CHAPTER 1
Networking Theory

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OUTLINE

- What is a data communication?
- How do networks communicate?
- Data Flow
- Internetworking device
- Addressing
- Network layers

Network Address

- Addresses are used to send information to the appropriate node
- Commonly used term for physical address:
  - Hardware address or
  - Ethernet address or
  - MAC (MEDIA ACCESS CONTROL) address or
  - NIC (NETWORK INTERFACE CARD) address

- Ethernet network cards are assigned a unique number

Network Address

- A MAC address consists of 48 bits that are usually written in groups of six pairs of hexadecimal digits. These groups are separated by either a dash or a colon.
- A MAC address is typically represented as a hexadecimal string, such as 08:00:27:b9:88:74.
- The MAC address is hard-coded into the NIC by the manufacturer, although modern NICs allow you to change the MAC address programmatically.

Network Address

Getting a specific MAC address

- The following method returns a string containing the MAC address for a NetworkInterface instance.
- The getHardwareAddress method returns an array of bytes holding the number.
- This array is then displayed as a MAC address.

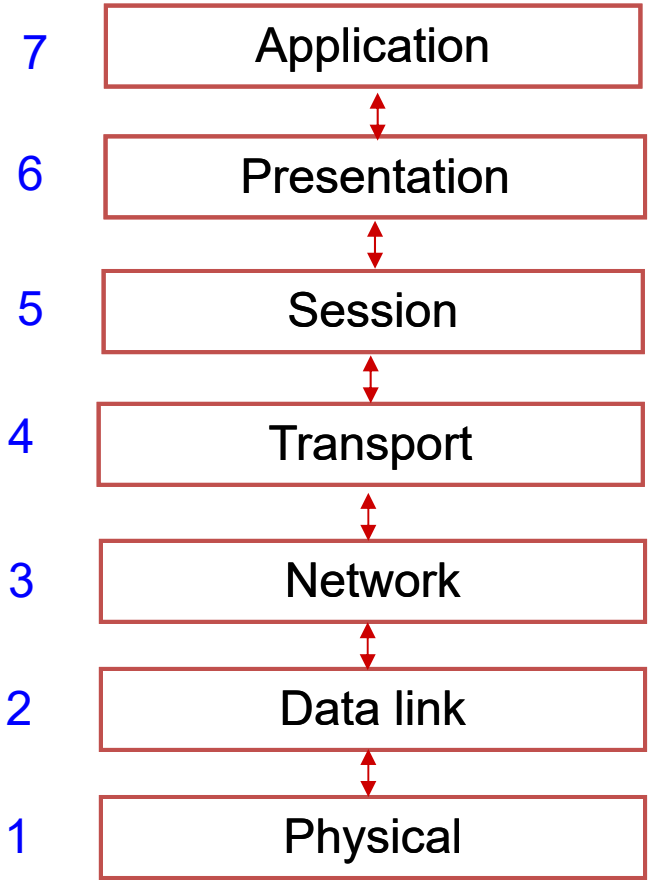
Network Address

```
public String getMACIdentifier(NetworkInterface network) {
   StringBuilder identifier = new StringBuilder();
   try {
         byte[] macBuffer = network.getHardwareAddress();
         if (macBuffer != null) {
            for (int i = 0; i < macBuffer.length; i++) {
                 identifier.append(
                String.format("%02X%s",macBuffer[i],
                (i < macBuffer.length - 1) ? ":" : ""));
             }
         } else {
             return "---";
         }
   } catch (SocketException ex) {
   ex.printStackTrace();
   }
  return identifier.toString();
}
```

Network Layers-OSI model

- There are several models describing how networks can be layered to support different tasks and protocols.
- One common model is the Open Systems Interconnection (OSI) model, which defines seven layers.
- Each layer of a network model can support one or more protocols.
- The relationships of various protocols are depicted in the following table and will be discussed in detail:

Network Layers-OSI model



Network Layers-OSI model

Layer	Example protocols
Application	HTTP, FTP, SMTP,….
Presentation	Transport layer security (TLS)
Session	Network file system (NFS)
Transport	TCP, UDP
Network	IP
Data link	Ethernet, frame relay
Physical	DSL, Bluetooth

Layer-7 Application layer

- The layer that delivers data to the user is called the application layer.

