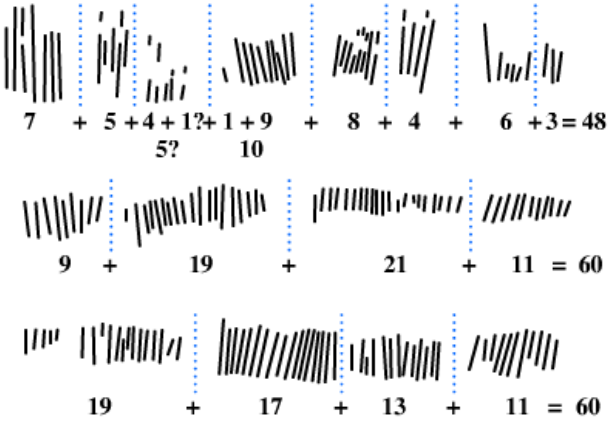
Internet Explained
Spring Fundamentals

Table of Content

Introduction to Internet
An Introduction to the Internet

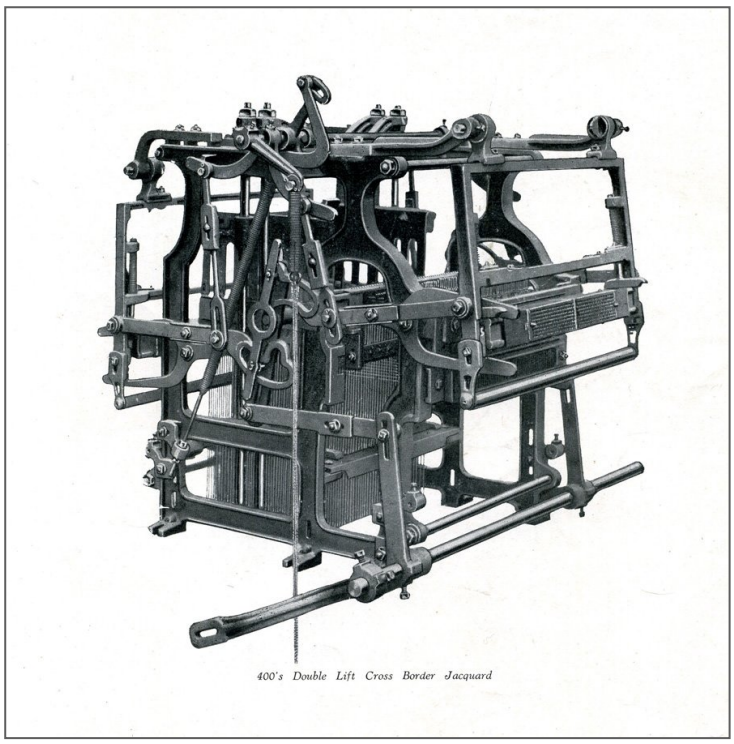
Ishango Bone

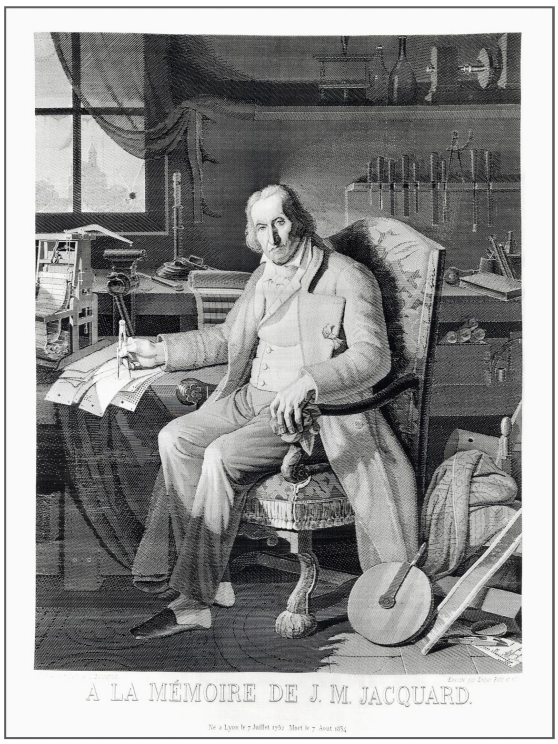
- The Ishango bone is a bone tool and possible mathematical object, dated to the Upper Paleolithic era
- The etchings on the bone are in three columns with marks asymmetrically grouped into sets, leading hypotheses such as that the implement indicates an understanding of decimals or prime numbers



Jacquard machine

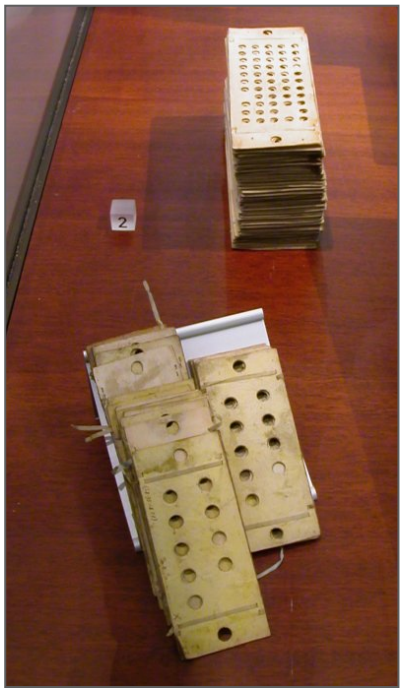
- Joseph-Marie Jacquard, a French weaver and merchant, patented his invention in 1804
- Machine use of interchangeable cards, upon which small holes were punched, which held instructions for weaving a pattern

