102: Linux

May, 2023

Audience

- Those who have some basic knowledge of how an OS works

Materials

- Filesystems overview
- Linux filesystem
- Bash command review
- Shell script flow control
- Networking

US patent

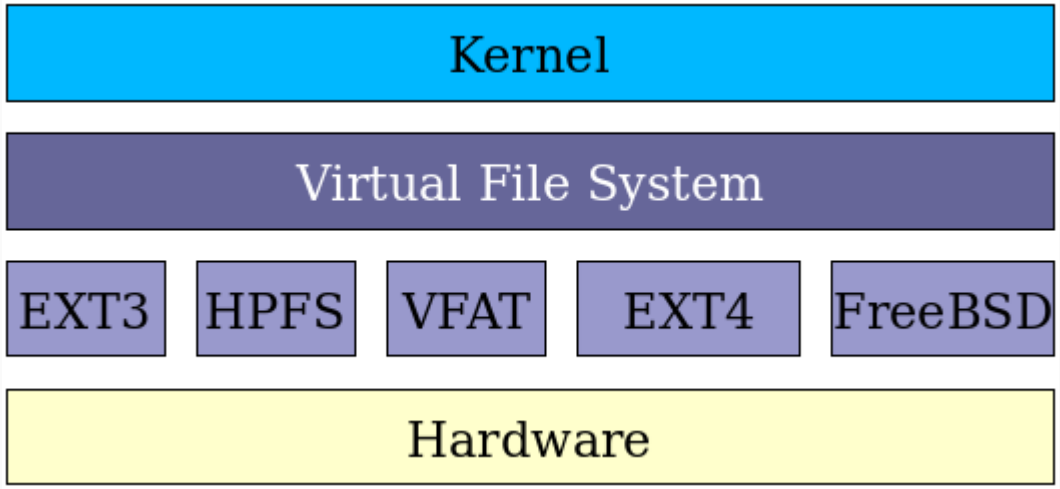
File Allocation Table (FAT) (1977~)

- FAT12 (1982, MS-DOS 1.25)
  - Volume max 32MB
  - Max no. of files: 4068
- FAT16 (1988, MS-DOS 4.0)
  - Volume max 2GB*
  - Max no. of files: 65460
- FAT32 (1996, Windows 95 OSR2)
  - Max file size: 4GB
  - Volume max 16TB*
- exFAT (2006)
  - Max file size: 16EB*
  - Volume max 128PB
- 8.3 filename and LFN
  - FILENA~1.TXT
- NTFS (1993, Windows NT 3.1)
  - Volume max 256TB-8PB*
  - Max file size: 16EB
  - encryption, compression
  - journaling

Linux and MacOS

- ext2/ext3/ext4
- btrfs
- XFS
- ZFS
- ...

