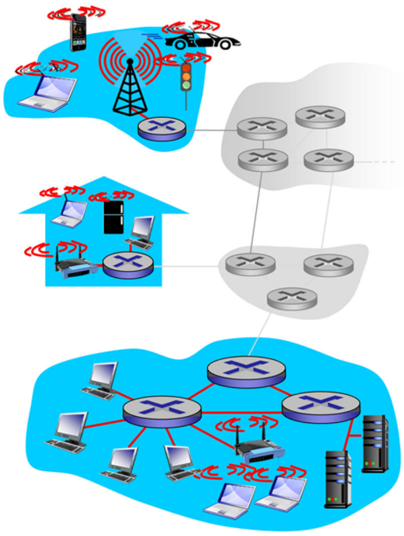
Access networks and physical media

Q: How to connect end systems to edge router?

- residential access nets
- institutional access networks (school, company)
- mobile access networks

keep in mind:

- bandwidth (bits per second) of access network?
- shared or dedicated?



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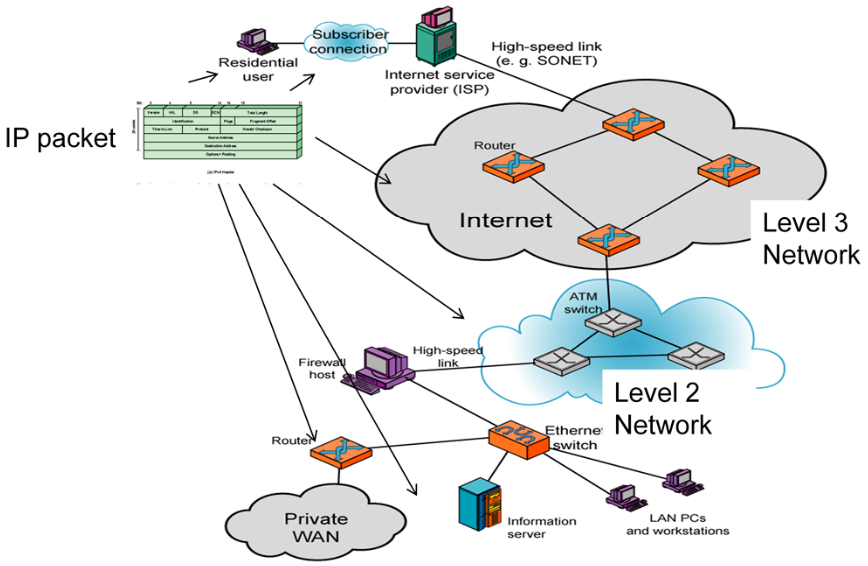
Example Configuration



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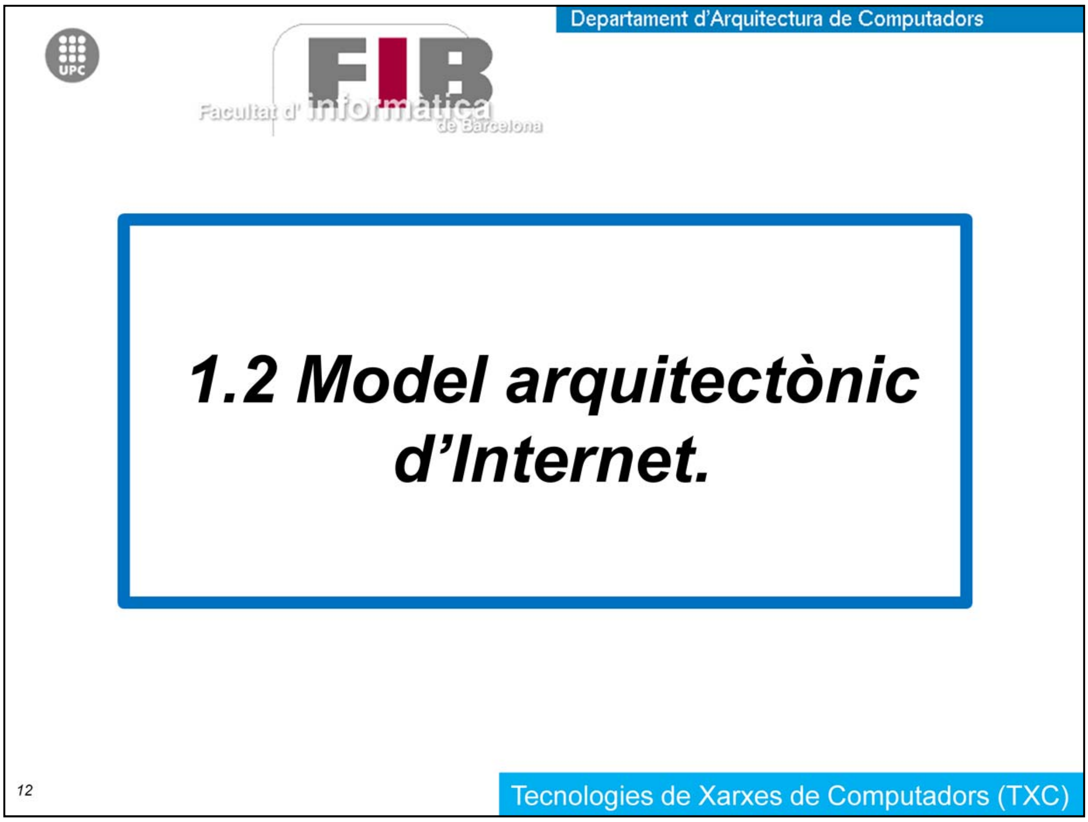
La figura il·lustra algunes de les comunicacions típics i elements de xarxa en ús avui en dia a Internet. A la part superior esquerra de la figura, veiem monousuari residencial connectat a un proveïdor de serveis d'Internet (ISP) a través d'algun tipus de connexió d'abonat. La Internet es compon d'un nombre d'encaminadors interconnectats que abasten tot el món. Els routers transmeten paquets de dades des de l'origen a la destinació a través d'Internet. La part inferior mostra una LAN implementat usant un únic commutador Ethernet. Això, que és comú en una petita empresa o una organització petita.