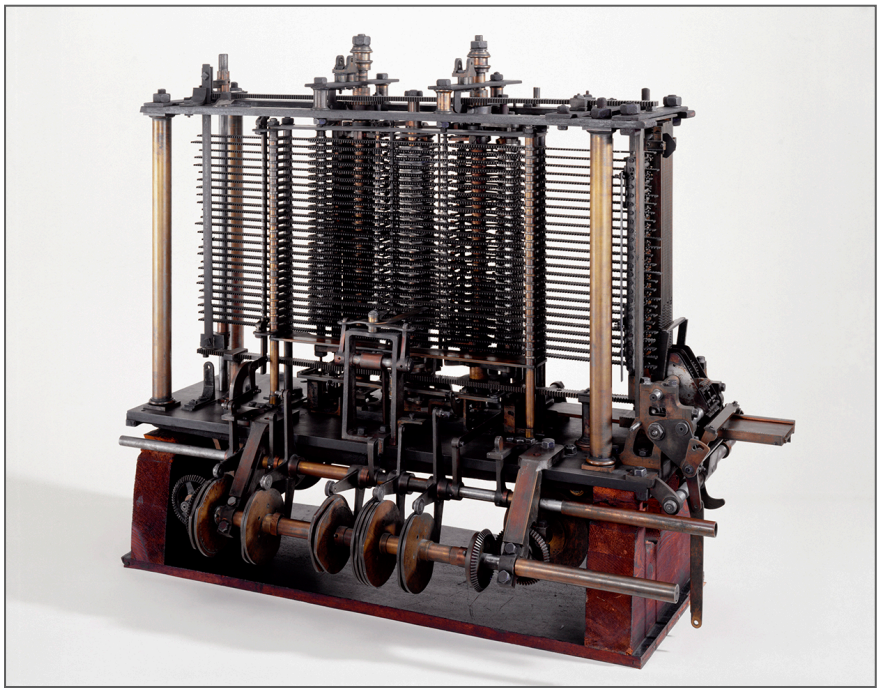


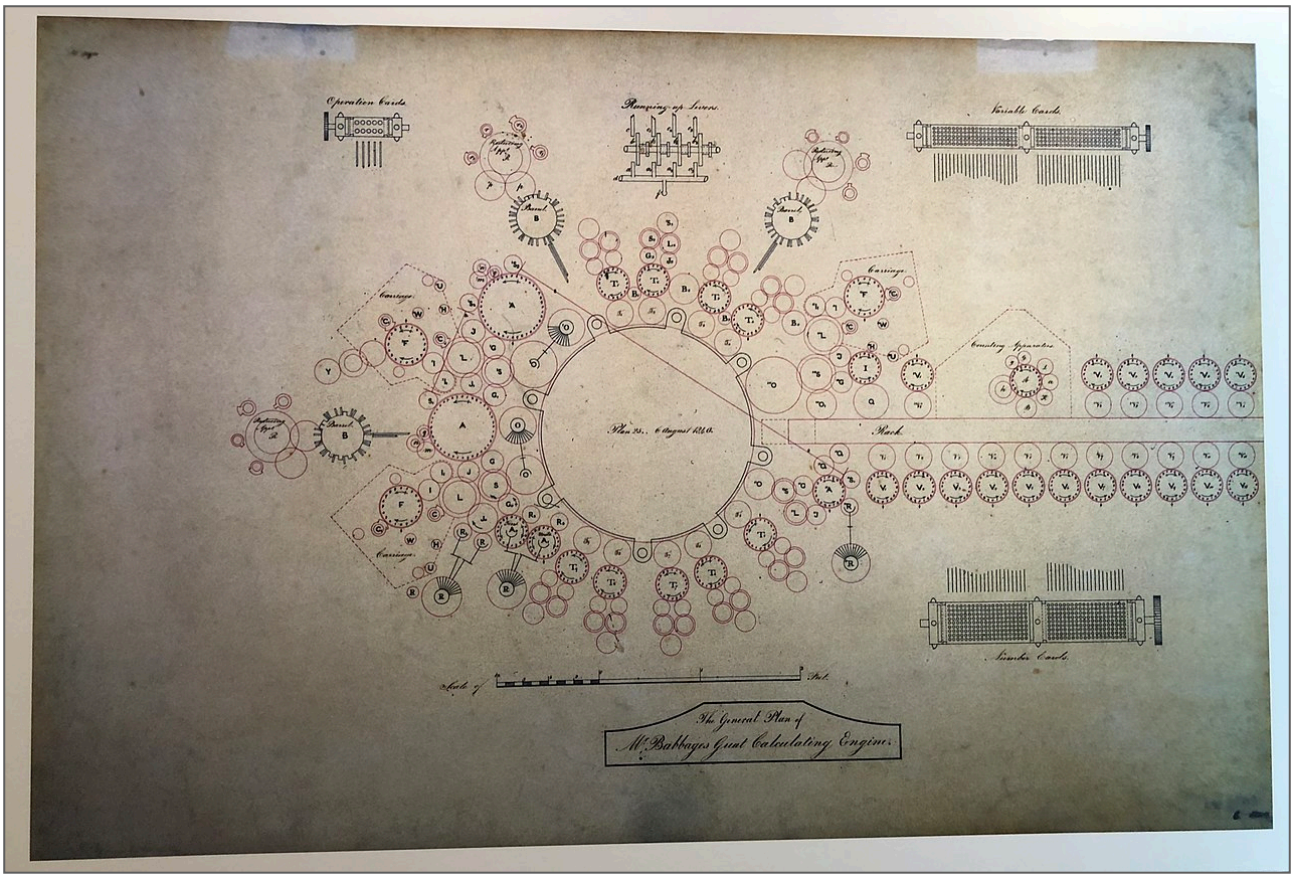


Analytical Engine

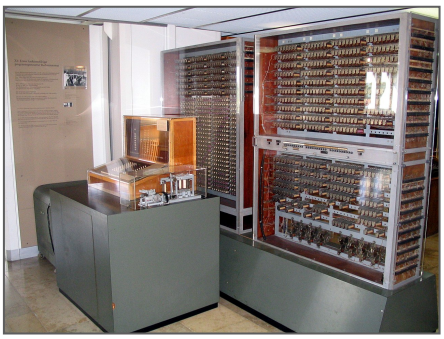
- The Analytical Engine was a proposed mechanical general-purpose computer designed by English mathematician and computer pioneer Charles Babbage
- The Analytical Engine incorporated an arithmetic logic unit, control flow in the form of conditional branching and loops, and integrated memory, making it the first design for a general-purpose computer that could be described in modern terms as Turing-complete







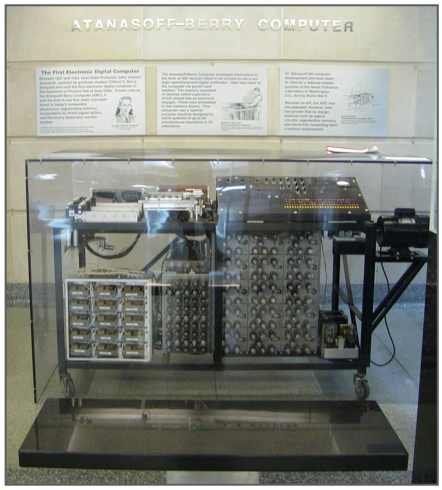
Tabulating machine & Z3

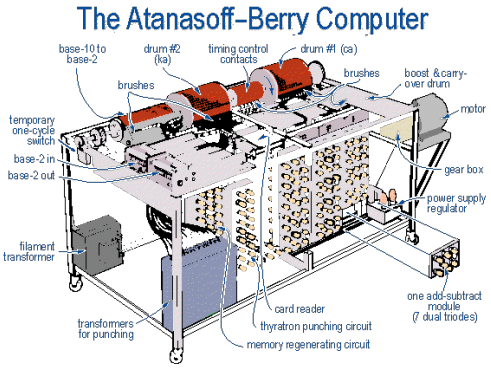


- The Tabulating machine was an electromechanical machine designed to assist in summarizing information stored on punched cards
- Invented by Herman Hollerith
- Later models were widely used for business applications such as accounting and inventory control
- The Z3 was a German electromechanical computer designed by Konard Zuse in 1935, and completed in 1941. It was the world's first working programmable, fully automatic digital computer

Atanasoff-Berry computer

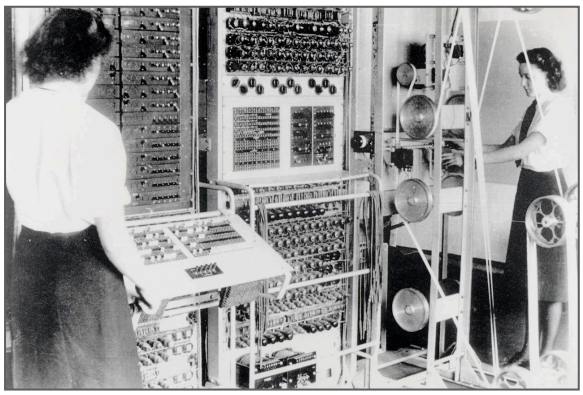
- The Atanasoff-Berry computer (ABC) was the first automatic electronic digital computer
- The ABC would be considered the first electronic ALU (Arithmetic Logic Unit) - which is integrated into every modern processor's design
- Its unique contribution was to make computing faster by being the first to use vacuum tubes to do the arithmetic calculations