- HFS/HFS+
- APFS

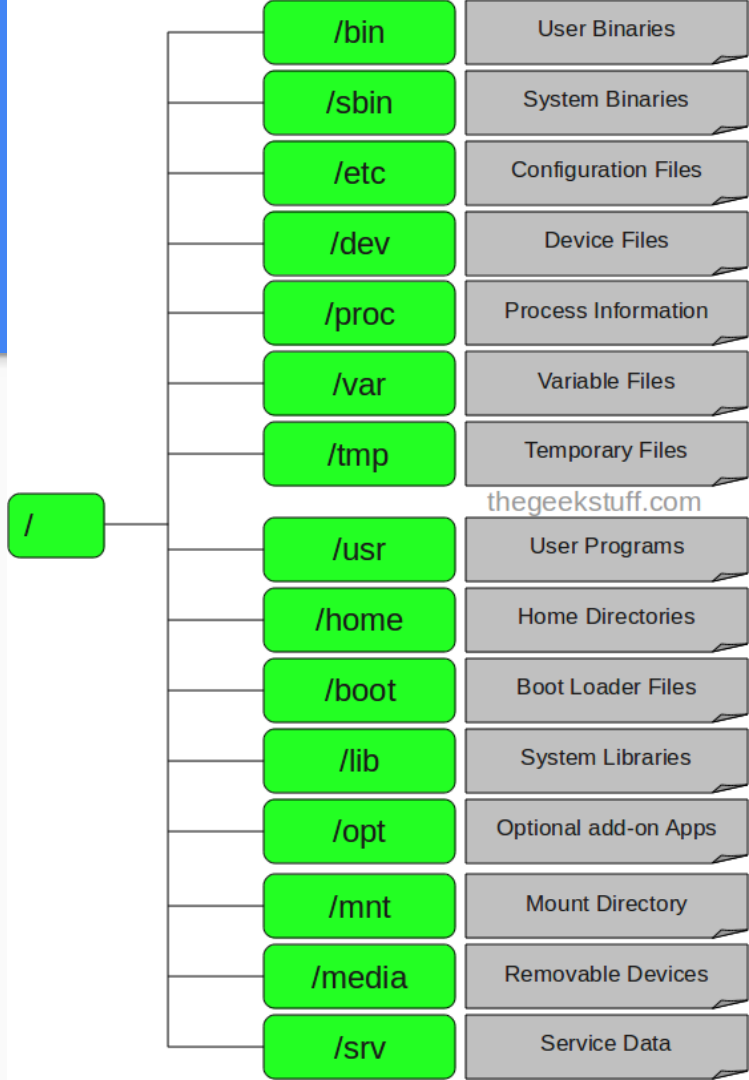


Directory/folder

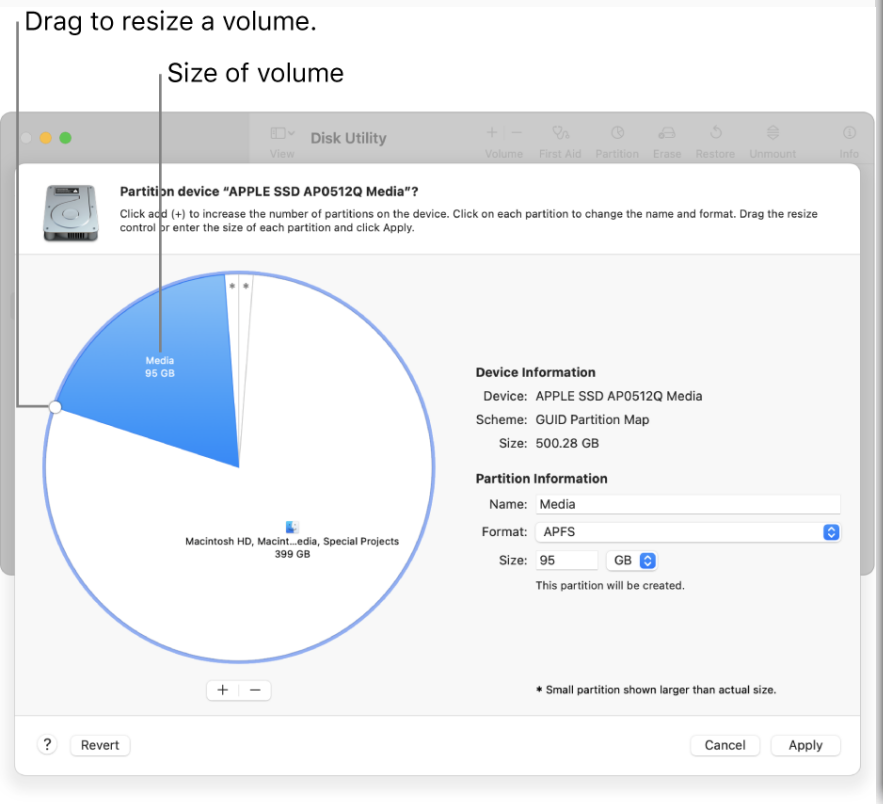
```
$ ls /
```

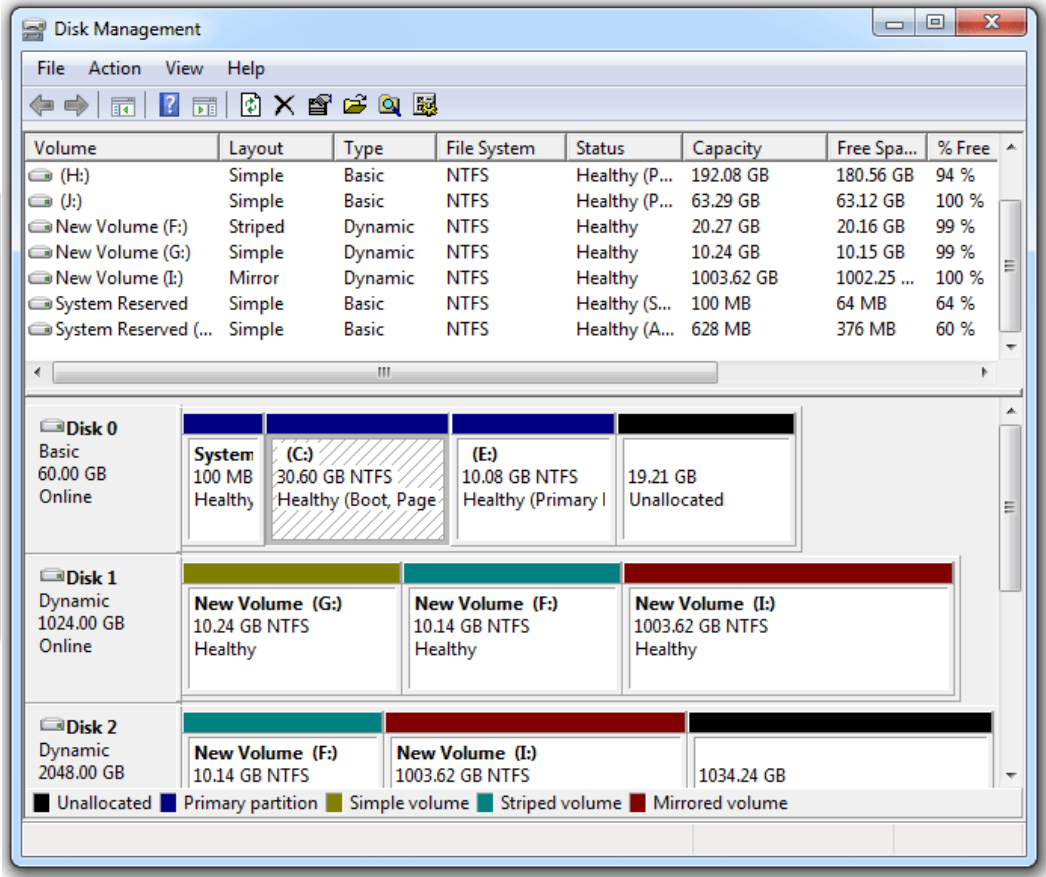
[Filesystem Hierarchy Standard]

[https://www.pathname.com/fhs/pub/fhs-2.3.pdf]



Partition vs volume