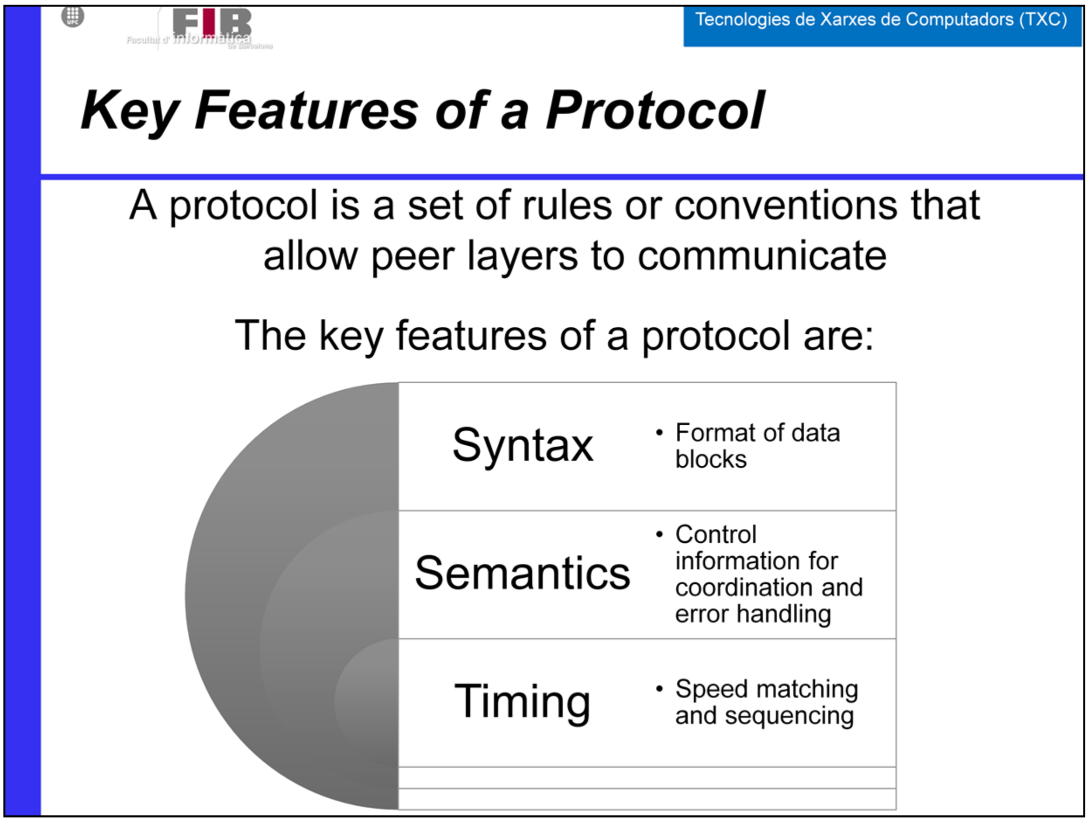
Model OSI d'interconnexió de sistemes oberts. Consultar el llibre Stallings en el capítol 2.

Tecnologies de Xarxes de Computadors (TXC)

Functions of Protocol Architecture

- Breaks logic into subtask modules which are implemented separately
- Modules are arranged in a vertical stack
  - *Each layer in the stack performs a subset of functions*
  - *Relies on next lower layer for primitive functions*
  - *Provides services to the next higher layer*
  - *Changes in one layer should not require changes in other layers*

It is clear that there must be a high degree of cooperation between the two computer systems. Instead of implementing the logic for this as a single module, the task is broken up into subtasks, each of which is implemented separately. In a protocol architecture, the modules are arranged in a vertical stack. Each layer in the stack performs a related subset of the functions required to communicate with another system. It relies on the next lower layer to perform more primitive functions and to conceal the details of those functions. It provides services to the next higher layer. Ideally, layers should be defined so that changes in one layer do not require changes in other layers.



