```yaml
id: 1706549822-WUAV
aliases:
  - CN Unit 1
tags:
  - notes
  - computer_networks
author: vortex
```

Service Description of the Internet

- Allows distributed applications running on its end systems to exchange data.
- Internet provides 2 types of services to these applications :
  - Connection Oriented (Reliable)
  - Connectionless (Unreliable)
- Internet doesn't provide a service that can make promises as to how long it will take to deliver data from sender to receiver.

> Alternative Definition of the internet : It is an infrastructure where new applications are constantly being invented and deployed.

Internet Protocols

> Defines the format and the order of the messages exchanged between 2 or more communicating entities as well as the actions taken on the transmission and receipt of a message or other event.

Network Edge

End Systems, Clients and Servers

- End Systems : Computers connected to the network
  - Also called `hosts` because they host application programs.
  - Hosts can be further divided into :
    - Clients
    - Servers

> Definition of Client and Server architecture: A `client` program is one that runs on one end system and requests and receives a `service` from a server program running on another end system.

  - Since client and server run on different end systems, this is a distributed system
- At this level of abstraction, the routers and switches and other `Nuts and Bolts` of the Internet act as black boxes and forward the packets of data between the distrubuted components.
- In addition to this some applications like Napster, GNUtella, KaZaA don't follow pure Server-Client Arch. They use P2P connection where one becomes the server when the other is requesting content from it.

Connectionless and Connection-Oriented Services

- The `TCP/IP` protocol and moreover the internet gives us 2 options.
- Developers of the distributed systems app have to choose one of these 2.
- Connection-Oriented:
  - There is a `Handshake` prior to the sending of actual data.
  - This handshake involves the sending of control packets between source and destination.
  - This prepares them for the barrage of packets which may come in the future.
  - It is called *Connection-Oriented* since the connection is very loosely made. This means that only the end systems are aware of the nature of the connection. The intermediate routers, links, etc do not have any data regarding this.
  - A connection on the internet is basically just a bunch of buffers allocated on the end systems and state variables.
  - This type of service has a few features :
    - Reliable data transfer: by acknowledgement and retransmission
    - Flow Control: so that neither system overwhelms the other. Hence restricts rate of end system.
    - Congestion Control: in case of congestion of router buffers, it may lead to packet loss. Forces rate reduction during times of congestion.

      > When buffers of the routers are congested and the end systems continue pumping in more and more packets.

  - On the internet it is called `TCP`
- Connectionless:
  - No handshake.
  - No features like reliability, flow control, congestion control.

- The internet's connectionless service is called `UDP(User Datagram Protocol)`.
- Data delivered sooner since there is no handshaking.

Network Access

- Residential
- Company
- Mobile

Access Networks

- The network that physically connects the edge devices to the first router/ edge router.
- Residential access networks have 2 ways of accessing the internet:
  - Digital Subscriber Line(DSL)
  - Cable

DSL

- In this mode of internet access, the same company that provides telephone services provides internet services.
- The very same line that us used for telephone comms is also used for internet data communication.
- The DSL modem at the user's home translates the digital signals to analog and this is translated back into digital at the Central Office(CO).
- At the CO there exists the Digital Subscriber Line Access Multiplexer(DSLAM). The telephone line exchanges data with this.
- The DSLAM also translates the analog signals to digital.
- The signals are transferred across line in different frequencies.
  - 50kHz-1MHz high freq band
  - 4kHz-50kHz Mid freq band
  - 2 way telephone line at 0-4kHz
- At the user's home there is also a `splitter` that splits the data and telephone signals.
- Maximum rate is affected by
  - the gauge of the twisted pair cable
  - degree of electrical interference
  - distance from the CO
- Usually if distance from CO is more than 5-10 miles, user must opt for another method of internet access.