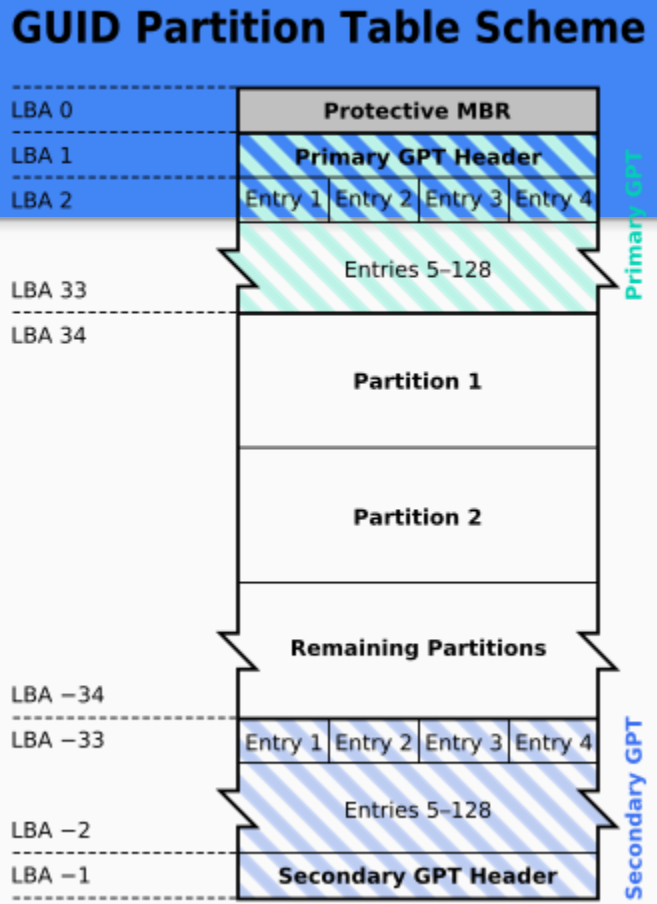
Master Boot Record (MBR) (1983)

- Boot code
  - 16 bit
  - beginning of the disk
- Partition table
  - 4 primary partitions
  - or 3 primary partitions and 1 extended partition (many logical partitions inside)
  - max 2TB disk