Of course, it takes two to communicate, so the same set of layered functions

must exist in two systems. Communication is achieved by having the corresponding,

or peer , layers in two systems communicate. The peer layers communicate by

means of formatted blocks of data that obey a set of rules or conventions known as

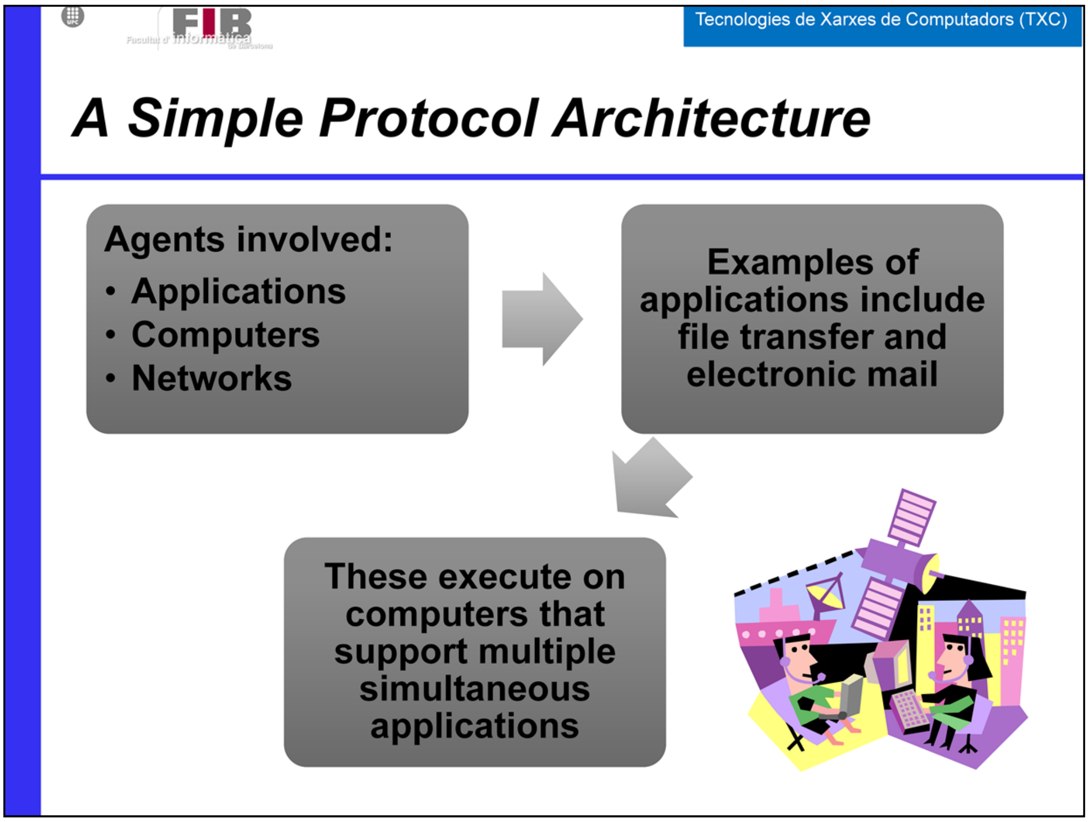
a protocol .

The key features of a protocol are as follows:

• Syntax : Concerns the format of the data blocks

• Semantics : Includes control information for coordination and error handling

• Timing : Includes speed matching and sequencing



In very general terms, distributed data communications can be said to involve three agents: applications, computers, and networks. Examples of applications include file transfer and electronic mail. These applications execute on computers that typically support multiple simultaneous applications. Computers are connected to networks, and the data to be exchanged are transferred by the network from one computer to another. Thus, the transfer of data from one application to another involves first getting the data to the computer in which the application resides and then getting it to the intended application within the computer.

Tecnologies de Xarxes de Computadors (TXC)

