Computer Networks 1 | CN1

Summary

CONTENTS

1. APPLICATION LAYER (7,6,5)

Combines Layers 7 (Application), 6 (Presentation) and 5 (Session).

1.1. COMMON PORTS

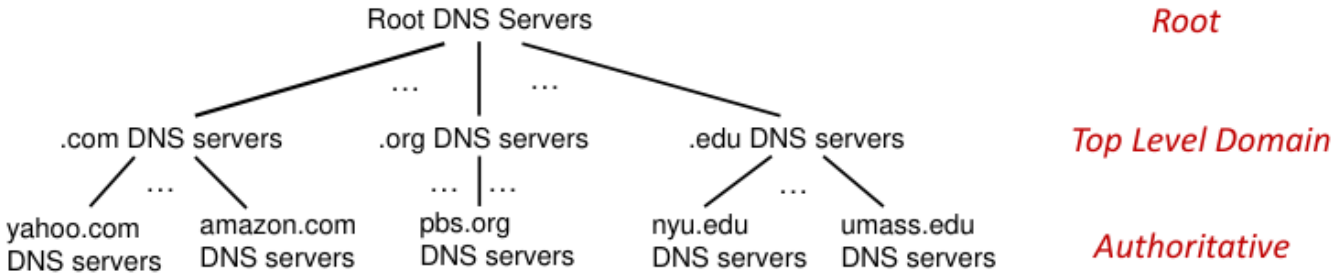
Protocol	*Port*	*Layer 4*
DNS	53	UDP, TCP
HTTP	80	TCP
HTTPS	443	TCP
FTP	20, 21	TCP
SMTP	25 (server) 587 (client)	TCP
POP3	110	TCP
DHCP	67 (server) 68 (client)	UDP

1.2. HTTP

Feature	*HTTP/1.0*	*HTTP/1.1*	*HTTP/2*	*HTTP/3*
Connection Management	One request per connection	Persistent connections by default	Multiplexing allows multiple streams	Uses QUIC for multiplexing
Request Methods	Limited (GET, POST, HEAD)	Enhanced (PUT, DELETE, OPTIONS, etc.)	Same as 1.1	Same as 1.1
Caching	Basic caching support	Improved caching with validation	Advanced caching capabilities	Same as 2 but with improved mechanisms
Header Compression	None	None	HPACK (header compression)	QPACK (header compression)
Server Push	Not supported	Not supported	Supported (automatic resource pushing)	Enhanced support for server push
Performance Improvements	None	Minor improvements over 1.0	Significant improvements in performance and latency	Further improvements in speed and efficiency
SSL/TLS Support	Not inherent	Not inherent, but commonly supported	Built-in support with ALPN (Application-Layer Protocol Negotiation)	Uses QUIC, which incorporates TLS 1.3
Transport Protocol	TCP	TCP	TCP	QUIC

1.3. DNS

Nameservers resolve domains to IP's through a distributed, hierarchical database.



Term	*Definition*
Iterated query	Local DNS server iteratively asks one server after the other, descending the domain name hierarchy step after step.
Recursive query	Local DNS server asks root server for domain, which in turn asks the TLD server, which in turn asks the authoritative server etc. until the "call stack" unwinds and returns the fully resolved domain to the query sender.
Caching	

1.3.1. Record types

Term	*Definition*
A	***name***: hostname ***value***: IPv4 address
AAAA	***name***: hostname ***value***: IPv6 address
CNAME	***name***: alias ***value***: canonical name
NS	***name***: domain ***value***: hostname of authoritateive NS for this domain
MX	***name***: domain ***value***: name of mailserver

1.4. E-MAIL

Term	*Definition*
ding	
dong	
your	
opinion	
is	
wrong	

2. TRANSPORT LAYER (4)

Segment size: 1440-1480b when using IPv4, <=1460b when using IPv6

2.1. PRIMARY RESPONSIBILITIES

– Process-to-process delivery (distinguish between multiple applications via ports)
– Ensure reliable transfer (acknowledgments, retransmissions & reordering)
– Flow control (sender does not overwhelm receiver)
– Congestion control (network is not overloaded)

Term	*Definition*
Port	***16 bit long*** numbers (0d**0**-0d**65'535**) for identifying applications to send packets to. ***Well-Known***: 0d**0**-0d**1'023** for universal TCP/IP applications, managed by the IANA. ***Registered***: 0d**1'024**-0d**49'151** for known applications, also managed by the IANA. ***Private***: 0d**49'152**-0d**65'535** for custom applications, not managed by the IANA.
Socket	Combination of ***IP:Port***.
Multiplexing	Sending data from multiple sockets at sender.
Demultiplexing	Delivering segments to correct socket at receiver.
Checksum	Detect errors (i.e., flipped bits) in transmitted segment.

2.2. TCP

TODO: frame

Connection-oriented, bidirectional, reliable, managed data flow.

Term	*Definition*
Handshake	Agreement on **starting sequence numbers**, **maximum segment size** and **window scaling**. 1) SEQ 2) SEQ+ACK 3) ACK
FIN	Termination of a connection. 1) FIN 2) FIN+ACK 3) ACK
Round Trip Time	***RTT*** is the time it takes for a packet to be sent to the receiver and acknowledged back to the sender.
Buffer size	Maximum amount of data (measured in bytes) that can be stored in memory while waiting to be processed or transmitted.
Maximum Segment Size	***MSS*** is the maximum payload size of a TCP packet. In IPv4 networks, typically, the size of the MSS is **1460 bytes** because it is encapsulated in the data link layer Ethernet frame size of **1500 bytes**.

2.2.1. Reliability

Term	*Definition*
Sequence numbers	***SEQ*** ensures that the packets arrive or can be reassembled in order.
Acknowledgement	***ACK*** ensures that the receiver gets all of the packets.

Term	*Definition*
Retransmission timeout	If an acknowledgment is not received before the timer for a segment expires, a retransmission timeout occurs, and the segment is **automatically retransmitted**.
Packet loss rate	Measures how many packets of the ones being sent actually arrive.