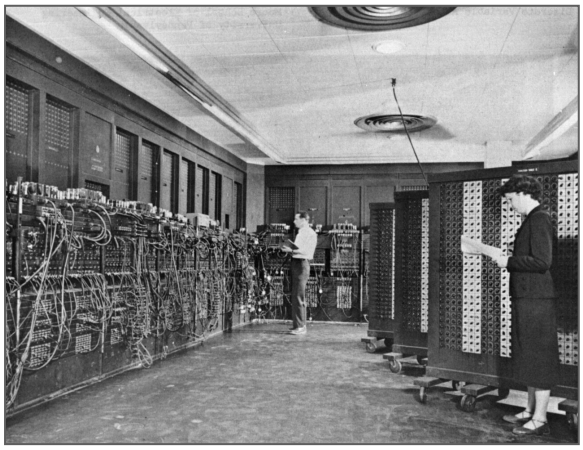




Colossus & ENIAC

- Colossus was a set of computers developed by British codebreakers in the years 1943-1945 to help in the cryptanalysis of the Lorenz cipher
- Colossus used thermionic valves (vacuum tubes) to perform Boolean and counting operations
- Colossus is thus regarded as the world's first programmable electronic, digital computer, although it was programmed by switches and plugs and not by a stored program
- ENIAC (Electronic Numerical Integrator and Computer) the first programmable, electronic, general-purpose digital computer. It was Turing-complete and able to solve "a large class of numerical problems" through reprogramming
- Was designed and primarily used to calculate artillery firing tables for the United States Army's Ballistic Research Laboratory



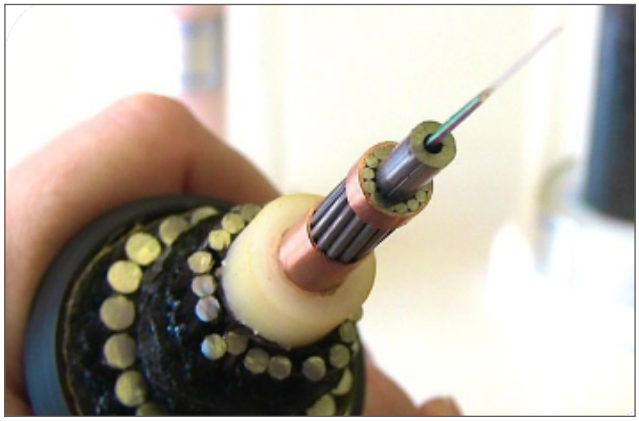


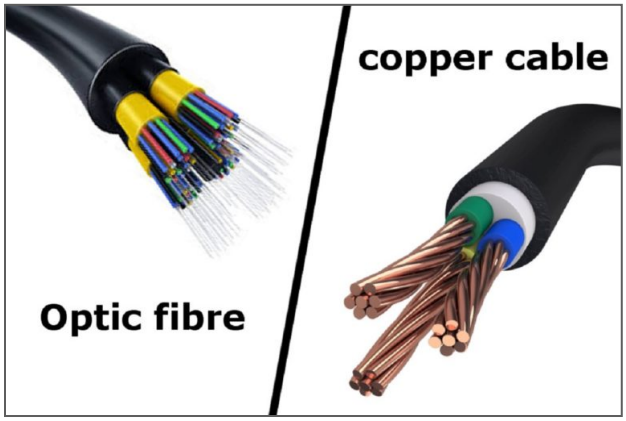
Internet – History

- Begins with the development of electric computers in the 1950s
- Packet switching networks were developed in the late 1960
- The internet protocol was developed in the 1970s
- In the 1980s at CERN Tim Berners-Lee created the World Wide Web – the first website, linking hypertext documents into an information system, accessible from any node on the network

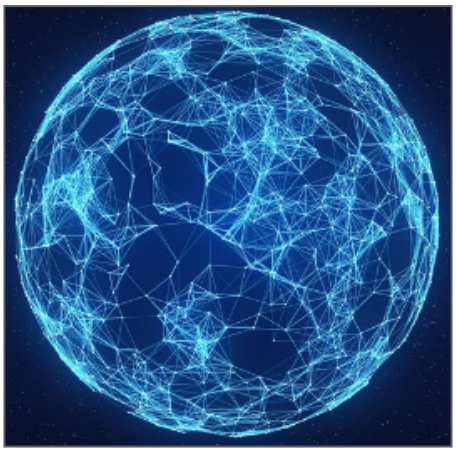
Internet – Introduction

- So, what is the Internet?
  - A simple answer to that question is a wire. A wire, which is buried into the ground or even in the ocean
  - That wire can be fibre optics, copper or occasionally beamed to satellites or through cell phone network





- ISPs (Internet Service Providers) have access to such cables
- We get indirectly connected to them though ISPs
- The Internet is a network of networks. It connects billions of devices together all over the globe that are connected to this wire in one form or another



What is a Network?

- Network - a group of two or more devices that can communicate
- It is comprised of a number of different computer systems connected by physical and/or wireless connections
- The scale can range from a single PC sharing out basic peripherals to massive data centers located around the World, to the Internet itself

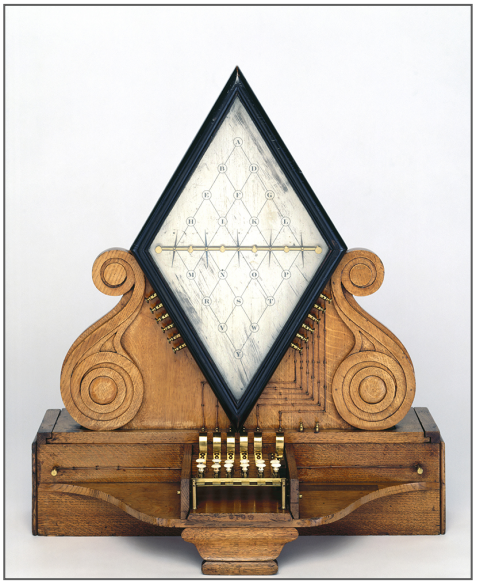
Networks and Internet

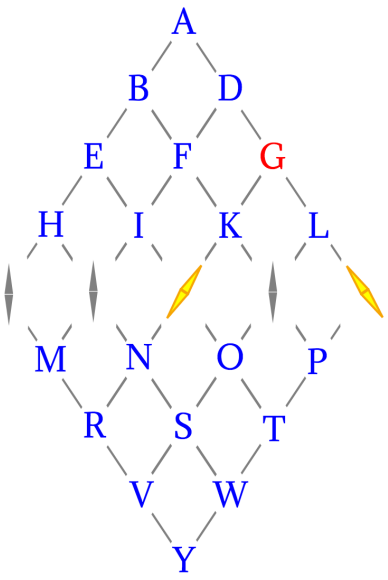
- The internet is made of hundreds of thousands of networks and billions of computers and devices connected physically
- These different systems connect to each other, communicate with each other and work together because of standards for how data is sent

Plain text
The fascinating story of plain text

Cooke and Wheatstone Telegraph

- Cooke and Wheatstone telegraph was invented around 1830s
- 5 needles – five cables
- Not all letters were present
- Easy to use
- ... John Tawell was hanged because of it