Protocol Architecture and Networks

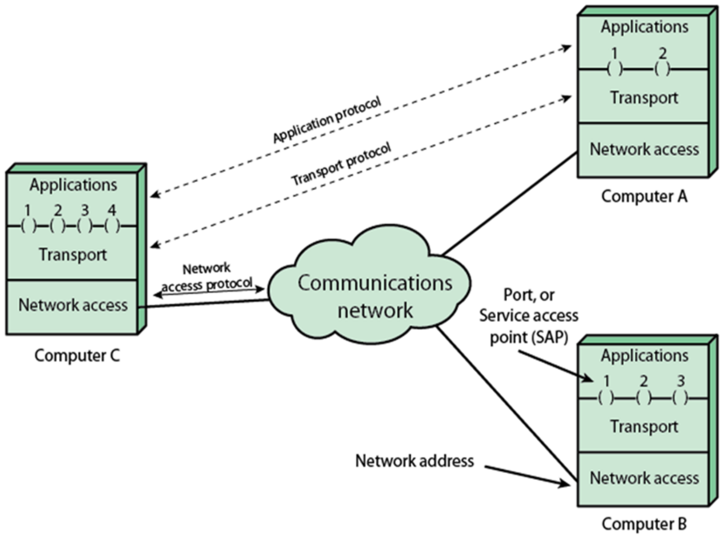


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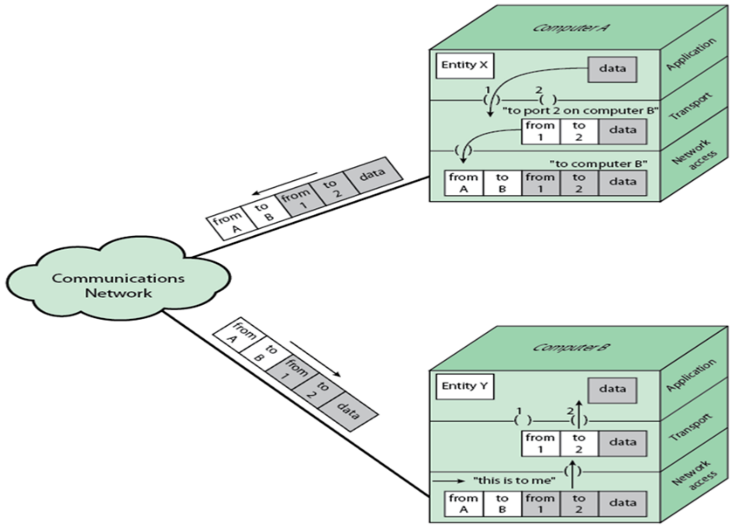
Figure 2.1 indicates that modules at the same level (peers) on different computers communicate with each other by means of a protocol. An application entity (e.g., a file transfer application) in one computer communicates with an application in another computer via an application-level protocol (e.g., the File Transfer Protocol). The interchange is not direct (indicated by the dashed line) but is mediated by a transport protocol that handles many of the details of transferring data between two computers. The transport protocol is also not direct, but relies on a network-level protocol to achieve network access and to route data through the network to the destination system. At each level, the cooperating peer entities focus on what they need to communicate to each other.

Protocols in a Simplified architecture



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Let us trace a simple operation. Suppose that an application, associated with port 1 at computer A, wishes to send a message to another application, associated with port 2 at computer B. The application at A hands the message over to its transport layer with instructions to send it to port 2 on computer B. The transport layer hands the message over to the network access layer, which instructs the network to send the message to computer B. Note that the network need not be told the identity of the destination port. All that it needs to know is that the data are intended for computer B. To control this operation, control information, as well as user data, must be transmitted, as suggested in Figure 2.2. Let us say that the sending application generates a block of data and passes this to the transport layer. The transport layer may break this block into two smaller pieces for convenience, as discussed subsequently. To each of these pieces the transport layer appends a transport **header**, containing protocol control information. The addition of control information to data is referred to as **encapsulation**.

Protocol "layers"

Networks are complex, with many "pieces":

- hosts
- routers
- links of various media
- applications
- protocols
- hardware, software

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Why layering?

dealing with complex systems:

- explicit structure allows identification, relationship of complex system's pieces
  - layered *reference model* for discussion
- modularization eases maintenance, updating of system
  - change of implementation of layer's service transparent to rest of system
  - e.g., change in gate procedure doesn't affect rest of system
- layering considered harmful?

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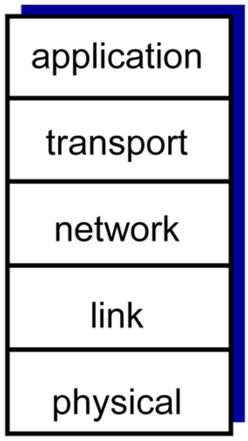
Internet protocol stack

- *application:* supporting network applications
  - FTP, SMTP, HTTP
- *transport:* process-process data transfer
  - TCP, UDP
- *network:* routing of datagrams from source to destination
  - IP, routing protocols
- *link:* data transfer between neighboring network elements
  - Ethernet, 802.11 (WiFi), PPP
- *physical:* bits “on the wire”



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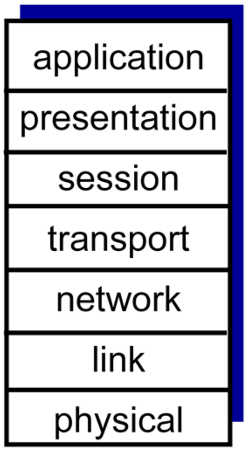
ISO/OSI reference model

- *presentation:* allow applications to interpret meaning of data, e.g., encryption, compression, machine-specific conventions
- *session:* synchronization, checkpointing, recovery of data exchange
- Internet stack "missing" these layers!
  - these services, *if needed,* must be implemented in application



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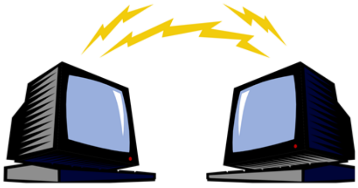
Physical Layer

- Covers the physical interface between computer and network
- Concerned with issues like:
  - Characteristics of transmission medium
  - Nature of the signals
  - Data rates
- Main Functions:
  - bits transmission organization
  - Bit synchronization

The physical layer covers the physical interface between a data transmission device (e.g., workstation, computer) and a transmission medium or network. This layer is concerned with specifying the characteristics of the transmission medium, the nature of the signals, the data rate, and related matters.