2.2.2. Throughput

Term	*Definition*
Throughput	Denoted by ***T***, is the amount of data that can be transmitted during a specified time. $T = \frac{W}{R} \leq C_{L3}$
Continuous sending	Sender transmits a stream of data packets in the given window size **without waiting for acknowledgments**.
Delayed ACK	Receiver waits for a short period to acknowledge **multiple segments** with a **single ACK**.
Selective ACK	Instead of asking for a retransmission of all missing segments, ***SACK*** (specified by the receiver) allows the sender to send only the lost segments, significantly improving efficiency.

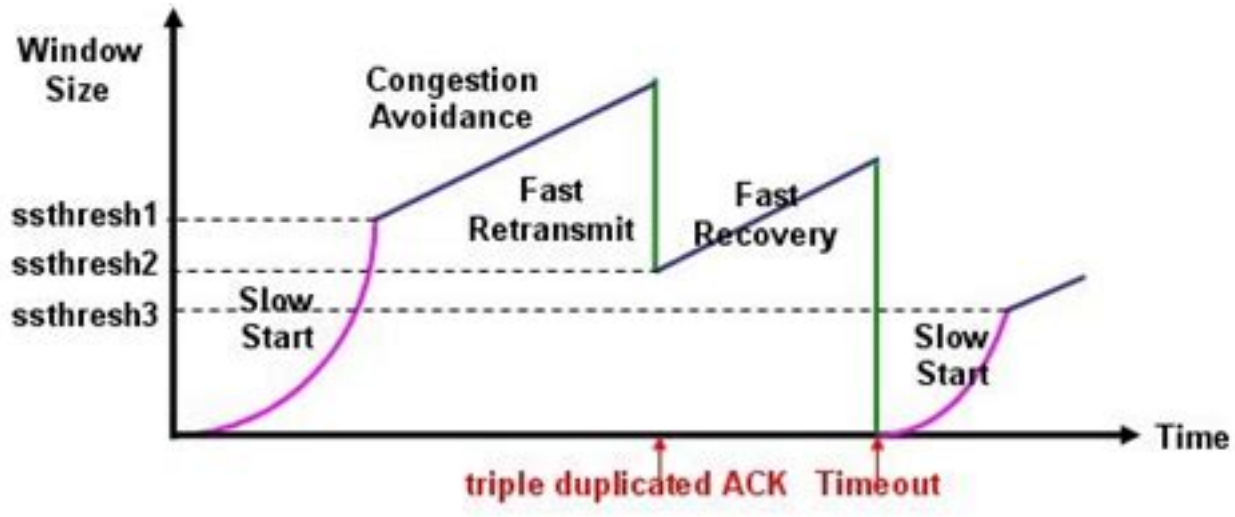
2.2.3. Flow control

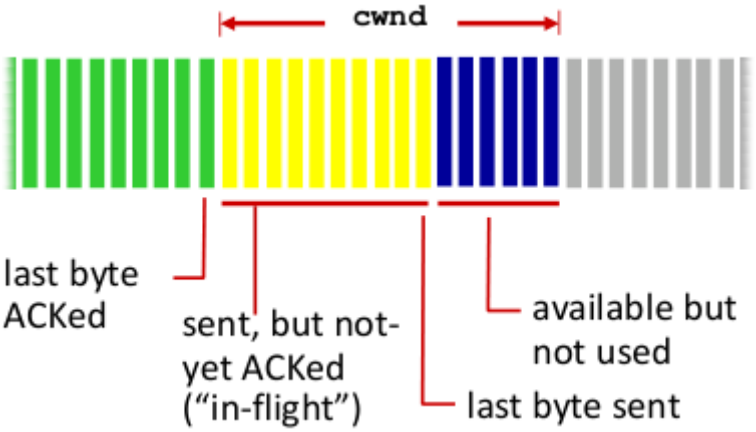
So that the sender does not overwhelm the receiver.

Term	*Definition*
Window Size	Denoted by ***W***, is a ***16 bit*** number sent with each packet by the receiver inside of the **rwnd** header field, indicating the amount of data he still has space for.
Window scale	Used when the TCP window size needs to be increased beyond the traditional maximum of 65,535 bytes due to the demands of high-speed networks. If the handshake header includes the **window scale option** and the packet header includes the **scaling factor** then the effective window size is calculated as such: **window size * scaling factor**

2.2.4. Congestion control

To prevent network congestion.



Term	*Definition*
Congestion window	
Sliding Window	Describes the process of the congestion window sliding to the right after receiving ACKs.
Slow start	Gradual growth (doubling **cwnd** every **RTT**) within the congestion window size at the start of a connection or after a period of state of no activity. ***Purpose***: Allows the sender to probe the available bandwidth in a controlled way.
Congestion avoidance	Transition from sluggish start to congestion avoidance segment after accomplishing a threshold. ***Purpose***: Maintains a truthful share of the community bandwidth even as heading off excessive congestion.
Fast Retransmit	Detects packet loss through duplicate acknowledgments and triggers speedy retransmission without waiting for the **retransmission timeout**. ***Purpose***: Speeds up the recuperation method with the aid of retransmitting lost packets without looking ahead to a timeout.
Fast Recovery	Enters a quick healing state after detecting packet loss, lowering congestion window and transitioning to congestion avoidance. ***Purpose***: Accelerates healing from congestion by way of avoiding a complete go back to slow begin after packet loss.
AIMD	Adjusts the congestion window size based on network situations following the **Additive Increase, Multiplicative Decrease** principle. ***Purpose***: Provides a balanced approach by way of linearly growing the window all through congestion avoidance and halving it on packet loss.