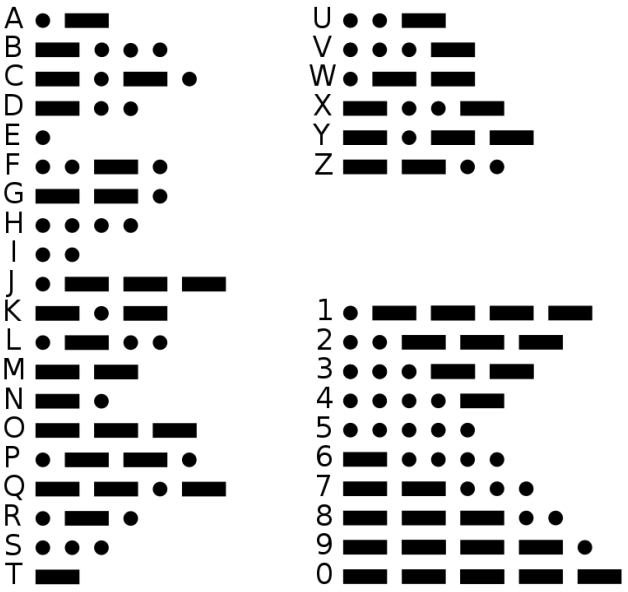


Samuel Morse, Friedrich Gerke

- Agreed as standard 1865
- Used around the world
- Lasted around 100 years

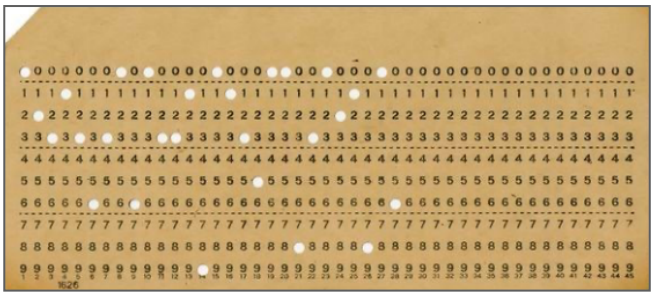
International Morse Code

1. The length of a dot is one unit.
2. A dash is three units.
3. The space between parts of the same letter is one unit.
4. The space between letters is three units.
5. The space between words is seven units.



ASCII

- Work began 1961
- First edition 1963
- Revision 1967
- Internet standard 2015



ASCII - control characters

Dec	Hex	Binary	HTML	Char	Description
0	00	00000000	&#0;	NUL	Null
1	01	00000001	&#1;	SOH	Start of Header
2	02	00000010	&#2;	STX	Start of Text
3	03	00000011	&#3;	ETX	End of Text
4	04	00000100	&#4;	EOT	End of Transmission
5	05	00000101	&#5;	ENQ	Enquiry
6	06	00000110	&#6;	ACK	Acknowledge
7	07	00000111	&#7;	BEL	Bell
8	08	00001000	&#8;	BS	Backspace
9	09	00001001		HT	Horizontal Tab
10	0A	00001010
LF	Line Feed
11	0B	00001011	&#11;	VT	Vertical Tab
12	0C	00001100		FF	Form Feed
13	0D	00001101
CR	Carriage Return
14	0E	00001110	&#14;	SO	Shift Out
15	0F	00001111	&#15;	SI	Shift In
16	10	00010000	&#16;	DLE	Data Link Escape
17	11	00010001	&#17;	DC1	Device Control 1
18	12	00010010	&#18;	DC2	Device Control 2
19	13	00010011	&#19;	DC3	Device Control 3
20	14	00010100	&#20;	DC4	Device Control 4
21	15	00010101	&#21;	NAK	Negative Acknowledge
22	16	00010110	&#22;	SYN	Synchronize
23	17	00010111	&#23;	ETB	End of Transmission Block
24	18	00011000	&#24;	CAN	Cancel
25	19	00011001	&#25;	EM	End of Medium

- Intended to control the machinery
- Many survive today

ASCII - \r\n

Windows

Linux

\n

Windows

\r\n

ASCII - string comparisons

Dec	Hex	Binary	HTML	Char	Description
65	41	01000001	&#65;	A	Capital A
66	42	01000010	&#66;	B	Capital B
67	43	01000011	&#67;	C	Capital C
68	44	01000100	&#68;	D	Capital D
69	45	01000101	&#69;	E	Capital E

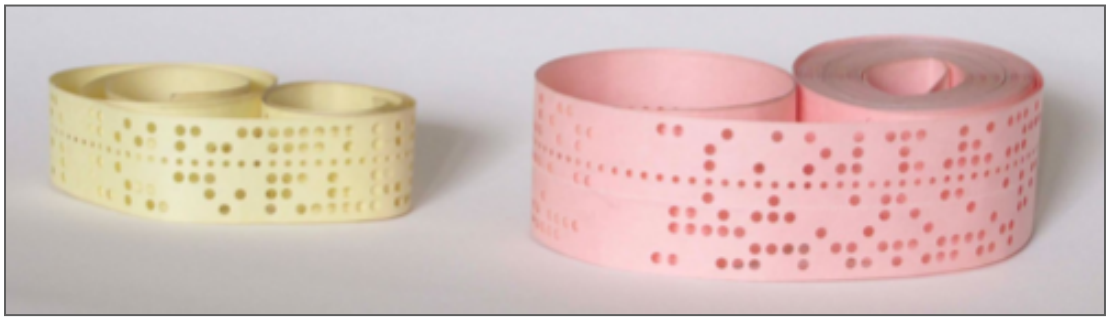
Dec	Hex	Binary	HTML	Char	Description
97	61	01100001	&#97;	a	Small a
98	62	01100010	&#98;	b	Small b
99	63	01100011	&#99;	c	Small c
100	64	01100100	&#100;	d	Small d
101	65	01100101	&#101;	e	Small e

ASCII - numbers

48	30	00110000	&#48;	0	Zero
49	31	00110001	&#49;	1	One
50	32	00110010	&#50;	2	Two
51	33	00110011	&#51;	3	Three
52	34	00110100	&#52;	4	Four
53	35	00110101	&#53;	5	Five
54	36	00110110	&#54;	6	Six
55	37	00110111	&#55;	7	Seven
56	38	00111000	&#56;	8	Eight
57	39	00111001	&#57;	9	Nine

ASCII - delete

1111111 (DEL)



ASCII - and the rest of the world

Windows-1251, KOI8

Code pages

kohuept

Çäðàñòè, äîêòîðå.