Network Access/Data Link Layer

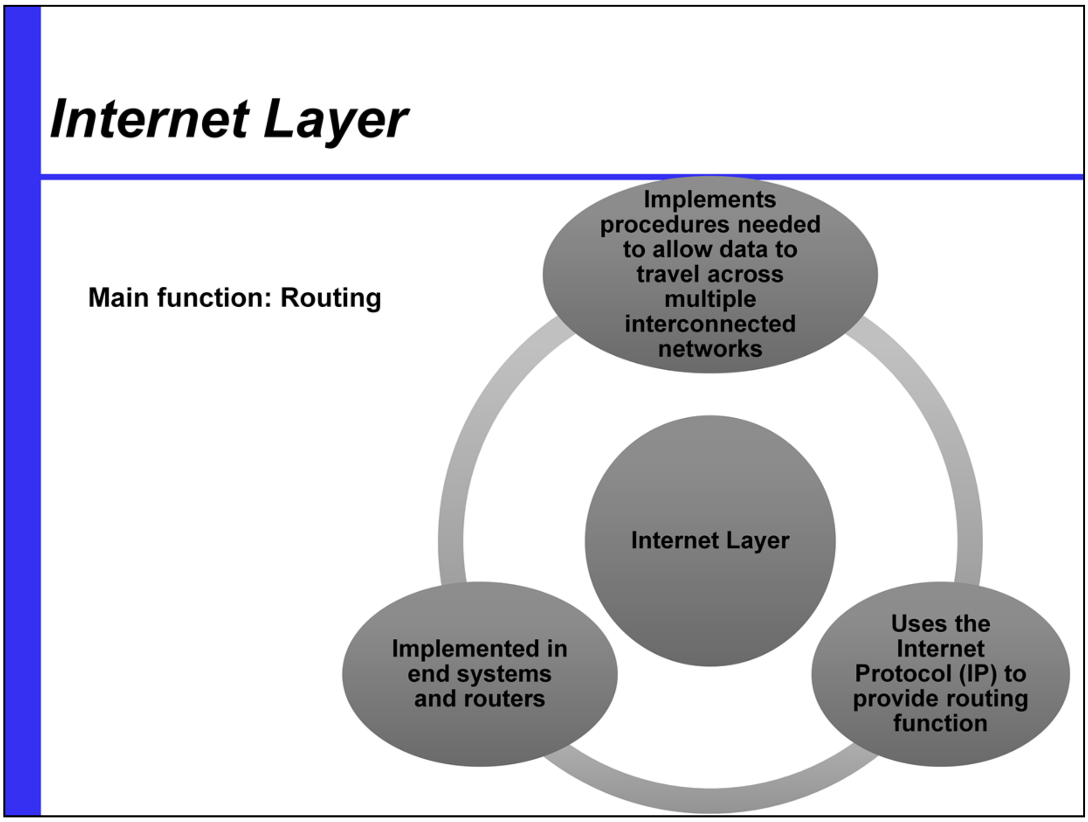
- Covers the exchange of data between an end system and the network that it is attached to
- Concerned with:
  - Access to and routing data across a network for two end systems attached to the same network
- Main functions:
  - Frame synchronization
  - Local Error control
  - Local Flow control