2.3. UDP

TODO: frame

2.4. QUIC

TODO: frame

Actually a layer 7 Protocol, running on top of UDP

3. NETWORK LAYER (3)

Packet size: **1500b**

3.1. SUBNETTING

Dividing a */X* network into *n* amount of */Y* subnets: $2^{Y-X} = n$.
Eg: Dividing a */16* network into */24* subnets will yield *256* subnets, because $2^{24-16} = 2^8 = 256$

3.2. IPV6

TODO: frame

3.2.1. Glossary

Term	*Definition*
Extension Header	Additional headers used in IPv6 to provide optional information. These can define aspects like payload size, routing, or fragmentation.
DHCPv6	Dynamic Host Configuration Protocol for IPv6; this allows servers to assign IPv6 addresses dynamically from a pool, similar to DHCP for IPv4.
NAT64	Network Address Translation from IPv6 to IPv4 and vice versa; it facilitates communication between IPv6 and IPv4 networks.
Neighbor Discovery Protocol **(NDP)**	A protocol in IPv6 for discovering other network nodes, determining their link-layer addresses, and ensuring that addresses are valid and reachable.
Internet Control Message Protocol **(ICMPv6)**	A crucial part of IPv6 that handles error messages and operational queries, with an expanded role compared to ICMP in IPv4.
MTU	Maximum Transmission Unit; the size of the largest packet that can be sent in a single frame over a network medium. IPv6 can handle larger MTUs compared to IPv4.
Multicast Listener Discovery **(MLD)**	IPv6 multicast routers can use MLD to discover multicast listeners on a directly attached link.
Path MTU Discovery **(PMTUD)**	Protocol for determining the Maximum Transmission Unit (MTU) size on the network path between two hosts, usually with the goal of avoiding IP fragmentation.

3.2.2. Special addresses

Term	*Definition*
Link-local Address	*FE80::/10* Used for local communication between devices on the same network segment.
Global Unicast Address	*2000::/3* A globally routable address, these addresses are equivalent to public IPv4 addresses and can be reached over the internet.
Unique Local Address **(ULA)**	*FC00::/7* An address for local communication that is not routable on the global internet, similar to private addresses in IPv4.
Multicast Address	*FF00::/8* An address that enables a single packet to be sent to multiple destinations simultaneously.
Anycast Address	An address assigned to multiple interfaces, where a packet sent to an anycast address is routed to the nearest (in terms of routing distance) interface.

Term	Definition
Reserved Address	Certain ranges in IPv6 are reserved for future use or specific functions. For example, addresses starting with ***::/128*** are reserved for unspecified addresses.
Documentation Address	***2001:DB8::/32*** Designated specifically for use in documentation and examples, ensuring it does not conflict with real-world addresses.
Link-local Multicast Address	***FF02::/16*** Part of the link-local address range; it enables devices to communicate within a local network without requiring an external routing address.

Addresses	Range	Scope
Unspecified	::/128	n/a
Loopback	::1	Host
IPv4-Embedded	64:ff9b::/96	n/a
Discard-Only	100::/64	n/a
Link-Local	fe80::/10	Link
Global Unicast	2000::/3	Global
Unique Local (ULA)	fc00::/7	Global
Multicast	ff00::/8	Variable

3.2.2.1. Multicast

Term	Definition
ff02::1	All nodes, within scope 2 (link-local).
ff02::2	All routers, within scope 2 (link-local).
ff02::1:ffxx:xxxx	The IPv6 node joins a solicited multicast address group from all the interfaces where unicast and anycast addresses are configured. Its scope is the link-local.

3.2.2.2. DHCPv6

Term	Definition
ff02::1:2	A link-scoped multicast address used by a client to communicate with neighboring (i.e., on-link) relay agents and servers. All servers and relay agents are members of this multicast group.
ff05::1:3	A site-scoped multicast address used by a relay agent to communicate with servers, either because the relay agent wants to send messages to all servers or because it does not know the unicast address of the servers.

3.2.3. Header

Term	Definition
Version	Always 6 with IPv6. IPv4 would be 4.
Flow Label	For identifying packets that require special handling, like real-time streaming.
Traffic Class	Priority or type of traffic.
Payload Length	Size of the payload in bytes.
Next Header	Type of optional header following the IPv6 header.

Term	Definition
Hop Limit	Maximum number of hops a packet can take before being discarded.

3.2.3.1. IPv6 Extension Headers currently defined

Term	Definition
Routing	Extended routing, like IPv4 loose source route. The Routing header is used by an IPv6 source to list one or more intermediate nodes to be “visited” on the way to a packet’s destination. There are different types of routing headers defined for different uses.
Fragmentation	Fragmentation and reassembly. The Fragment header is used by an IPv6 source to send a packet larger than would fit in the path MTU to its destination.
Authentication	Integrity and authentication, security. The Authentication Header (AH) is used by IPsec to provide security services like integrity and data origin authentication to IPv6 traffic.
Encapsulating Security Payload	Confidentiality. Encapsulating Security Payload (ESP) Extension Header [RFC2406(opens in a new tab)] is used by IPsec to provide security services like confidentiality and/or integrity to IPv6 packets. The ESP Extension Header can be followed by an additional Destination Options Extension Header and the upper layer datagram.
Hop-by-Hop Option	Special options that require hop-by-hop processing. The Hop-by-Hop Options header is used to carry optional information that may be examined and processed by every node along a packet’s delivery path. The information is included in the form of one or more options using a TLV (Type-Length-Value) format.
Destination Options	Optional information to be examined by the destination node. The Destination Options header is used to carry optional information that is meant to be examined only by a packet’s destination node(s). The information is included in the form of one or more options using a TLV (Type-Length-Value) format.

3.2.4. Neighbor Discovery protocol (ND)

3.2.4.1. Host - Router Discovery Functions

Term	Definition
Router discovery	Hosts can locate routers residing on attached links.
Prefix discovery	Hosts can discover address prefixes that are on-link for attached links.
Parameter discovery	Hosts can find parameters (e.g., MTU).
Address autoconfiguration	Stateless configuration of addresses of network interfaces.
Redirect	Provide a better next-hop route for certain destinations.

3.2.4.2. Host - Host Communication Functions

Term	*Definition*
Address resolution	Mapping between IP addresses and link-layer addresses. This is equivalent to ARP for IPv4. This function allows to resolve the link-layer address of another node in the link when only the IPv6 address of that node is known.
Next-hop determination	Hosts can find next-hop routers for a destination.
Neighbor unreachability detection (NUD)	Determine that a neighbor is no longer reachable on the link.
Duplicate address detection (DAD)	Nodes can check whether an address is already in use.