K O H Ц E P T

203 207 206 195 197 210 212

11001011 11001111 11001110 11000011 11000101 11010010 11010100
01001011 01001111 01001110 01000011 01000101 01010010 01010100

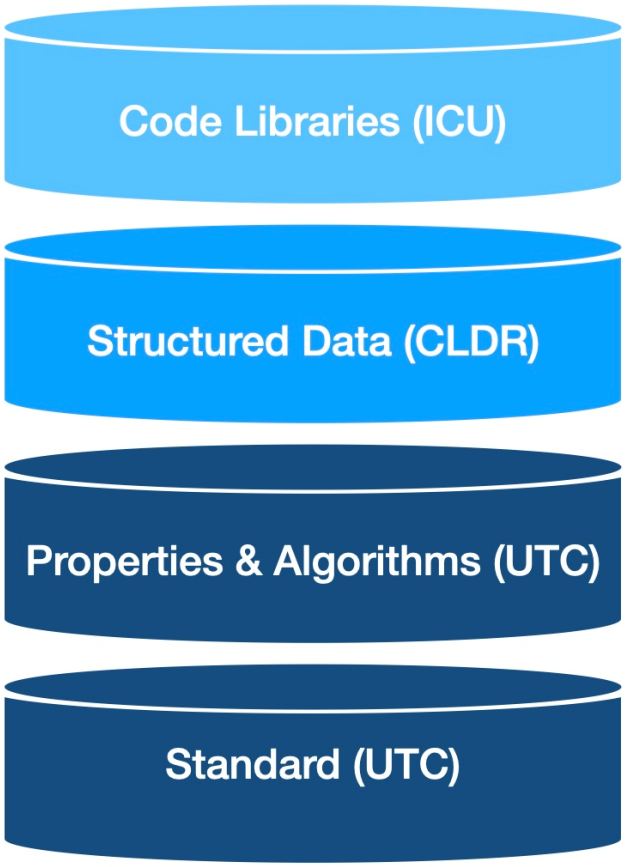
75 79 78 67 69 82 84

K O N C E R T

Unicode

- Everyone in the world should be able to use their own language on phones and computers

The standards body for the internationalization of software and services

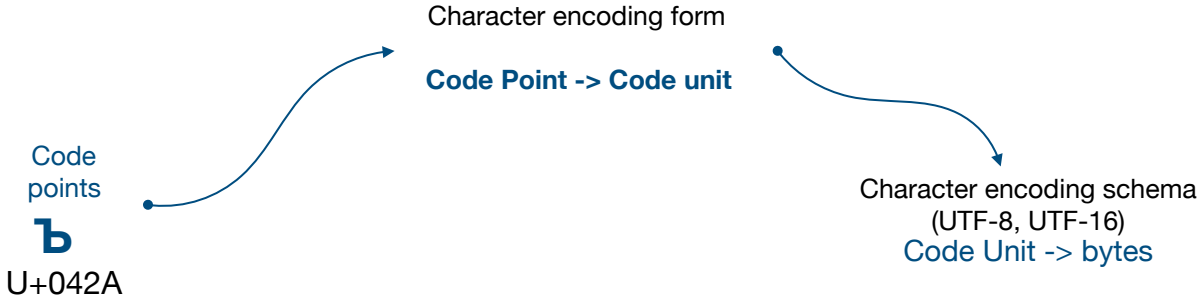


Allow easy integration into operating system, applications, services, and more

Language-specific data for sorting, formatting, and processing of dates, times, numbers, currencies, and more

Provide character/emoji properties and behavior to ensure correct and consistent use across all platforms

Encoding of nearly 150,000 characters covering the world's languages (and emoji!)



UTF-16

H	E	L	L	O	!
00|48	00|65	00|6c	00|6c	00|6f	00|21

UTF-8

	00	01	02	03	04	05	06	07	08	09	0A	0B	0C	0D	0E	0F	
00	3C	68	74	6D	6C	3E	0A	3C	62	6F	64	79	3E	0A	20	20	<html> <body>
10	20	D0	97	D0	B4	D1	80	D0	B0	D0	B2	D0	B5	D0	B9	D1	З□д□р□а□в□е□й□т
20	82	D0	B5	21	0A	3C	2F	62	6F	64	79	3E	0A	3C	2F	68	□е□! </body> </h
30	74	6D	6C	3E													tml>

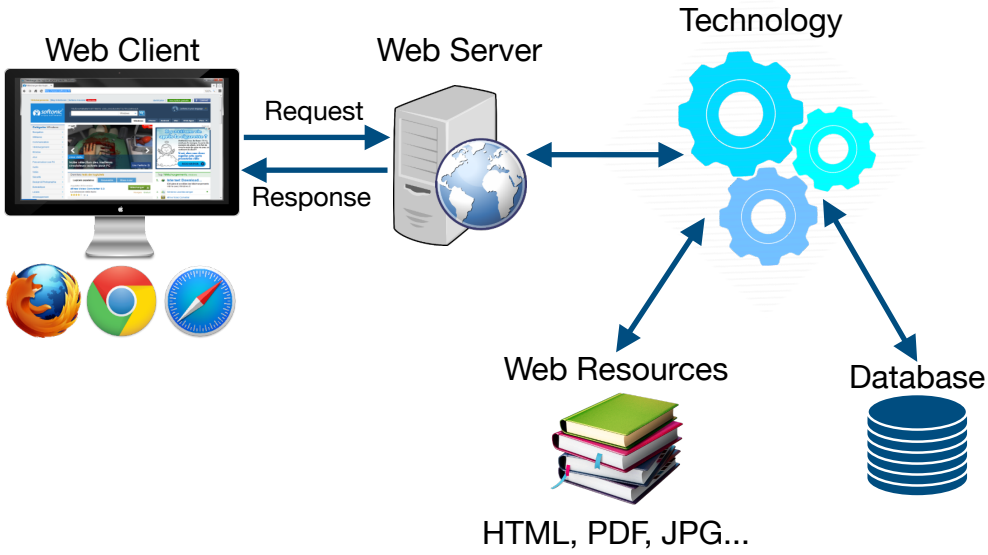
Code point ↔ UTF-8 conversion

First code point	Last code point	Byte 1	Byte 2	Byte 3	Byte 4
U+0000	U+007F	0xxxxxxx			
U+0080	U+07FF	110xxxxx	10xxxxxx		
U+0800	U+FFFF	1110xxxx	10xxxxxx	10xxxxxx	
U+10000	[b]U+10FFFF	11110xxx	10xxxxxx	10xxxxxx	10xxxxxx

```
<html>
<body>
   Здравейте!
</body>
</html>
```

How Does the Internet Work?

Web Server Work Model

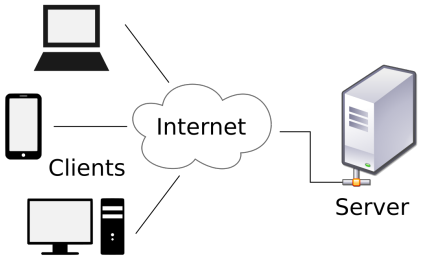


Important Definitions

- To understand how the Internet works, first we need to get acquainted with a few definitions
- What is?
  - Server and Client
  - Network Protocol
  - Packets
  - TCP vs UDP

Server and Clients

- All of the machines on the Internet are either servers or clients
- Servers are the machines that provide services to other machines
- Clients are the machines that are used to connect to those services



Network Protocol

- Network Protocol – a set of rules and standards, that allow communication between network devices
- Network protocols include mechanisms for devices to identify and make connections with each other
- Example for standard network protocols:
  - TCP, UDP, IP, ARP
  - HTTP, FTP, TFTP, SMPT, SSH

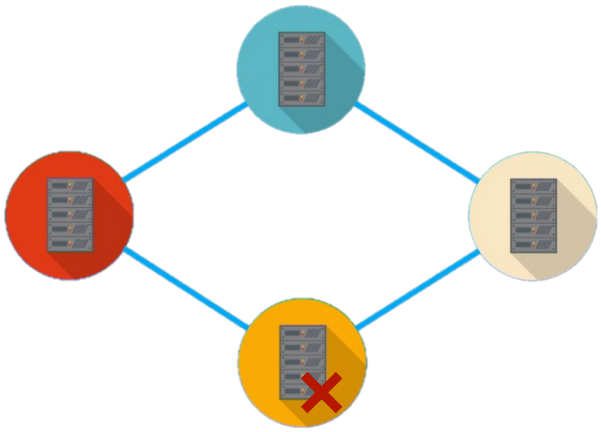
Packets
Sending and Receiving Information