- Application layer provides platform to send and receive data over the network.

- We have examples of some applications that communicate with network and fall in this layer.

For examples:

Browsers : Mozilla Firefox, Internet Explorer, Google Chrome etc

Layer-7 Application layer

Application layer protocols that we should know:

TFTP (***Trivial File Transfer Protocol***) :
Used to transfer the files rapidly.

DNS (***Domain Naming System***) :
Used to translate the name with IP address and vice versa.

Telnet: used to connect remote devices (enables a user to manage device remotely).

HTTP (***Hypertext Transfer Protocol***) :
Used to browse web pages.

Layer-7 Application layer

FTP (***File Transfer Protocol***) :
Used to reliably sends/retrieves files.

SMTP (***Simple Mail Transfer Protocol***) :
Used to sends email.

POP3 (***Post Office Protocol v.3***) :
Used to retrieves email.

SNMP (Simple **Network** Management Protocol): With this protocol you can manage and monitor network elements (routers, switches, printers, IP telephones etc.), collect information about them.

Layer-6 Presentation layer

- Presentation layer prepares the data (formatting of information for further processing or display).
- It takes data from application layer and marks it with formatting code such as .doc, .jpg, .txt, .avi etc.
- These formatting code make the presentation layer realize easily that particular file is formatted with particular type of application.
- Presentation layer also deals with compression and decompression of data file.

Layer-5 Session layer

- Session layer deals with connections for multiple users and control between them.
- The session layer tracks the dialogs between users , which are also called sessions.
- This layer provides its services to the presentation layer.

  - For example, web servers may have many users communicating with it at a given time.
  - Therefore, session layer has the responsibility of keeping track of which user communicates on which path.

Layer 4 Transport layer

- **Transport Layer**

  this is the most important layer to study.

- **Transport layer provides the following services: -**
  - It initiates and maintains the connection between two devices.
  - It multiplexes connections that allow multiple applications to simultaneously send and receive data.

  - In this layer data transmission method can be connection oriented or connection less (according to the requirement).

    - For unreliable data delivery; connection less method is used, connection less method uses UDP protocol.
    - For reliable data delivery; connection oriented method is used, connection oriented method uses TCP protocol.

Layer 4 Transport layer

- When Implemented a reliable connection, sequence numbers and acknowledgments (ACKs) are used.
- Reliable connection uses flow control method (windowing).

Layer 4 Transport layer

Remember five main functions of transport layer.

- (1) Segmentation
- (2) Connection management
- (3) Reliable and unreliable data delivery
- (4) Flow control
- (5) Connection multiplexing

Layer 4 Transport layer

(1) Segmentation:

- Segmentation is the process of breaking large data file into smaller files that can be exchanged by network.
- To understand this process for example a 700 MB movie that you want to download from internet.
- You have 2MBPS internet connection.
- How will you download a 700MB movie on 2MBPS internet connection?
- In this case segmentation process is used.
- On server, transport layer breaks 700MB movie in smaller size of segments (less than your internet connection speed).

Layer 4 Transport layer

(1) Segmentation cont.

- Assume that 700Mb movie is divided in 700 segments.
- Each segment has file size of 1Mb that your PC can easily download at current connection speed.
- Now your PC will download 700 small files instead of one large file.
- Once your browser receives all segments from server, it will return a message indicating download is completed.
- Transport layer at your PC will merge all segments back in a single 700Mb movie file.
- End user will never know how a 700Mb movie transferred through the 2Mbps connection line.

Layer 4 Transport layer

(2) Connection management

- Transport layer setup, maintain and end connections for session layer.
- Transport layer use two protocols for connection management UDP and TCP.

UDP

- UDP is a connection less protocol.
- Connection-less transmission is said to be unreliable.
- Now, don't get worried about the term "unreliable" this doesn't mean that the data isn't going to get its destination; its only means that it isn't guaranteed to get its destination.
- example, when you are sending a postcard, you put it in the mailbox, and chances are good for postcard to be reached to the destination address but not guarantee.

Layer 4 Transport layer

(2) Connection management cont.