3.2.4.3. Packet types

Name	*Type*	*Description*
Router Solicitation **(RS)**	133	To locate routers on an attached link.
Router Advertisement **(RA)**	134	Used by routers to advertise their presence periodically or in response to a RS message.
Neighbor Solicitation **(NS)**	135	To find the MAC-address of the neighbor or to check if the neighbor is still reachable.
Neighbor Advertisement **(NA)**	136	To respond to a Neighbor Solicitation message.
Redirect	137	To point the host to a better first hop router for a destination.

3.2.5. Stateless Address Autoconfiguration (SLAAC)

A method for automatically configuring IPv6 addresses without a DHCP server, relying on local network information.

3.2.5.1. Autoconfigure link-local address

Mac address: **70:07:12:34:56:78**

1) Flip **7th** bit: 7**2**:07:12:34:56:78. If it is “0”, the address is locally administered and if it is “1”, the address is globally unique.
2) Insert **FFEE** in the middle: 7207:12**FF:EE**34:5678
3) Combine with link-local prefix: **FE80::**7207:12FF:EE34:5678

New address: **FE80::7207:12FF:EE34:5678**

3.2.5.2. Perform Duplicate Address Detection (DAD)

To make sure that the address is actually unique in the local segment.

Upon configuring an IPv6 address, every node joins a **multicast group** identified by the address ***FF02::1:FFxx:xxxx*** where xx:xxxx are the **last 6 hexadecimal values** in the IPv6 unicast address, eg. FF02::1:FF**34:5678**

1) The host sends a Neighbor Solicitation message from the Unspecified Address (::) to the Solicited Node multicast address.
2) If the generated address is in use, the host using that address sends a Neighbor Advertisement back. The sending host then knows the tentative address can not be used.
3) The host then proceeds to generate a new address and sends a new Neighbor Solicitation message to the link.
4) If there is no reply after some time, the host informs all the other hosts that it uses this address and it sends a Neighbor Advertisement message to the All Nodes address.
5) The host assigns the address to the interface and now has an active IPv6 link. This is the so-called Link-local Address Assignment.

3.2.5.3. Router search

1) Router solicitation
2) Router advertisement

3.2.5.4. Generating global unicast address

Based on the information from the Router Advertisement, the host generates a global unicast address and wants to know if it is available to use, so it does the DAD process again. If it is not a duplicate, the host will use it.

3.2.6. DHCPv6

3.2.6.1. Flags

Term	*Definition*
A	Host can perform SLAAC to generate its own IPv6 address based on the prefix(es) contained in the RA message.
O	Host can fetch additional options from the DHCPv6. The DHCPv6 does not provide IPv6 addresses in this case.
M	Host will get its IP address and additional options from a DHCPv6 server.
L	The prefix shared in the RA is reachable on the link.

3.3. IPV4

TODO: frame

3.3.1. Network classes (private nets)

Term	*Definition*
A	**10.0.0.0** - 10.255.255.255 (10/*8* prefix)
B	**172.16.0.0** - 172.31.255.255 (172.16/*12* prefix)
C	**192.168.0.0** - 192.168.255.255 (192.168/*16* prefix)

3.3.2. Subnetting

3.3.2.1. Calculating subnet mask

/24 = ***1111 1111 . 1111 1111 . 1111 1111 . 0000 0000*** = 255.255.255.0
/10 = ***1111 1111 . 1100 0000 . 0000 0000 . 0000 0000*** = 255.192.0.0

3.3.2.2. Calculating increment

Address increment = $\frac{\text{amount of addresses}}{256}$ or $2^{8-(\text{mask mod } 8)}$
Let there be 4 subsequent networks starting with 10.0.0.0, each being /20
Amount of addresses = $2^{32-20} = 2^{12} = 4096$. Increment = $\frac{4096}{256} = 16$
Alternatively: $2^{8-(20 \bmod 8)} = 2^{8-4} = 2^4 = 16$
Networks = 10.0.**0**.0/20, 10.0.**16**.0/20, 10.0.**32**.0/20, 10.0.**48**.0/20

3.4. ROUTING

– routing table

3.4.1. Data plane

– local, per-router function
– determines how datagram arriving on router input port is forwarded to router output port

3.4.2. Control plane

– network-wide logic

– determines how datagram is routed among routers along end-to-end path from source to destination host

3.4.3. Dynamic

TODO

3.4.3.1. Dijkstra's algorithm (Link State)

3.4.3.2. OSPF (Open Shortest Path First) (Distance vector)

3.4.3.3. BGP (Border Gateway Protocol)

3.4.4. Fragmentation

– offset = transferred bytes / 8

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4. DATA LINK LAYER (2)

TODO

Functions:

– error detection

– flow control

– addressing

– layer 2 packets change after each intermediary node (switch/router)

– switching
  – switch table
  – flooding
  – learning

– vlans
  – forwarding between vlans is done via routing
  – trunk port
    – carries frames betwween vlans defined over multiple physicas switches
  – frame format
  – spanning tree
    – so that broadcast packets will now continuously loop
    – a switch is selected as root
    – a tree-like loop-free topology is established
    – bridge protocol data units
      – Hello BPDU
      – Topology Change Notification (TCN) BPDU
      – comparison algorithm

4.1. ETHERNET

Ethernet specifies and implements encoding and decoding schemes that enable frame bits to be carried as signals across both copper and fiber cables. Ethernet separates the functions of the data link layer into two sublayers: Logical Link Control and Media Access Control.

Logical Link Control (LLC)	*Media Access Control (MAC)*
Handles communication between the network layer and the MAC sublayer. Provides a way to identify the protocol that is passed from the data link layer to the network layer.	Data encapsulation: Includes frame assembly before transmission, frame parsing upon reception of a frame, data link layer MAC addressing and error detection. Media Access Control: Ethernet is a shared media and all devices can transmit at any time.