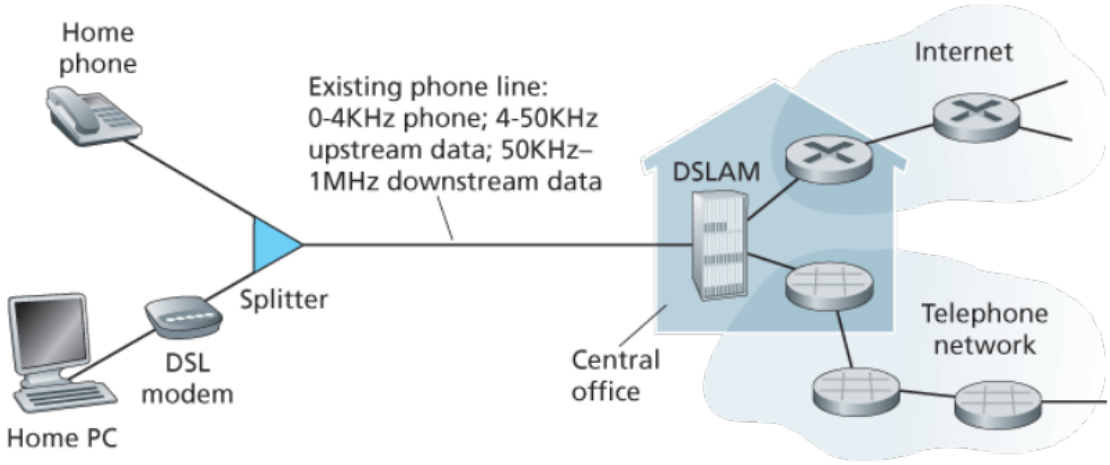


Figure 1.5 DSL Internet access

Cable

- Obtains data from the cable tv infrastructure.
- fiber is used to connect the head end and subsequently coax is used to connect to individual homes.
- the network hub for each neighbourhood can handle between 500 and 5000 homes.
- Since both types of cables are used its called Hybrid Fiber Coax(HFC).

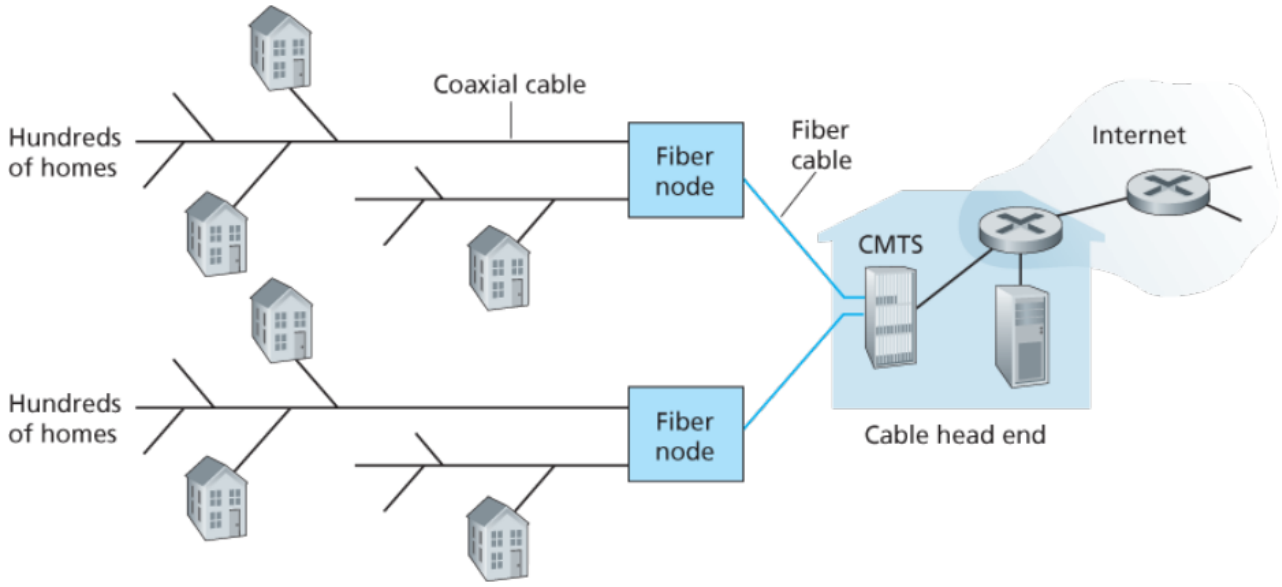


Figure 1.6 A hybrid fiber-coaxial access network

- Has a cable modem termination system(CMTS). This is similar to the DSLAM.
- Splitter in the modem divides HFC network into high freq and low freq channels.
- `Shared broadcast service`. This means that information has to travel down a common stream to all the houses as shown. Hence if one user is watching a large video, then it slows down for everyone on the network.