- **TCP**
  - TCP is a connection oriented protocol.
  - Connection-oriented transmission is said to be reliable.
  - example of TCP as registry AD facility available in Indian post office.
    - For this level of service, you have to buy extra ticket and put a group of extra labels on it to track where it is going and where it has been.
    - You get a acknowledgment when it is delivered.
    - In this method you have a guaranteed delivery.
    - This method costs you more, but it is reliable!

Layer 4 Transport layer

(2) Connection management cont.

Characteristic	TCP	UDP
Connection	Connection-oriented	Connectionless
Reliability	Higher	Lower
Order of packets	Order restored	Order potentially lost
Transmission time	Slower than UDP	Faster than TCP
Error checking	Yes	Yes, but no recovery options
Acknowledgement	Yes	No

Layer 4 Transport layer

(2) Connection management cont.

- TCP is used for a number of protocols, such as HTTP, Simple Mail Transfer Protocol (SMTP), and File Transfer Protocol (FTP).

- UDP is used for time-critical data transmissions such as online gaming, video streaming and for Voice Over IP (VOIP).

Layer 4 Transport layer

(3) Reliability

- Reliability means guaranteed data delivery.
- Connection oriented method is used to insure delivery of each single segment.
- In this approach before sending any segments three ways handshake process is done.

Layer 4 Transport layer

(3) Reliability cont.

- **Three ways handshake process**

(1) PC1 sends a SYN single to PC2 indicating that it wants to establish a reliable session.
(2) PC2 replies with ACK/SYN signal where ACK is the acknowledgment of PC1's SYN signal and SYN indicates that PC2 is ready to establish a reliable session.
(3) PC1 replies with ACK signal indicating that is has received SYN signal and session is now fully established.

Layer 4 Transport layer

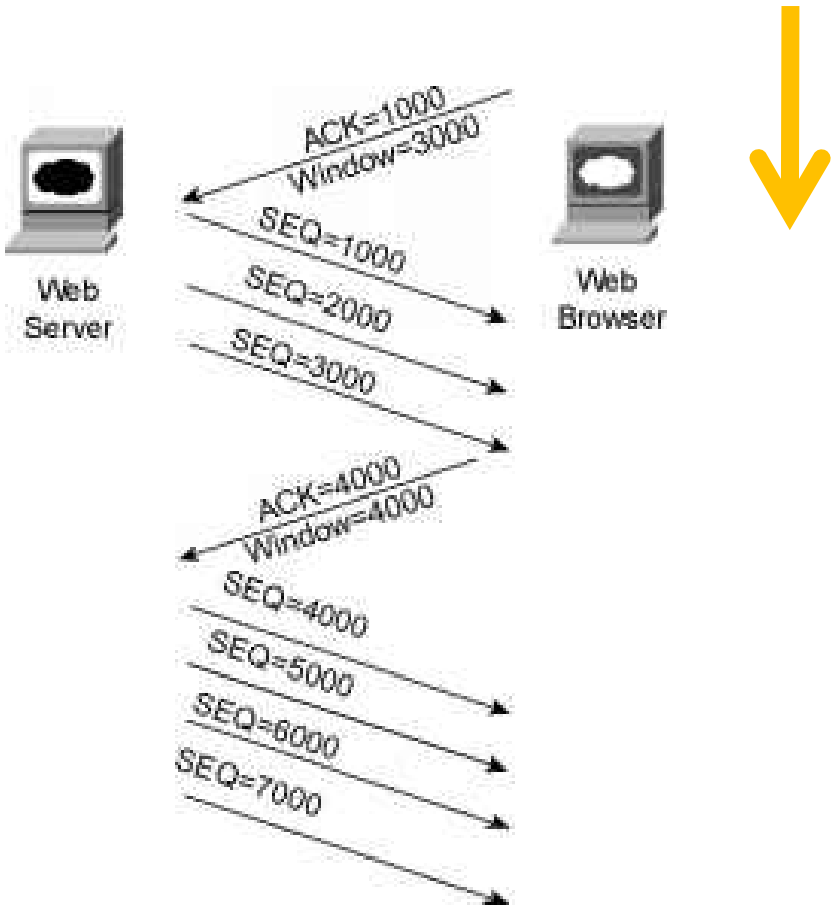
- Once connection is established, data transmission will be initiated.