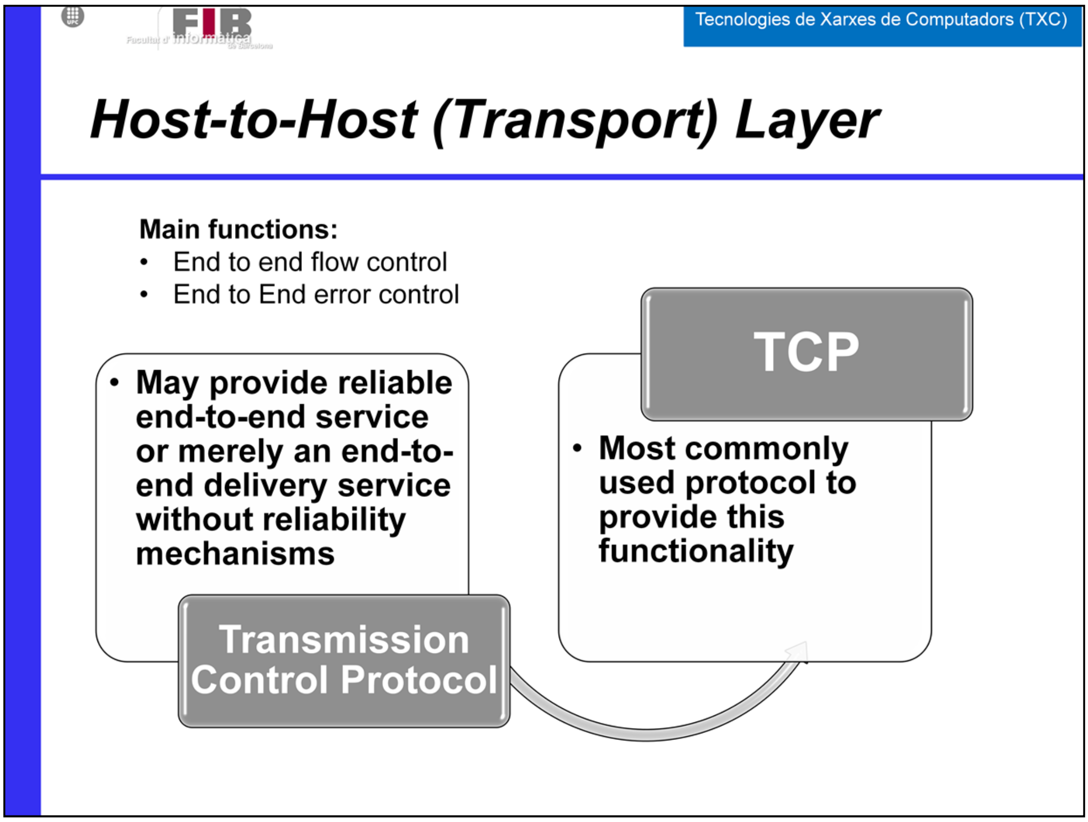
The network access/data link layer is discussed in Section 2.2. This layer is concerned

with access to and routing data across a network for two end systems attached

to the same network.



In those cases where two devices are attached to different networks, procedures are needed to allow data to traverse multiple interconnected networks. This is the function of the internet layer . The Internet Protocol (IP) is used at this layer to provide the routing function across multiple networks. This protocol is implemented not only in the end systems but also in routers . A router is a processor that connects two networks and whose primary function is to relay data from one network to the other on its route from the source to the destination end system.



The host-to-host layer , or transport layer , may provide reliable end-to-end service, as discussed in Section 2.2, or merely an end-to-end delivery service without reliability mechanisms. The Transmission Control Protocol (TCP) is the most commonly used protocol to provide this functionality.

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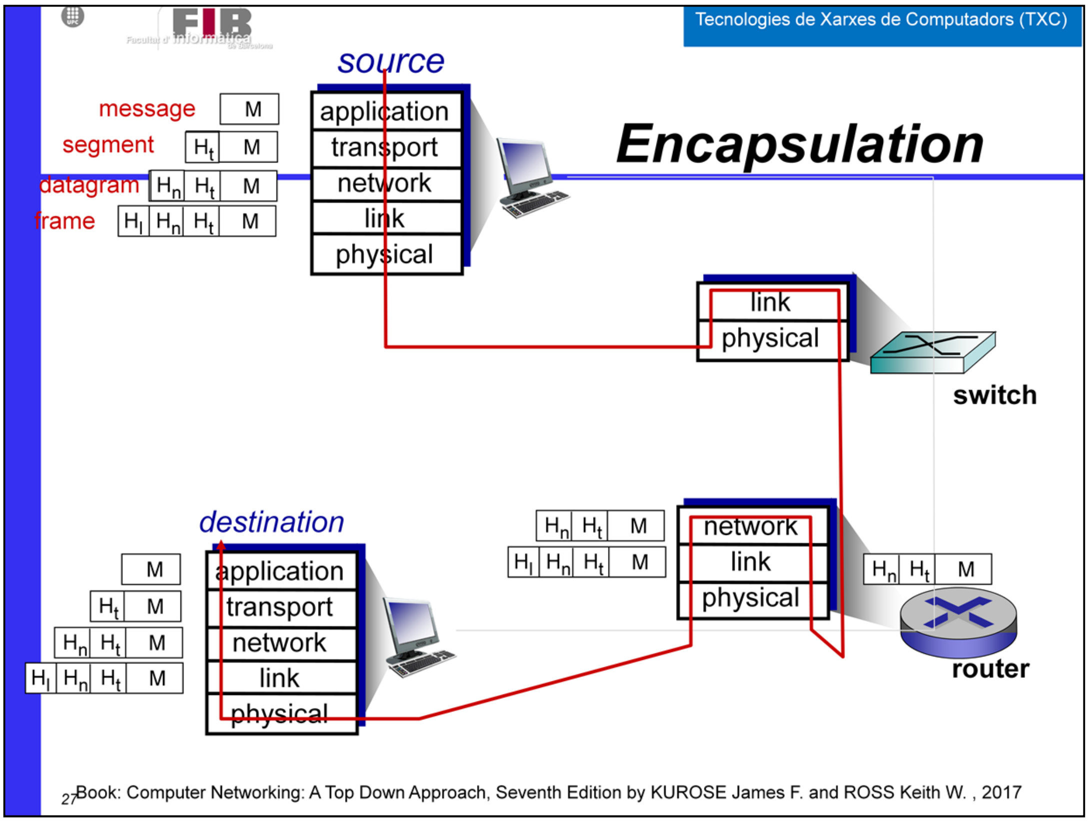
Application Layer