Fiber to the Home(FTTH)

- Direct fiber connection to the home.
- One shared fiber leaves the CO and on getting closer to homes it splits(using a splitter) into one fiber per home.
  Types:
- Active Optical Network(AON)
- Passive Optical Network(PON)
- Every home has a Optical Network Terminator(ONT), connected via fiber to a network splitter.
- A single fiber connects this splitter to a OLT(Optical Line Terminator) at the CO.
    - OLT converts the optical signals to electrical signals.

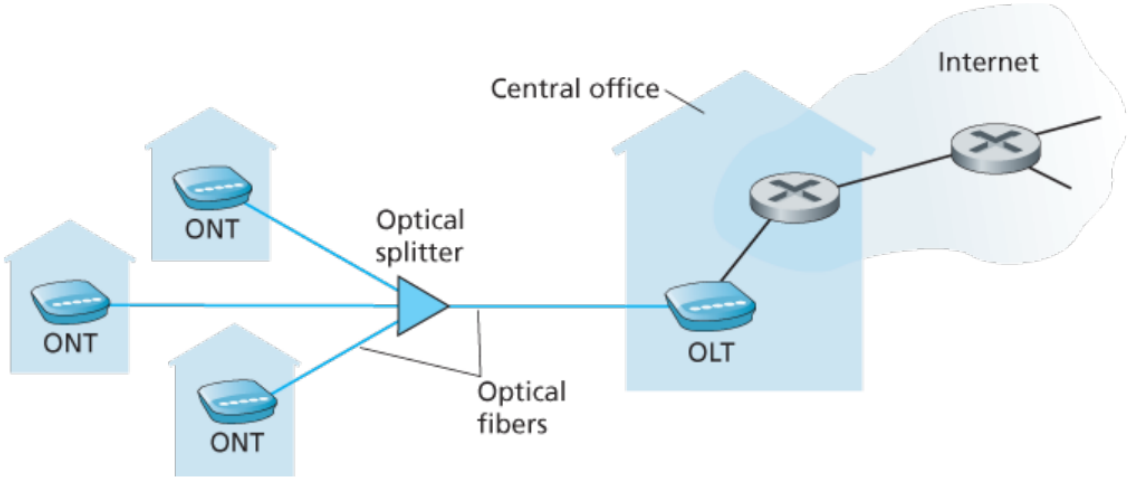


Figure 1.7 FTTH Internet access

- In regions where DSL,Cable and FTTH are not available, there exists satellite and dial-up internet solutions.

Physical Media

- Bits are forwarded across network devices through physical links.
- These links can be of 2 types:
    - guided(along a solid medium)
    - unguided(across the atmosphere/outerspace etc)
- Usually material cost is very low. But cost of installation is very high which is why we usually install surplus physical links even though we may not need them as of now.

Twisted pair cable

- consists of 2 or more 1mm thick wires twisted in a spiral(to reduce electrical interference)
- Unshielded Twisted Pair(UTP) is used within buildings for computer networks.
- Their transmission depends on the:
  - Thickness
  - Distance
- modern twisted pairs have upto 10Gbps of bandwidth over 100s of metres.