- To provide maximum reliability it includes following functions:-
  - Detect lost packets and resend them
  - Detect packets that arrived out of order and reorder them
  - Recognize duplicate packets and drop extra packets
  - Avoid congestion by implementing flow control

Layer 4 Transport layer

(4) Flow control

- The transport layer implements Windowing of flow control methods:



Layer 4 Transport layer

Windowing

- In windowing a window size is defined between sender and receiver (how many frames of bytes can be transmitted at a time).
- After sending the segments, sender host will wait for an acknowledgement signal.
- If any packet lost in the way, receiver will respond with acknowledgement for lost packet.
- Sender will resend lost packet again.

Layer 4 Transport layer

(5) Connection Multiplexing/Application Mapping

- Connection multiplexing feature allows multiple applications to connect at a time.
- For example a server performs a number of functions like email, FTP, DNS, Web service, file service, data service etc.
- Suppose server has a single IP address, how server will perform all these different functions for all the hosts that want to connect with it?
- To make this possible, transport layer assigns a unique number for each connection.
- These numbers are called port numbers.
- These port numbers allow multiple applications to send and receive data simultaneously.

Layer 4 Transport layer

(5) Connection Multiplexing/Application Mapping cont.

- **ports**
  - Each computer with an ip address has several thousand logical ports
  - Each port is identified by a number between 1 and 65,535.
  - each port can be allocated to a particular service.

  - **Port numbers are divided into the following ranges**

Port number	Descriptions
0–1023	Well-Known—For common TCP/IP functions and applications
1024–49151	Registered—For applications built by companies
49152–65535	Dynamic/Private—For dynamic connections or unregistered applications

Layer 4 Transport layer

(5) Connection Multiplexing/Application Mapping cont.