Packets

- Everything that is created on a computer is translated into digital information using bits
- Bits need to have a way to be transmitted over the internet
- Every message, file or stream of information is broken down into small chunks called packets
- When packets are sent on the internet, they usually travel the network together
- But they might have to take a different route to get the destination
- Each packet contains some important information inside of it called the header:
  - Where it came from
  - Where is it going
  - How long it is
    - This is how the packet is known to be complete
    - All the packets in the message are the same size

- How many packets there are in the overall message

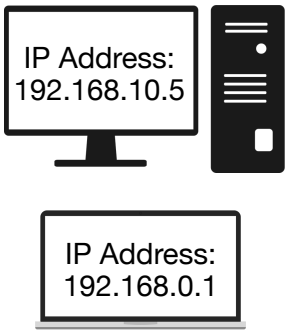
Traveling of the Packets in the Network



Internet Protocol
IPv4, IPv6 and DNS

Internet Protocol

- One of the most important protocols used in Internet communication is the Internet Protocol (IP)
- All the devices on the Internet have addresses
- They are called IP Addresses
- The IP address is unique to each computer or a device at the edge of the network

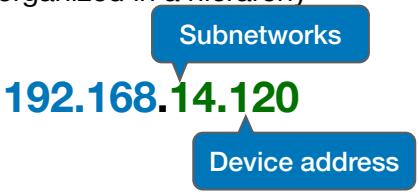


IPv4

- IPv4 is a sequence of four, three-digit numbers separated by a period
  - Each number can be a number from 0 to 255
  - IPv4 is not enough for all network devices connected to the internet
- In 1995, a new version of the internet protocol was created, it's called IPv6

IP Address

- An IP Address has many parts, organized in a hierarchy



- This version of IP Addressing is called IPv4
  - Provides more than 4 billion 32 bits unique addresses

IP address classes

Class A **0. 0. 0. 0 =** **127.255.255.255 =**	00000000. 01111111. 0nnnnnnn.	00000000. 11111111. HHHHHHHH	00000000. 11111111. HHHHHHHH	00000000 11111111 HHHHHHHH
Class B **128. 0. 0. 0 =** **191.255.255.255 =**	10000000. 10111111. 10nnnnnn.	00000000. 11111111. nnnnnnnn.	00000000. 11111111. HHHHHHHH	00000000 11111111 HHHHHHHH
Class C **192. 0. 0. 0 =** **223.255.255.255 =**	11000000. 11011111. 110nnnnn.	00000000. 11111111. nnnnnnnn.	00000000. 11111111. nnnnnnnn.	00000000 11111111 HHHHHHHH
Class D **224. 0. 0. 0 =** **239.255.255.255 =**	11100000. 11101111. 1110XXXX.	00000000. 11111111. XXXXXXXX.	00000000. 11111111. XXXXXXXX.	00000000 11111111 XXXXXXXX
Class E **240. 0. 0. 0 =** **255.255.255.255 =**	11110000. 11111111. 1111XXXX.	00000000. 11111111. XXXXXXXX.	00000000. 11111111. XXXXXXXX.	00000000 11111111 XXXXXXXX

What Is CIDR (Classless Inter-Domain Routing)

- Classless Inter-Domain Routing, is an IP addressing scheme that improves the allocation of IP addresses.
- It replaces the old system on classes A, B, and C.
- This scheme also helped greatly extend the life of IPv4 as well as slow growth of routing tables.

IPv4 Private Address Space and Filtering

CIDR	IP address range	Class
10.0.0.0/8	10.0.0.0–10.255.255.255	A
172.16.0.0/12	172.16.0.0–172.31.255.255	B
192.168.0.0/16	192.168.0.0–192.168.255.255	C

IPv6

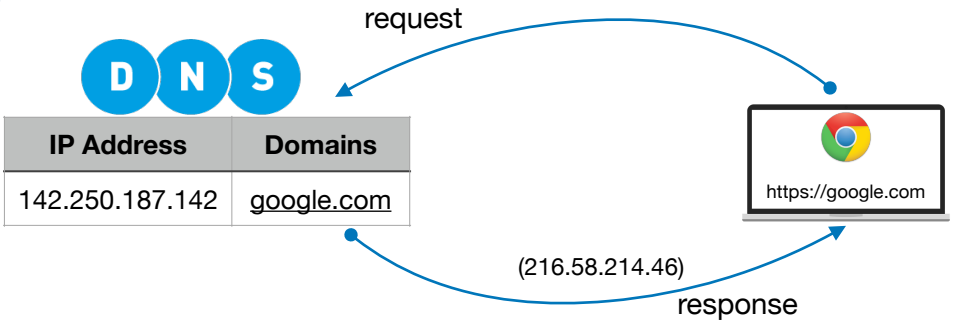
- IPV6 uses 128 bits - 340 undecillion unique addresses
  - That's more than the atoms on the surface of the Earth
- These 128 bits are organized into eight 16 bit sections
- Each 16 bit block is converted to hexadecimal and it's separated with a colon
- This is a full IPV6 address:
  - 3FFE:F200:0234:AB00:0123:4567:8901:ABCD
- The leading zeroes in IPv6 can usually be left out

What is a DNS?

www.google.com — Domain name

- The domain name is a human way to access IP addresses for devices and websites around the world
- It is a sequence of phrases that map to a giant Internet-wide database of IP addresses
- When a domain name is entered in the browser, a request is made to something called a DNS (Domain Name Server)
- This server holds a cache of tons of domain names, and their matching IP addresses

DNS Example



Reliability and TCP

Reliability

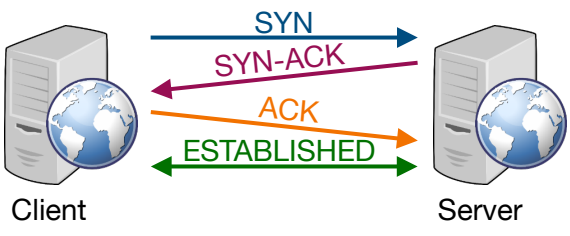
- When packets are transmitted from one location to another, they can take different paths
- When they got to the destination, they are unorganized and sometimes not complete
- So the message needs to be audited and reviewed in order to put it together in the right way
- The **Transmission Control Protocol** or **TCP** does exactly that

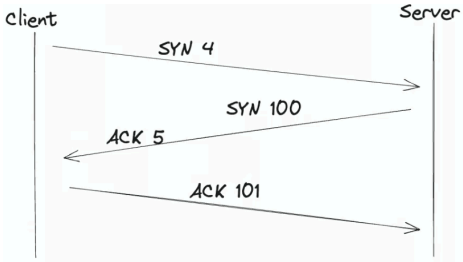
Transmission Control Protocol - TCP

- TCP uses a process, where it looks at all the packets in a message and checks them
- Using the header information in each packet it knows:
  - How many there are
  - How large they should be
  - In which order the packets should be in
- Using this checklist, it is able to rearrange the packets
- If it finds that a packet doesn't match the expected characteristic, it is discarded

- TCP has to verify that all the packets are:
  - In the right order
  - Free of any issues

- After that it certifies the data and the packets are merged together to recreate the original file that was on the sender's device





TCP vs UDP

- TCP places reliability in a higher priority than speed or latency
- For instances where reliability isn't as important, but speed is, there is another protocol called UDP or User Datagram Protocol
- UDP doesn't do excessive reliability checks, but it can send information at a faster rate
- TCP is the foundation of how a majority of data transmitted over networks