Coaxial cable

- Concentric copper wires
- can acheive tens of Mbps of speeds.
- can be used as a "Guided Shared media" where multiple connected devices can all get access to the same data
- popularly used for television cable connections

Fiber Optics

- Thin and flexible
- can conduct and transmit light pulses
- each pulse represents one bit
- very low signal attenuation across large distances
- very hard to tap
- This has become the de-facto solution for overseas/other large distance communications
- The high costs of the optical devices like transmitters and receivers has hindered their use in short range applications.
- Optical Carrier(OC) speeds range from 58.1Mbps to 39.8Gbps.
- These link specifications are mentioned as `OC-n` (OC-1,OC-3,OC-192 etc)

Terrestrial radio channels

- Electroagnetic radiation to transfer information.
- No physical connections required.
- Environment determines the:
  - Path loss and shadow fading(loss due to distance and obstructions)
  - multipath fading(due to reflections from interfering objects)
  - interference(from other sources of radiation)
- can be classified as :
  - short distance
  - medium distance

- large distance

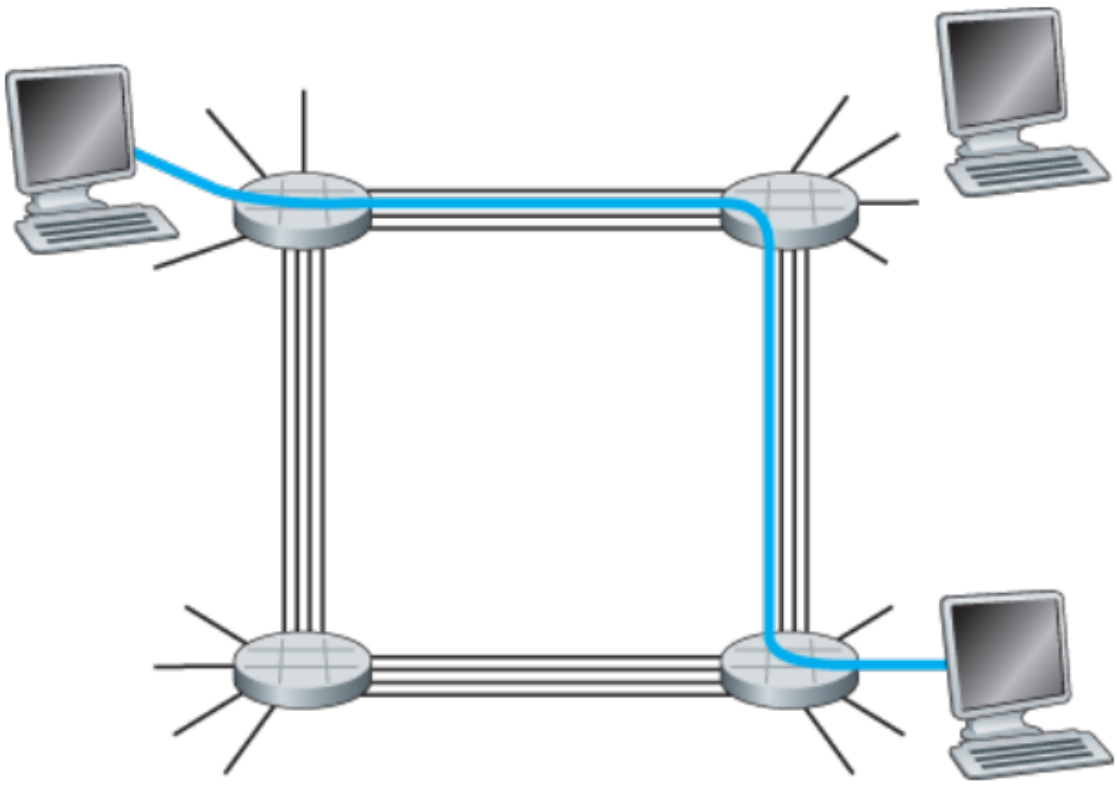
Satellite Radio channels

- Satellites are used to establish communications between 2 earth based transmitter/receivers(ground stations)
- Mainly of 2 types:
  - geostationary - remain above the same spot on the earth at all times.
  - low earth orbiting(LEO) - not at the same spot. communicate with other sattelites to provide coverage.
- Satellites take the received signal and regenerate that using a `repeater` and transmit to the ground station

Network Core

Circuit Switching

- Dedicated end-to-end connection between 2 hosts.
- The resources needed between the source and the destination are reserved for the duration of the transfer.
- The concept of queuing(as in packet switching) doesn't exist here.