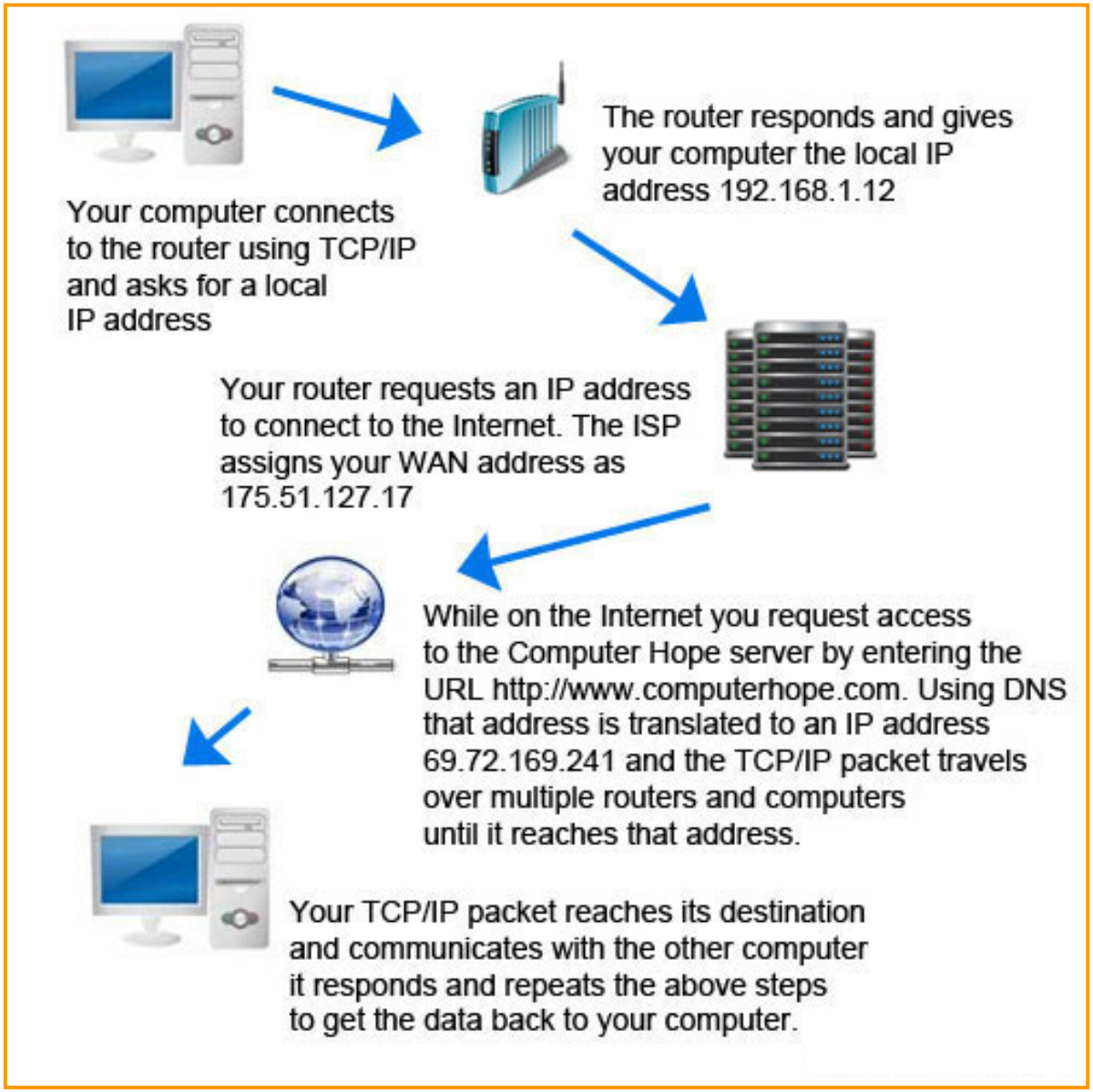
Well-known port assignments

FTP	21
TELNET	23
SMTP	25
HTTP	80
POP3	110

Layer 3 Network layer

- Network layer receive segment from transport layer and wrap it with IP header that is known as datagram (Datagram is called packet).
- Router works on this layer.
- Main functions of this layer are following:-
  - Define IP address
  - Find routes based on IP address to reach its destination

Layer 3 Network layer



This picture is taken from our "How do computers connect to each other over the Internet" page and gives a good overview of how a computer can talk to another computer over the Internet using an IP address.

If you want to find your IP address
open command prompt
windows-> type cmd **ipconfig**
and enter on windows
you will find your IP4 and IP6 address .

Layer 2 data link layer

- Data link layer receive packet from network layer and wrap it with Header that is known as frame.

  Or

- Divides the stream of bits received from physical layer into frames (data unit)

- **Main functions of data link layer are**
  - Defines the hardware address (Media Access Control (MAC))
  - Defines how the received packet from network layer is summarized in the data link layer as a frame

Layer 1 physical layer

- Physical layer deals with communication media.
- This layer receive frames from data link layer and convert them into bits.
- It loads these bits on actual communication media.
- Depending on media type these bit values are converted into signal.

Example

- **Data Exchange Process**
  - In data exchange process, Layers on receiving computer perform the same task of sender but in reverse mode.
  - For example on sending computer, presentation layer compress the data, the same presentation layer on receiving computer decompress the data.

Example

On sending computer

- Accessing the application layer with sending data .
- Application provides data to the presentation layer.
- Presentation layer format the data as per network requirement and forward it's to session layer.
- Session layer initiate the connection and forward the data to the transport layer.
- Transport layer broke down the large data file in smaller segments and add a header with control information(describe how to determine whether the data is complete, uncorrupted, in the correct sequence, and so forth).

Example

On sending computer cont.

- Segments are forwarded to the network layer.
- Network layer add its header, with logical address (ip) and convert segment into packet. Network layer forwards packet to data link layer.
- Data link layer attach its header to the packet and convert it into frame.
- Frames are forwarded to the physical layers that convert them into signals. These signals are loaded in media.