- Contains the logic needed to support the various user applications
- A separate module is needed for each different type of application that is peculiar to that application
- Main APP protocols:
  - HTTP
  - FTP
  - SMTP
  - TELNET
  - SSH

Finally, the application layer contains the logic needed to support the various user applications. For each different type of application, such as file transfer, a separate module is needed that is peculiar to that application.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Encapsulation
source
message
segment
datagram
frame
M
Ht M
Hn Ht M
Hl Hn Ht M
application
transport
network
link
physical
link
physical
switch
destination
network
link
physical
router
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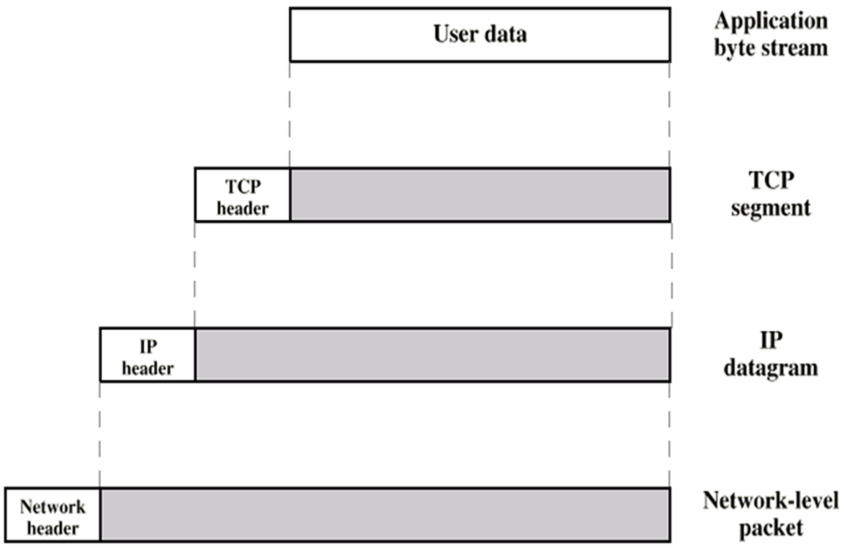
Operation of TCP/IP



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Let us trace a simple operation. Suppose that a process, associated with port 3 at host A, wishes to send a message to another process, associated with port 2 at host B. The process at A hands the message down to TCP with instructions to send it to host B, port 2. TCP hands the message down to IP with instructions to send it to host B. Note that IP need not be told the identity of the destination port. All it needs to know is that the data are intended for host B. Next, IP hands the message down to the network access layer (e.g., Ethernet logic) with instructions to send it to router J (the first hop on the way to B). To control this operation, control information as well as user data must be transmitted, as suggested in Figure 2.5. Let us say that the sending process generates a block of data and passes this to TCP. TCP may break this block into smaller pieces to make it more manageable. To each of these pieces, TCP appends control nformation known as the TCP header, forming a **TCP segment**. The control information is to be used by the peer TCP protocol entity at host B.