- each link has multiple circuits that can be assigned.
- Multiplexing in Circuit Switched networks:
  - Frequency Division Multiplexing(FDM):
    - Frequecy spectrum of the link is shared among the connections establised across te link.
    - The width of this frequency band is called `bandwidth`.
  - Time Division Multiplexing(TDM):
    - Time is divided into fixed `units/frames`.
    - Each frame is divided into fixed `time slots`
    - One timeslot in each frame is alotted to a connection.

Packet Switching

- Data is transferred across network in small chunks called `packets`,
- Between the Source and destination, they pass through communication links called packet switches.
- Resources between the source and destination are accessed on demand and hence they may need to wait to access some resources(hence the need for queuing).
- `Store and forward` manner: links wait for entire packet to arrive before tranferring even 1 bit of the data.
- This adds processing delay to the network.
- $TransmissionDelay : L/R$
- Each router may have multiple links to outbound channels.
- Each link has something known as an `output buffer`.
- This stores the packets that are about to be sent on that link.
- In case of congestion on that link, packets will get queued in the output buffer. This leads to `queuing delays`.
- In case the buffer space fills up and the packets are still incoming, either the incoming of one of the already existent packets from the buffer are dropped. This is called `packet loss`.
- Packet swicthed networks usually follow a random order of transfer. This is called `statistical multiplexing`.
- If there are `Q` links of rate `R` bps, sending a packet of size `L`, the delay in sending this message excluding queuing and end-to-end delays is QL/R

Advantages	**Disadvantages**	
More efficient, less costly, simpler	Variable and unpredictable queuing delays	

Advantages	Disadvantages	
Better sharing of bandwidth compared to circuit switch		

- We calculate the probability that the number of simultaneous users on packet switching can exceed the rated number of simultaneous users that a link can handle.

Message Segmentation

- In popular practice we often get the message divided from the source into segments and put it back togeather at the destination.
- When we transmit entire messages without the use of segmentation, it is called `message switching`.
- Since Packet switching follows the store and forward philosophy, each link must wait for the *entire* message to be tranferred completely before proceeding with the next link.
- In segmented transfer, we can use the concept of `pipelining` which essentially means that we can transfer the segments of the packets `simultaneously`.
- This greately reduces the delay in the transfer of the message between the source and the destination as none of the nodes are sitting idle as opposed to message switching.
- One more advantage of segmentation is that, in message switching if transfer fails at any node the entire message must be discarded. But in this case if a packet fails, then just that packet must be discarded.
- One of the shortcomings of segmentation is that each packet must have a `header` containing control information. In message switching this is only required once whereas in segmented package switching this is required for all the segments. Hence the overhead of headers per byte in the segmented packet switching is more as compared to message switching.

Forwarding tables

- The router has forwarding tables that examines portions of the destination addresses and maps that to output ports/links.
- The router uses this table to determine across which outbound link to direct the packet which enters it.
- These forwarding tables are generated using routing protocols which determine the shortest path from one node to the next and accordingly set the routing tables.
- Hence Packet switching is great for `bursty` traffic.
- In Circuit Switched:
  - $Numberofusers = \frac{linkcapacity}{usercapacity}$
- In Packet Switched:

- Find binomial distribution

Delays

$d_{nodal} = d_{proc} + d_{queue} + d_{trans} + d_{prop}$

d_{trans} :