4.1.1. Carrier Sense Multiple Access with Collision Detection (CSMA/CD)

Defines how the Ethernet logical bus is accessed. It is in effect within a collision domain and if a device's network interface card (NIC) is operating in half-duplex mode. It helps prevent collisions and defines how to act when a collision does occur.

– Carrier Sense: Listen to the medium
– Multiple Access: Sending if medium is free, else waiting for a random time and try again
– Collision: The amplitude of the signal increases beacuse a collision occurs.
– Collision Detection / Backoff algorithm: The nodes stop transmitting for a random period of time, which is different for each device.

After 16 tries, the host gives up the transmission attempt and discards the frame. The network is overloaded or broken.

4.1.1.1. Collision domain

TODO

4.1.1.2. What happens when a collision occurs?

– A jam signal informs all devices that a collision occurred.
– The collision invokes a random backoff algorithm.
– Each device on the Ethernet segment stops transmitting until their backoff timers expire.
– All hosts have equal priority to transmit after the timers have expired.

4.1.2. Frame Check Sequence (FCS)

TODO

4.1.3. Half-duplex vs Full-duplex

TODO

4.1.4. Ethernet II Frame

Size: 64B (1518 Bytes)				
DA 6B	SA 6B	Type 2B	DATA (MAC SDU) 0 (+64 padding) … 1500B	FCS 4B

Most common type in use today. Also called the DIX frame.

MAC PDU must be at least 64B to guarantee that all collisions can be detected. If it's smaller, the frame must be filled with Padding Bytes.

4.1.5. IEEE 802.3 Frame

Size: 64B (1518 Bytes)					
DA 6B	SA 6B	Length 2B	LLC 802.2	LLC SDU	FCS 4B

4.2. MAC-ADDRESS

Size: 6B (48bit)	
Organizationally Unique Identifier (OUI) 3B	NIC specific 3B

Used for identifying interfaces.

7th bit: Globally unique (0) or locally administered (1)

8th bit: Unicast (0) or multicast (1)

4.3. ADDRESS RESOLUTION PROTOCOL (ARP)

Maps network addresses to data link layer addresses. Resolves IPv4 addresses to MAC addresses.

IPv6 does not need ARP because it uses the Neighnor Discovery Protocol (NDP).

ARP table holds mappings from IPv4 to MAC addresses. Entries are added by monitoring the traffic and adding source IP and MAC addresses of the incoming packets to the table. If no entry is found inside of the ARP table, then the node launches an ARP discovery process. This is done by sending an ARP broadcast request and receiving an ARP reply from the requested MAC addresses' host. When a node receives a packet with a destination IP address where no cached entry for the MAC address can be found, the encapsulation of the IPv4 packet fails and the packet gets dropped.

ARP has no validation if the sender of a frame is correct. ARP spoofing, also called ARP poisoning, refers to the method of inserting the wrong MAC address into ARP requests and responses by the node. An attacker can lead sent frames to the wrong destination and has the ability to read the traffic (MITM attack). Configuring static ARP entries is one way to prevent ARP spoofing.

4.4. SWITCH

– All devices connected to the switch ports form a ***broadcast domain***

4.5. VLAN

TODO

LAN: all devices in the same broadcast domain

VLAN: Virtual separation of LAN on a switch

Reasons for using VLANs:

– To reduce CPU overhead on each device by reducing the number of devices that receive each broadcast frame
– To reduce security risks by reducing the number of hosts that receive copies of frames that the switches flood (broadcasts, multicasts, and unknown unicasts)
– To improve security for hosts that send sensitive data by keeping those hosts on a sepa- rate VLAN
– To create more flexible designs that group users by department, or by groups that work together, instead of by physical location
– To solve problems more quickly, because the failure domain for many problems is the same set of devices as those in the same broadcast domain
– To reduce the workload for the Spanning Tree Protocol (STP) by limiting a VLAN to a single access switch

4.5.1. Trunking

With ***trunking***, only a single cable is needed to carry traffic for all VLANs. VLAN trunking works by applying ***VLAN tagging***, where the sending switch adds an extra header to each frame before sending it across the trunk link. This trunking header contains a VLAN Identifier (VLAN ID), allowing the receiving switch to determine the VLAN to which each frame belongs. Switch ports that are assigned to a single VLAN and

carry traffic for only that VLAN are referred to as ***access ports***. Ports that carry traffic for multiple VLANs using VLAN tagging are called ***trunk ports***.

4.5.2. 802.1Q

The standard of how to tag an ethernet frame in a trunk is defined in IEEE 802.1Q. 802.1Q inserts an extra 4 byte 802.1Q VLAN header into the original frame's Ethernet header.

4.5.3. Inter-VLAN Routing

4.5.3.1. Attaching a Router

A router can be added to a switch using multiple VLANs. The cable from the switch to the router gets configured as a trunk. The router then can simply perform its usual routing logic between the subnets. This concept is called ***Router-on-a-Stick***.

4.5.3.2. Using a Layer 3 Switch

With the use of a switch with layer 3 capabilities, the need for a separate router is omitted, as the switch brings the ability for routing by itself. Routing can be turned on that switch and packets between the VLANs get routed.

4.5.4. Link Aggregation Group (LAG)

Combine a number of physical ports together to one logical port.

4.5.5. Link Aggregation Control Protocol (LACP)

IEEE specification (802.3ad) that also enables several physical ports to be bundled together to form a LAG. LACP enables a switch to negotiate an automatic bundle by sending LACP packets to the peer.