Operation of TCP/IP

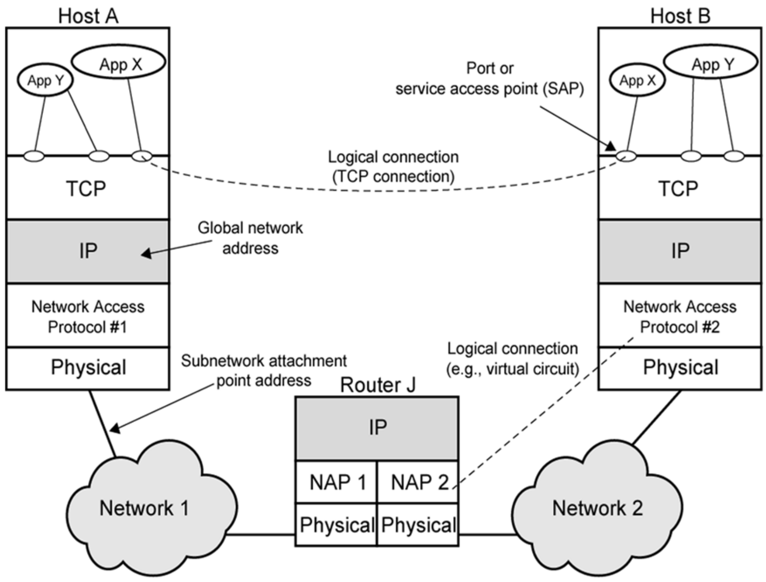

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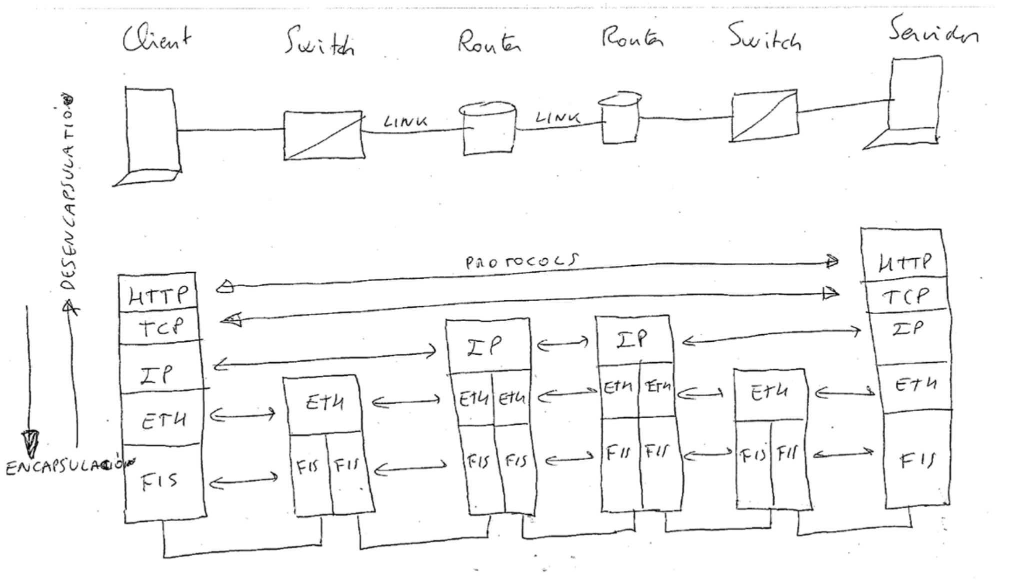
Figure 2.4 indicates how these protocols are configured for communications. To make clear that the total communications facility may consist of multiple networks, the constituent networks are usually referred to as **subnetworks**. Some sort of network access protocol, such as the Ethernet or WiFi logic, is used to connect a computer to a subnetwork. This protocol enables the host to send data across the subnetwork to another host or, if the target host is on another subnetwork, to a router that will forward the data. IP is implemented in all of the end systems and the routers. It acts as a relay to move a block of data from one host, through one or more routers, to another host. TCP is implemented only in the end systems; it keeps track of the blocks of data to assure that all are delivered reliably to the appropriate application.

Exemple


Client
Switch
Router
Router
Switch
Servidor
LINK
LINK
PROTOCOLS
DESENCAPSULACIÓ
ENCAPSULACIÓ
HTTP
TCP
IP
ETH
FIS

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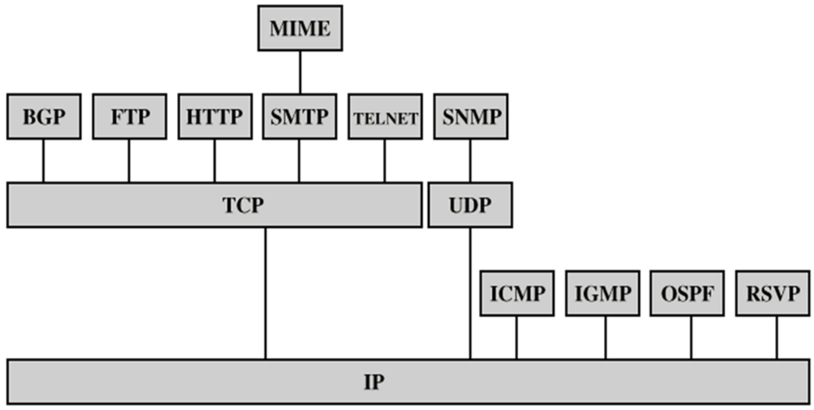
TCP/IP Protocols



BGP = Border Gateway Protocol
FTP = File Transfer Protocol
HTTP = Hypertext Transfer Protocol
ICMP = Internet Control Message Protocol
IGMP = Internet Group Management Protocol
IP = Internet Protocol
MIME = Multi-Purpose Internet Mail Extension
OSPF = Open Shortest Path First
RSVP = Resource ReSerVation Protocol
SMTP = Simple Mail Transfer Protocol
SNMP = Simple Network Management Protocol
TCP = Transmission Control Protocol
UDP = User Datagram Protocol

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Each layer in the TCP/IP protocol suite interacts with its immediate adjacent layers. At the source, the application layer makes use of the services of the end-to-end layer and provides data down to that layer. A similar relationship exists at the interface between the transport and internet layers and at the interface of the internet and network access layers. At the destination, each layer delivers data up to the next higher layer. This use of each individual layer is not required by the architecture. As Figure suggests, it is possible to develop applications that directly invoke the services of any one of the layers. Most applications require a reliable end-to-end protocol and thus make use of TCP. Some special-purpose applications do not need the services of TCP. Some of these applications, such as the Simple Network Management Protocol (SNMP), use an alternative end-to-end protocol known as the User Datagram Protocol (UDP); others may make use of IP directly. Applications that do not involve internetworking and that do not need TCP have been developed to invoke the network access layer directly.