- Due to store and forward philosophy
- L/R

  d_{prop} :
- Due to the length of the physical media
- d/s

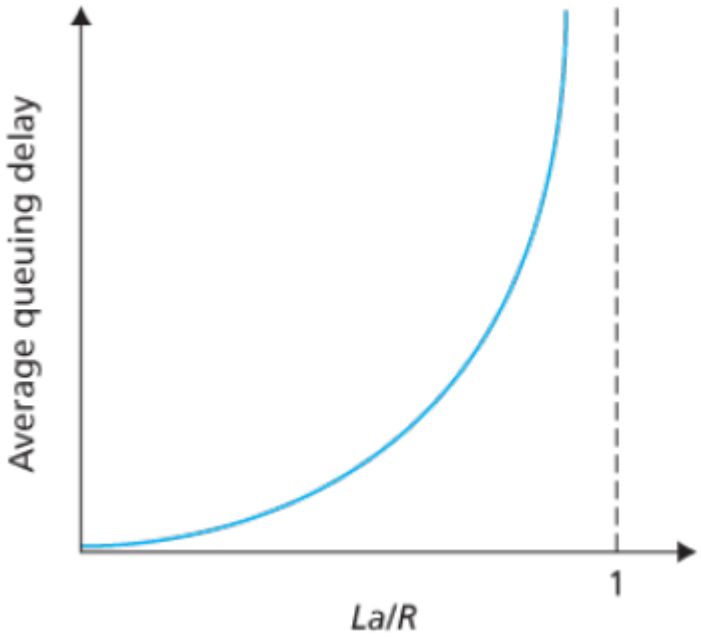
  d_{queue} : depends on the congestion of the router

  d_{proc} : checking bit errors

Queuing Delay

$Intensity(I) = \frac{La}{R}$

- When $I >= 1$, queuing delay approaches ∞
- When $I < 1$, queuing delay is finite
- We must aim to bring I as close to zero as possible.



- If the queue of the node fills up and a new packet is incoming, it gets dropped.
- As the intensity increases this increases.
- If there are $N - 1$ routers between destination and source ,

    - $d_{end-to-end} = N(d_{proc} + d_{trans} + d_{prop})$
- Traceroute: program to calculate end-to-end delay

Throughput

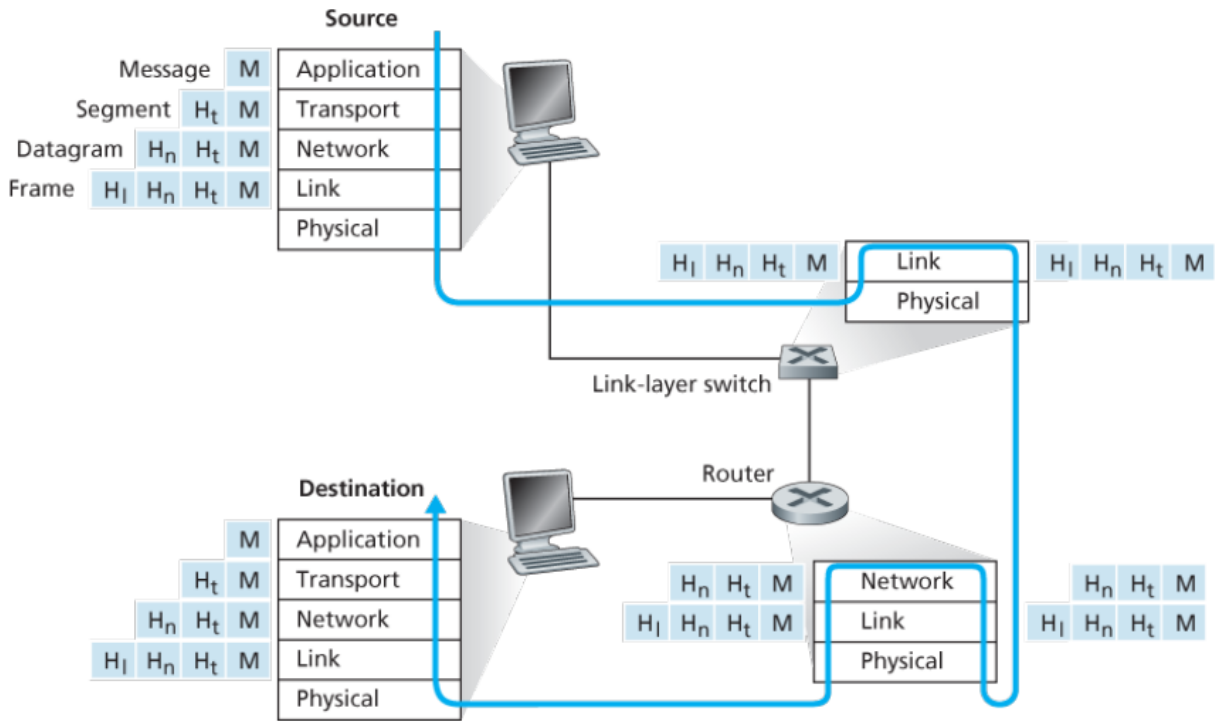
- Rate at which bits are being received(bits/sec).
- Types:
    - Instantaneous
    - Average