Example

On receiving computer

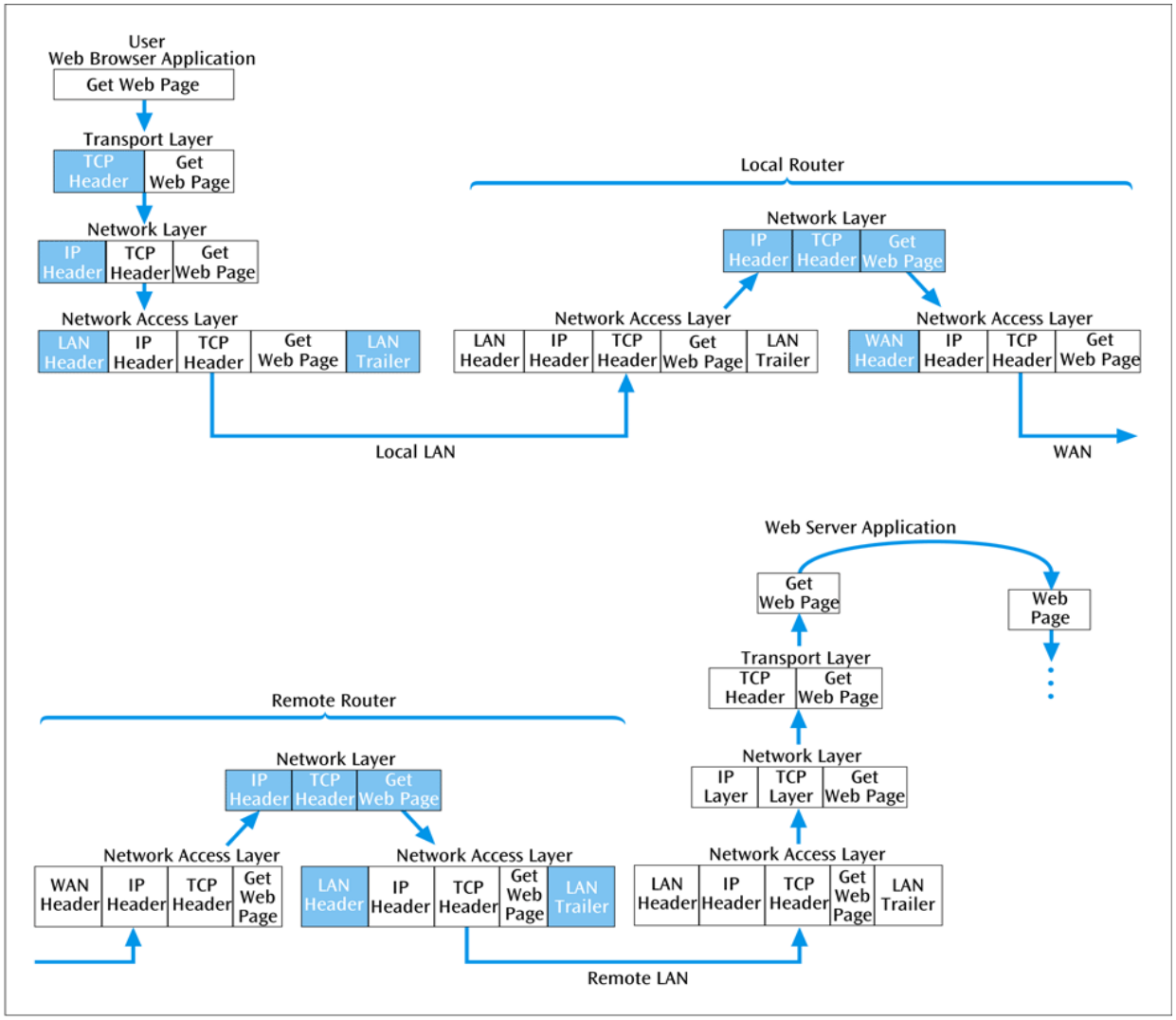
- Physical layer receive signals from media and convert them in frames.
- Frames are forwarded to the data link layer.
- Data link layer check the frame.
- All frame with error are dropped here.
- If frame is correct, data link layer strip down its header from frame and hand over packet to network layer.
- Network layer check the packet with its own implementations. If it's found everything fine with packet, it strips down its header from packet and hand over segment to transport layer.

Example

On receiving computer cont.

- Transport layer again do the same job. It verifies the segments with its own protocol rules. Only the verified segments are processed.
- Data is handed over the session layer.
- Session layer keep track of open connection and forwarded the receiving data to presentation layer.
- Presentation form the data in such a way that application layer use it.
- Application layer on receiving computer find the appropriate application from the computer and open data within particular application.

Example



Path of a Web page request as it flows from browser to Internet server and back

THE END

END