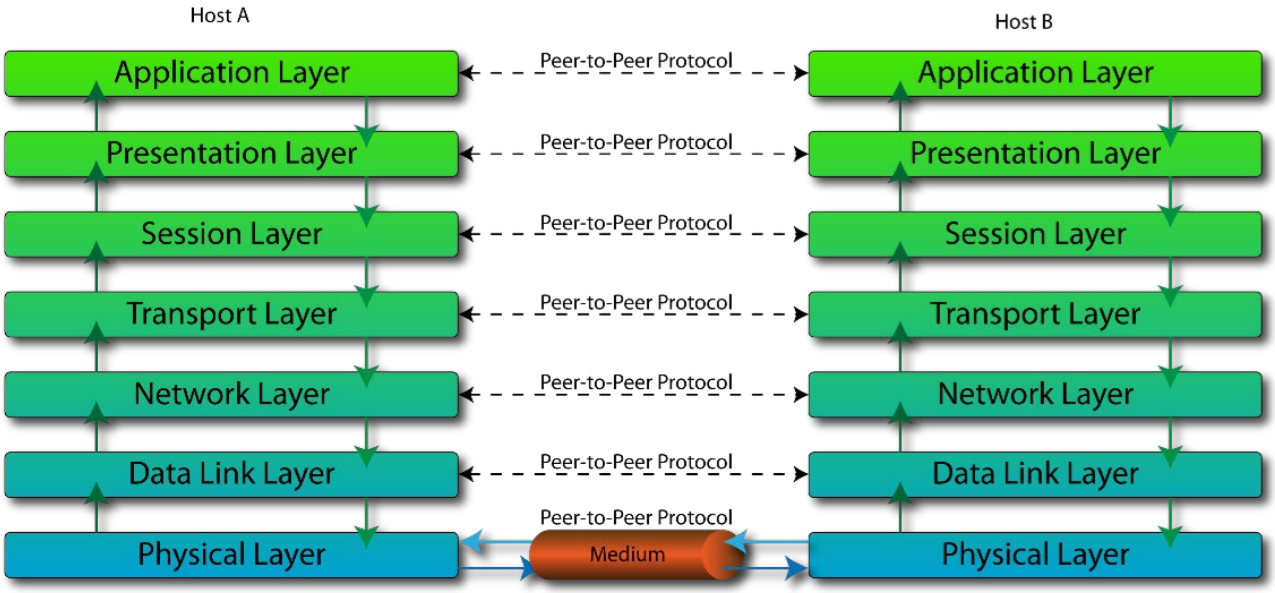
User Datagram Protocol

- UDP does not establish a session and it does not guarantee data delivery
- It is known as the "fire-and-forgot" protocol
  - It sends data and it doesn't really care if the data is received at the other end

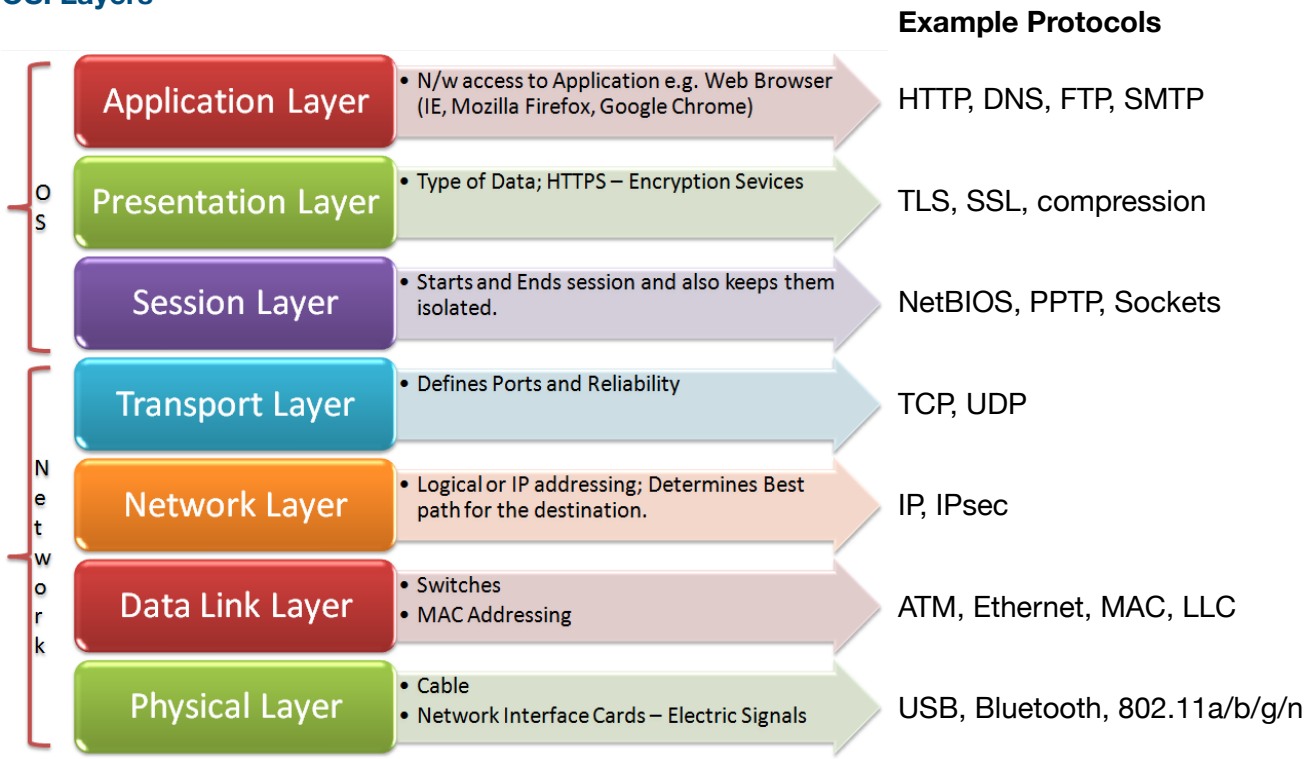
The OSI Model

What is the OSI Model?