OSI Layer Model

- Application layer
    - Protocols: HTTP,SMTP,FTP,DNS
    - Data: Message
    - Interfaces the process and the protocols
- Transport Layer
    - Protocols: TCP,UDP
    - Data: Segment
    - Communication between processes
- Network Layer
    - Protocol: IP
    - Data: Datagram
    - Host to Host communication
    - Has routing protocols that determine which paths can be taken
- Link Layer
    - Protocols: Ethernet, WiFi, DOCSIS
    - Data: Frames
    - Node-Node communication
- Physical Layer
    - Protocols: Link dependent like ethernet
    - Data: Bits
    - moves the bits between adjacent network elements
- Additional layers in the 7 layer model
    - Presentation Layer:
        - Data compression
        - Data encryption
        - Data formatting

- Session Layer
  - Checkpointing
  - Sync of data exchange

Encapsulation



- At each stage the packet has a header and payload field.
- Attachment of header to the payload is called encapsulation
- Apart from this encapsulation also attaches a trailer that help mark the end of the data.

Sockets

- Interface between application and transport layer.
- It is an API exposed by the host
- Developer has full control over the socket on the application layer side but none on the transport layer side

- Socket = IP+PORT

Protocol	Port
File Transfer (FTP)	21
Secure FTP / SSH FTP (SFTP)	22
FTP Secure (FTPS)	989 (data), 990 (command)
Trivial File Transfer Protocol (TFTP)	69
Telnet	23
Hypertext Transfer Protocol (HTTP)	80
Hypertext Transfer Protocol Secure (HTTPS)	443
Secure Copy (SCP)	22
Secure Shell (SSH)	22
Simple Mail Transport Protocol (SMTP)	25
Simple Network Management Protocol (SNMP)	160, 161, 162
NetBIOS	137 (name service), 138 (datagram), 139 (session)

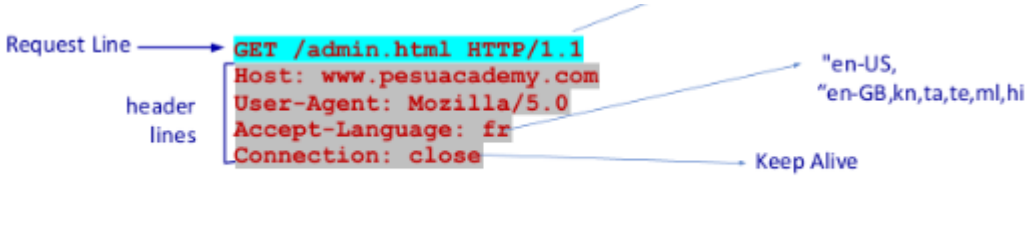
- Transport layer can provide the following services to the user:
  - Reliable data transfer
  - timing
  - security
  - throughput
  - TCP/UDP