4.6. ERROR DETECTION

EDC

4.6.1. Cyclic Redundancy Check (CRC)

- D: data bits
- G: bit pattern

4.7. WIRELESS

TODO: frame

- Different MAC address
- CSMA/CA instead of CSMA/CD
  - carrier-sense multiple acdess with collision avoidance
  - carrier sense: is shared medium free?
  - collision avoidance: request to send (RTS) / clear to sent (CTS)
  - distributed coordination function (DCF)
- Hidden node problem
  - RTC/CTS
- Network Allocation Vector (NAV)
- SIFS (high), PIFS (medium), DIFS (lowest priority)
- RA, TA, DA, SA, BSSID + To/From DS
- (Fast) roaming

5. PHYSICAL LAYER (1)

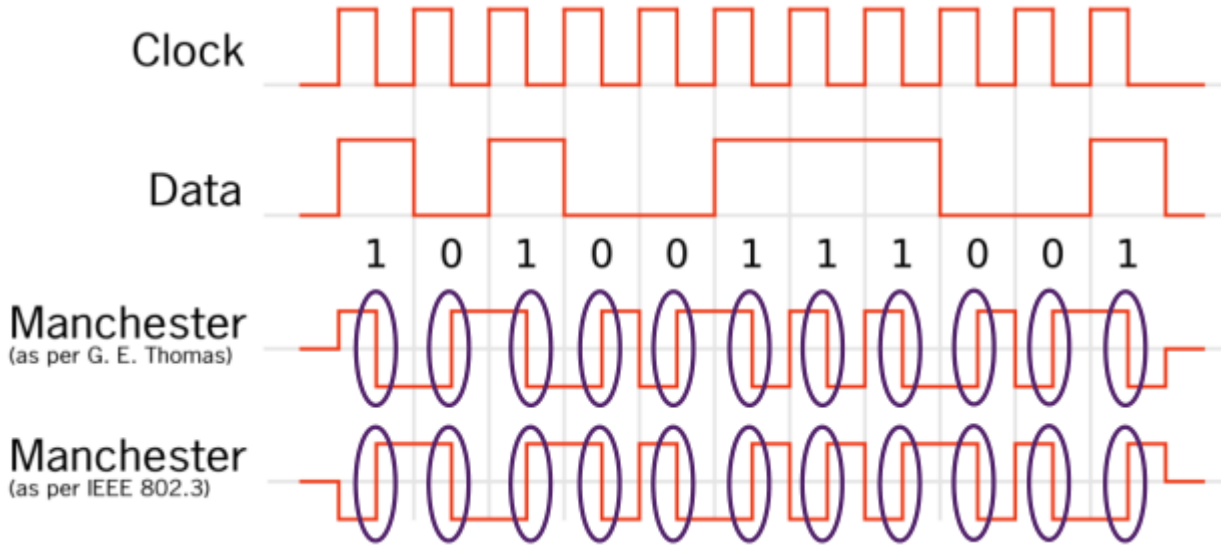
- responsibilities
  - Representing bits as physical signals (electrical voltage, light pulses, radio waves)
  - Defining cables, connectors, modulation methods, and wireless frequencies

  - Synchronization of transmitter and receiver
  - Data rates and physical medium characteristics
- Wi-Fi
- synchronisation,clock rates
- copper,fiber,wireless
- signal degradation,distance,interference
- signal bits (start-bit,data-bits,parity-bit,stop-bit)
- 10/100BASE-TX transceiver components
- single-in,single-out / multiple-input,multiple-output

5.1. ENCODINGS

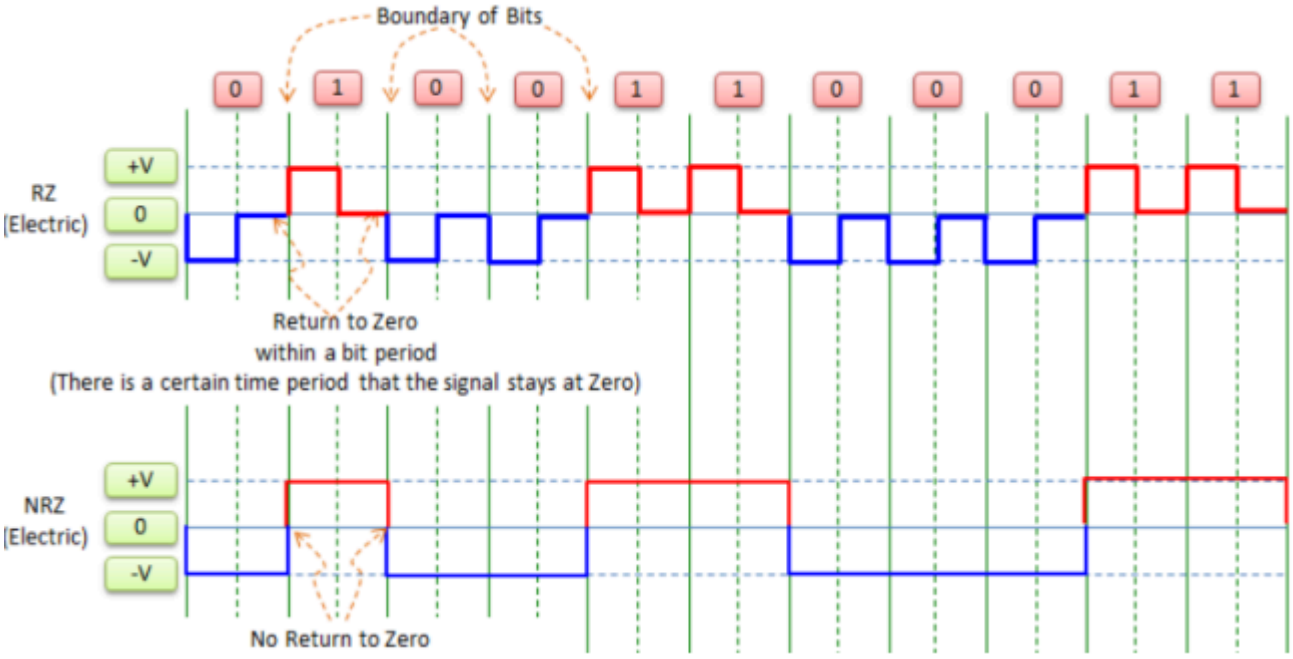
Encoding converts the stream of bits into a format recognizable by the next device in the network path.