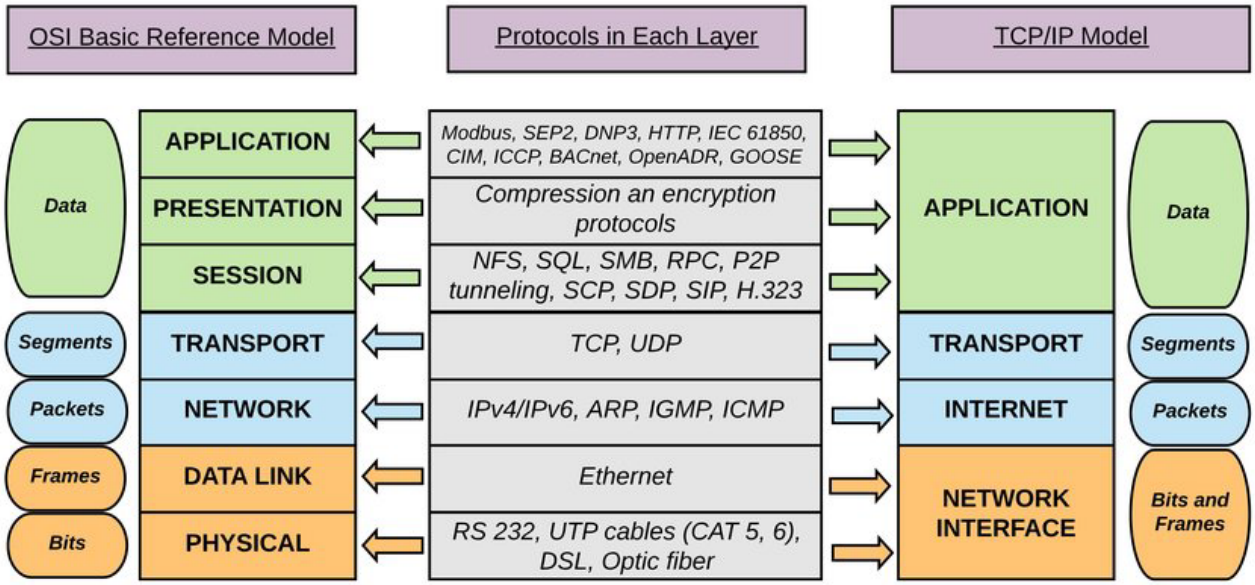
- OSI model stands for Open System Interconnect
- It consists of 7 layers
  - Each layer serves the layer above it and in return, is served by the layer below it
- Understanding each layer of the model helps us with:
  - Troubleshooting
  - Communicating better with technical and non-technical individuals about any system



OSI Layers

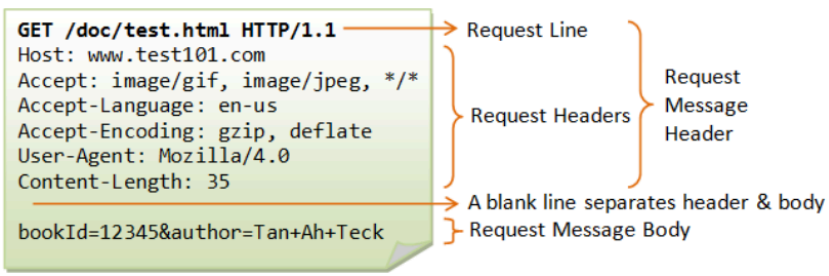


TCP/IP model mapping to OSI



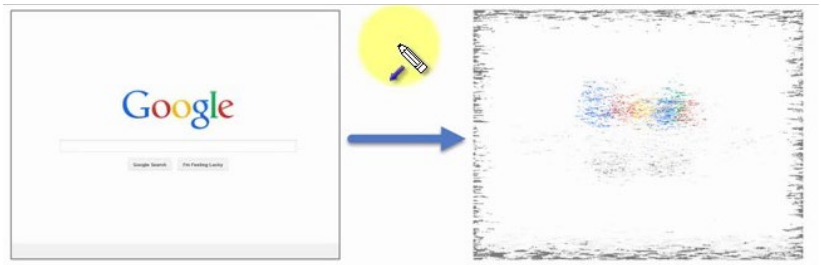
Application Layer – 7

- Enables different applications like the browser to use the network and present it to the End User
- Protocol examples
  - Domain Name System (DNS)
  - File Transfer Protocol (FTP)
  - HyperText Transfer Protocol (HTTP)
  - Simple Mail Transfer Protocol (SMTP)



Presentation Layer – 6

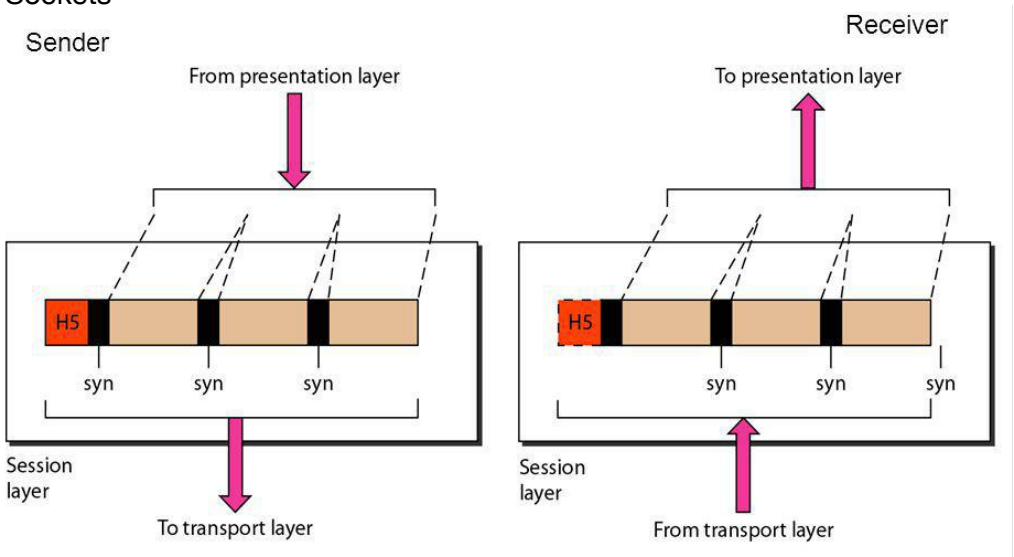
- This layer is a part of an operating system (OS)
- Converts incoming and outgoing data from one presentation format to another



- Converts incoming and outgoing data from one presentation format to another
- Example:
  - From clear text to encrypted (or compressed) text
  - Back to clear text

Session Layer – 5

- This layer sets up coordinates and terminates conversations
- Its services include authentication and reconnection after an interruption
- e.g.: Sockets



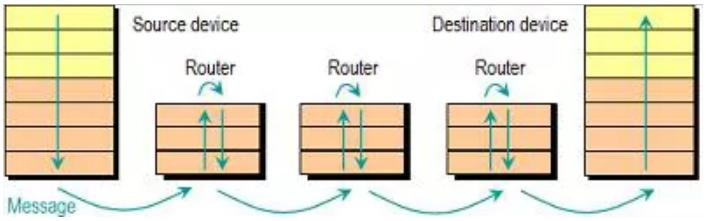
Transport Layer – 4

- Responsible for end-to-end communication over a network
- Provides logical communication between application processes
- Responsible for the management of error correction, providing quality and reliability to the end user
- Protocol examples:
  - **Transmission Control Protocol (TCP)**
  - **User Datagram Protocol (UDP)**

Network Layer – 3

- Provides the functional and procedural means of transferring packets from one node to another
- Responds to service requests from the transport layer and issues service requests to the data link layer
- Protocol examples:

- Internet Protocol (IP)
- IPSec (IP + Auth)



Data Link Layer – 2

- Provides node-to-node data transfer
- It detects and possibly corrects errors that may occur in the physical layer
- Divides into two sublayers:
  - Medium access control (MAC) layer – controlling how devices in a network gain access to a medium and permission to transmit data
  - Logical link control (LLC) layer – identifying encapsulating network layer protocols, controls error checking and frame synchronization
- Protocol examples:
  - Asynchronous Transfer Mode (ATM)
  - Ethernet
  - MAC

Destination address	Source address	Other header	...1001101010001001...	Frame footer

Physical Layer – 1

- The things you can actually physically touch
- Converts the binary from the upper layers into signals, transmits them over local media (electrical, light, or radio signals)
- Examples:
  - Ethernet
  - USB
  - Bluetooth
  - 802.11a/b/g/n

Summary

- Internet, Definitions of Internet
- Sending and Receiving Information
- OSI model
  - Layers
- Network Hardware
- The Future of the Internet