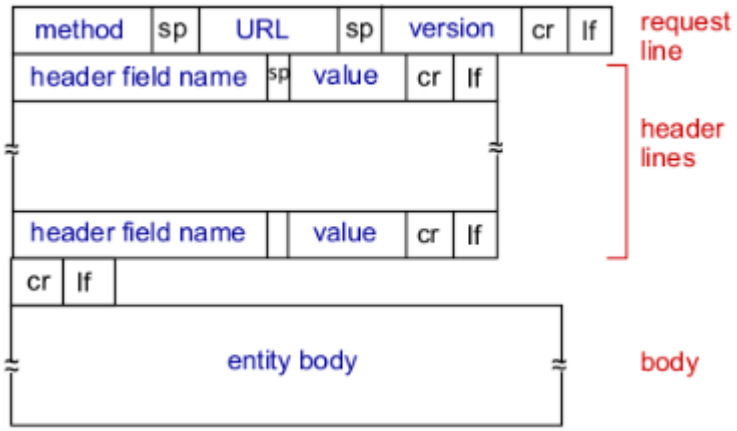
Web and HTTP

- On demand service.
- HTTP is the heart of web applications. (defined in RFC 2616,1945)
  - client makes a request at port 80
  - server accepts and servers the requested content
  - connection is closed
  - Stateless(doesn't store past history)
- Types:
  - Persistent
    - connection is left open
    - subsequent responses and requests happen over the same connection.
    - 2RTT for connection
  - Non Persistent
    - 2RTT per object
- RTT(Round Trip Time): time to travel from client to server and back
  - one RTT for TCP
  - one RTT for HTTP request
  - file transfer time
  - Non persistent response time = 2RTT+file transmission time

- By default HTTP uses Persistent with pipelining

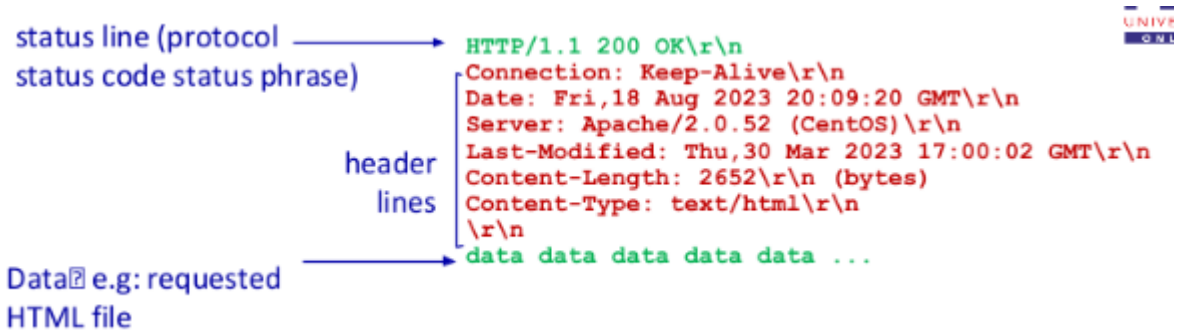
HTTP Request message

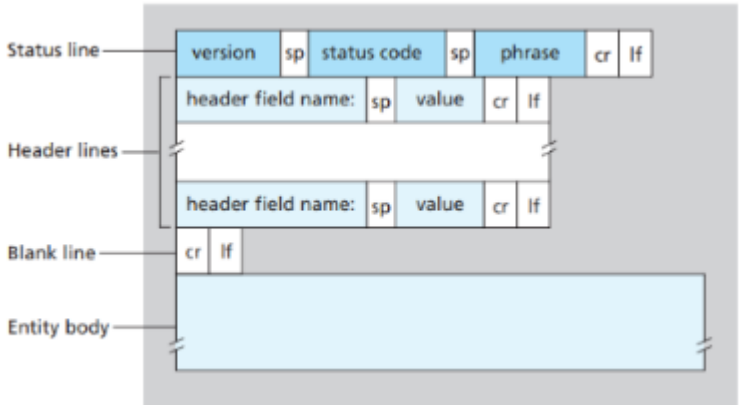




- RFC 1945,2616,7540
- HTTP Request Messages
  - GET
  - POST
  - PUT
  - HEAD
  - DELETE

HTTP Response Message





- Status Codes:
  - 200: OK
  - 301: Moved Permanently
  - 400: Bad request
  - 404: Not found
  - 505: HTTP Version not supported

HTTP and HTTPS

- HTTPS uses an SSL(Secure socket layer) certificate to encrypt the information
- TSL(Transport Security Layer) provides secure communications between C/S
- HTTPS operates on the Transport layer

Cookies

- Site specific data used to keep track of user sessions
- HTTP is stateless and hence doesn't store history.
- Cookies are used to maintain some state

Web Cache

- Proxy server; satisfies HTTP requests on behalf of WS
- Keeps copies of recently requested assets
- Act as both client and server
  - Reduces response time
  - Reduces traffic