5.1.1. Manchester encoding



- Self-clocking

5.1.2. RZ (Return-to-Zero)



- Self-clocking

5.1.3. NRZ (Non-Return-to-Zero)

– Not self-clocking

5.1.4. 8b/10b (Clock recovery)

Maps 8-bit words to 10-bit symbols – prevents too many zeros or ones in a row.

5.2. POWER AND DB

Term	*Definition*
dB	decibel
dBm	decibel ratio to 1mW
dBi	antenna gain compared to isotropic radiator
RSSI	Received signal strength indication
SNR	Signal to Noise Ratio
Receiver Sensitivity	up to which level signals can be received successfully

$$\text{decibels} = 10 \cdot \log_{10}(\text{milliwatts})$$

$$\text{milliwatts} = 10^{\frac{\text{decibels}}{10}}$$

5.2.1. Law of 3s

– A value of 3 dB means that the power value of interest is double the reference value
– A value of −3 dB means the power value of interest is half the reference

5.2.2. Law of 10s

– A value of 10 dB means that the power value of interest is 10 times the reference value
– A value of −10 dB means the power value of interest is 1/10 of the reference

5.3. MODULATION

Altering the carrier signal.

5.4. FIBER MEDIA

Single-Mode	*Multimode*
Very small core	Larger core
Expensive lasers	Less expensive LEDs
Long-distance applications	up to 10Gbps over 500 meters
	LEDs transmit at different angles

5.4.1. Eye Diagram

– An eye diagram results from superimposing the “0”s and “1”s of a high-speed digital data stream.
– An eye diagram shows a relative performance of the signal
– The opening of the eye provides valuable information about the ability of the receiver to detect the signal correctly
– For a good transmission system, the eye opening should be as wide and open as possible

TODO: image

5.4.2. Attenuation

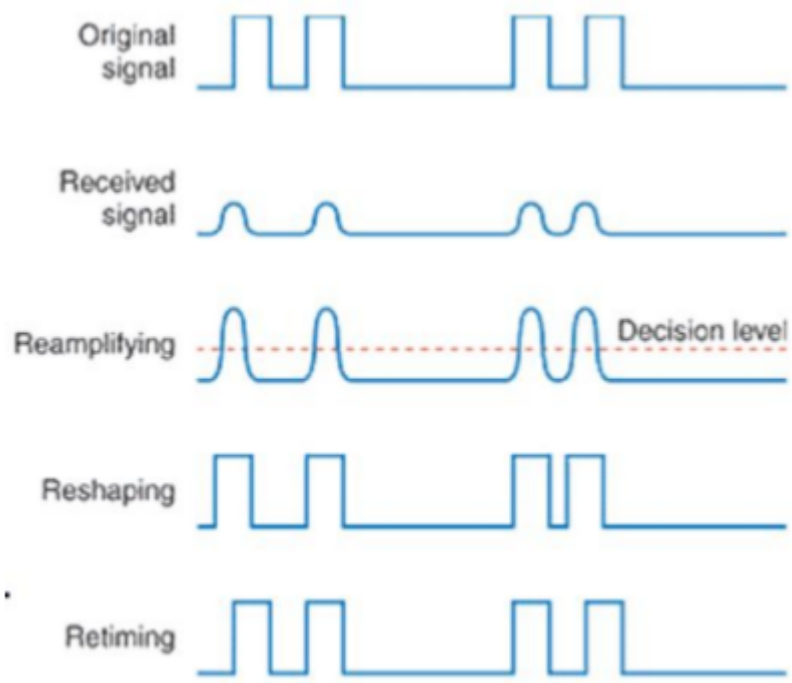
– Absorption by the fiber material
– Scattering of the light from the fiber

Term	Definition
Microbends	Caused by small distortions of the fiber in manufacturing
Macrobends	Caused by wrapping fiber around a corner with too small a bending radius
Back reflections	Caused by reflections at fiber ends, like connectors
Fiber splices	Caused by poor alignment or dirt
Mechanical connections	Physical gaps between fibers

5.4.3. Dispersion

Term	Definition
Chromatic Dispersion	– Different wavelengths travel at different speeds – Causes spreading of the light pulse
Polarization Mode Dispersion (PMD)	– Single-mode fiber supports two polarization states – Fast and slow axes have different group velocities – Causes spreading of the light pulse

5.4.4. Regeneration

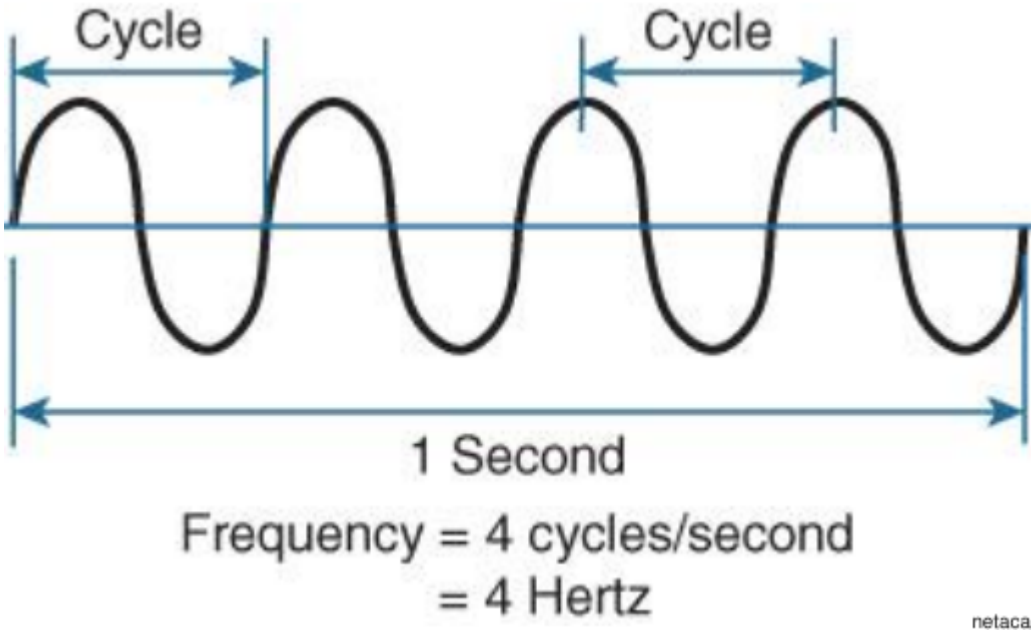


Term	Definition
Re-amplifying	Makes the analog signal stronger (i.e. makes the light brighter)
Reshaping	Restores the original pulse shape that is used to distinguish 1’s and 0’s.
Retiming	Restores the original timing between the pulses. Usually involves an Optical-Electric-Optical (O-E-O) conversion.

5.5. FREQUENCY

Term	Definition
Hertz (Hz)	Number of cycles per second
Bandwidth	Width of frequency space required within the band

Term	Definition
Wavelength	Measure of the physical distance that a wave travels over on cycle. Increases as the frequency decreases



6. CISCO

6.1. ROUTER SETUP

```
Router> enable
Router# configure terminal
Router(config)#
```

6.2. INTERFACES

6.2.1. Static IP Assignment

```
Router(config)# interface GigabetEthernet 0/0/1
Router(config-if)# ip address 172.16.0.0 255.255.255.252
Router(config-if)# no shutdown
Router(config-if)# exit
```

6.2.2. DHCP Assignment

```
Router(config)# interface GigabetEthernet 0/1/1
Router(config-if)# ip address dhcp
Router(config-if)# no shutdown
Router(config-if)# exit
```

6.2.3. Show

```
Router(config)# do show ip interface brief
Router# show ip interface brief
Router# show ip interface GigabetEthernet 0/0/1
```

6.3. VLAN

```
Switch(config)# vlan 120
Switch(config-if)# name vlan-server
Switch(config-if)# exit
```

6.3.1. Assign IP

```
Switch(config)# interface vlan 120
Switch(config-if)# ip address 10.120.0.10 255.255.255.0
```

6.3.2. Access Port

```
Switch(config)# interface GigabitEthernet 0/0/1
Switch(config-if)# switchport mode access
Switch(config-if)# switchport access vlan 120
Switch(config-if)# exit
Switch(config)# interface GigabitEthernet 0/0/1-5
Switch(config-if)# switchport mode access
Switch(config-if)# switchport access vlan 120
Switch(config-if)# exit
```

6.3.3. Access Port

```
Switch(config-if)# switchport mode trunk
```

6.3.4. VTP (Virtual Trunk Protocol)

6.3.4.1. Server

```
Switch(config)# vtp domain ins
Switch(config)# vtp mode server
```

6.3.4.2. Client

```
Switch(config)# vtp domain ins
Switch(config)# vtp mode client
```

6.3.5. LACP (Link Aggregation Control Protocol)

```
Switch(config-if)# channel-group 5 mode active
Switch(config-if)# channel-group 5 mode passive
```

6.3.6. Load Balancing

```
Switch(config)# port-channel load-balance <strategy>
```

6.3.7. STP (Spanning Tree Protocol)

6.3.7.1. Bridge priority

```
Switch(config)# spanning-tree vlan 1 priority <priority>
```

6.3.7.2. Interface costs

```
Switch(config-if)# spanning-tree cost 100
```

6.3.7.3. PortFast mode

```
Switch(config-if)# spanning-tree portfast
```

6.3.7.4. Show

```
Switch# show spanning-tree
Switch# show spanning-tree root
```

6.4. ROUTING

6.4.1. Static

6.4.1.1. IPv4

```
Router(config-if)# ip route <destination_network_id> <subnet_mask> <next_hop_router>
<adminitrative_distance>?
Router(config-if)# ip route 10.0.0.0 255.0.0.0 192.168.1.1
```

6.4.1.2. IPv6

```
Router(config-if)# ip route <ipv6_prefix> <outgoing_interface> <next-hop>
<administrative_distance>?
```

```
Router(config-if)# ipv6 route 2001:db8:2103:a::/64 GigabitEthernet1/0/1
fe80::ba27:ebff:fea8:3e50
```

6.4.2. OSPF

6.4.2.1. IPv4

```
Router(config)# router ospf <process-id>
Router(config-if)# ip ospf <process-id> area <area-nr>
```

6.4.2.2. IPv6

```
Router(config)# ipv6 router ospf <process-id>
Router(config-if)# ipv6 ospf <process-id> area <area-nr>
```

6.4.3. Show

```
Router# show ip route
Router# show ip ospf route
```

6.5. DHCP

6.5.1. Create Pool

```
Router#(config-if) ip dhcp pool DEV
 network 192.168.1.0 255.255.255.0
 default-router 192.168.1.1
 dns-server 1.1.1.1 8.8.8.8
 lease 5
 domain-name enterprise.com
```

6.5.2. Relay Agent

```
Router(config-if)# ip helper-address 176.16.12.10
```

6.6. NAT

6.6.1. IF Inside

```
Router(config-if)# ip nat inside
```

6.6.2. IF Outside

```
Router(config-if)# ip nat outside
```

6.6.3. ACL (Access Control List)

```
Router(config-if)# access-list 1 permit 192.168.1.0 0.0.0.255
```

6.6.4. PAT (Nat overload)

```
Router(config-if)# ip nat inside source list 1 interface GigabitEthernet0/1 overload
```

6.7. IPV6

```
Router(config-if)# ipv6 enable
```

6.7.1. DHCPv6

```
Router(config-if)# ipv6 dhcp client pd MY_PREFIX
Router(config-if)# ipv6 address autoconfig default
```

6.8. TROUBLESHOOTING

6.8.1. Ping

```
Router# ping <destination-ip> source <interface-name>
```

6.8.2. Traceroute

```
Router# traceroute <destination-ip> source <interface-name> numeric
```

7. BINARY, DECIMAL, HEX

0x**A4 6A** = 0b**1010 0100 0110 1010** = 0d**42'090**
0x**04 B0** = 0b**0100 1011 0000** = 0d**1'200**
0x**01 D4 C0** = 0b**0001 1101 0100 1100 0000** = 0d**120'000**