1990s, Intel

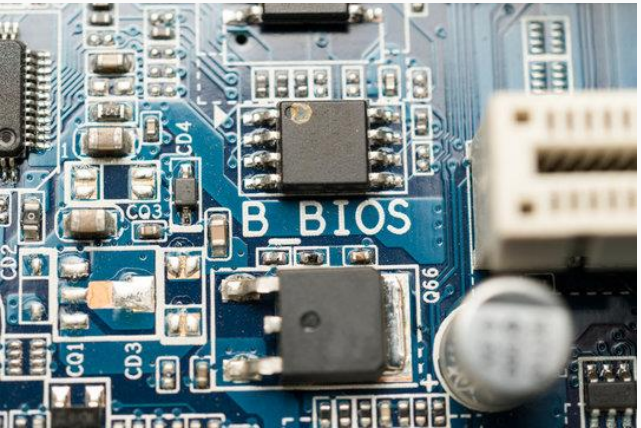
GUID Partition Table (GPT)

- No boot code
- Stored at the beginning and the end of the disk
- Max 256 partitions
- Max 64ZB disk
- Windows Vista ~ requires UEFI

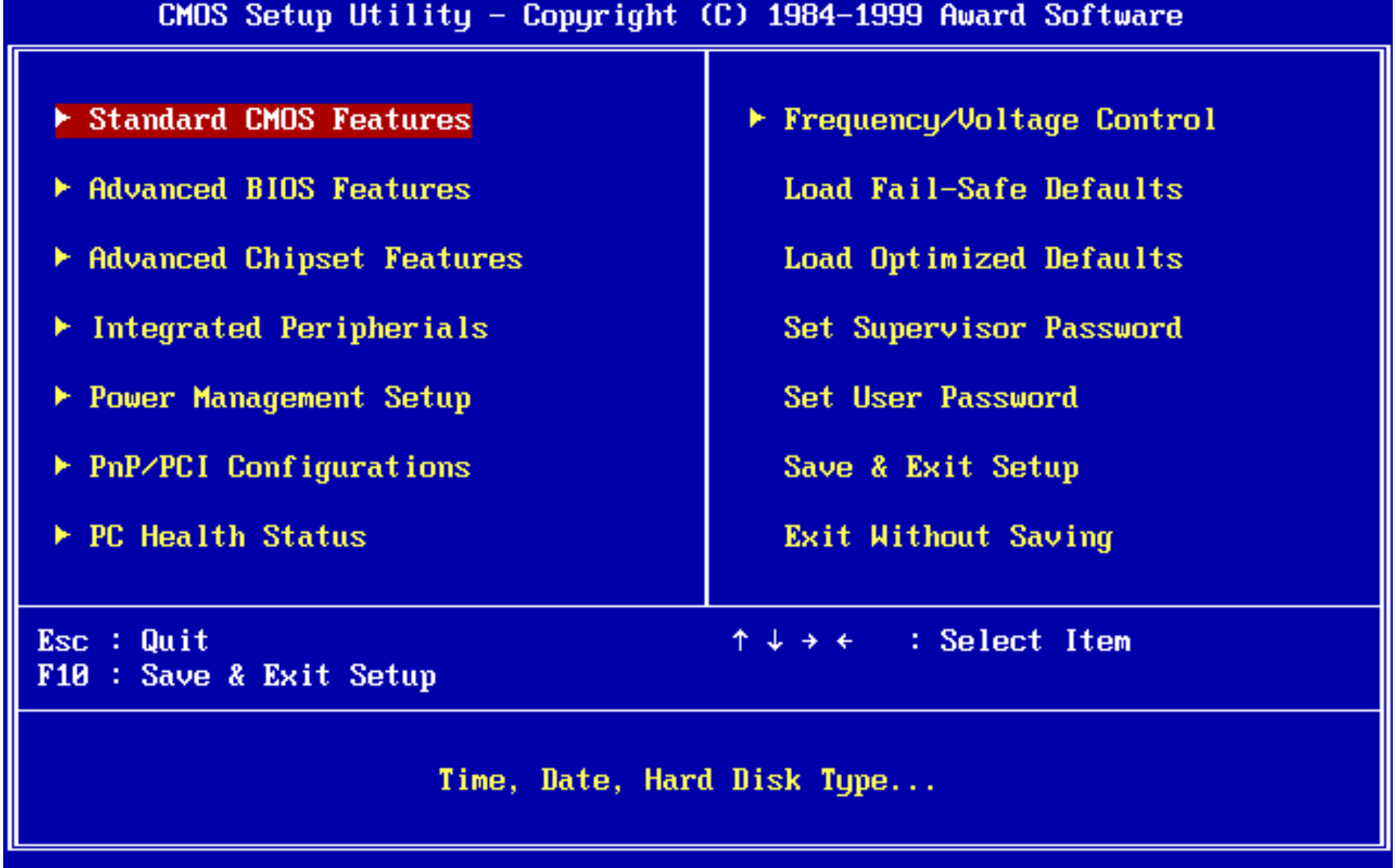


BIOS vs UEFI

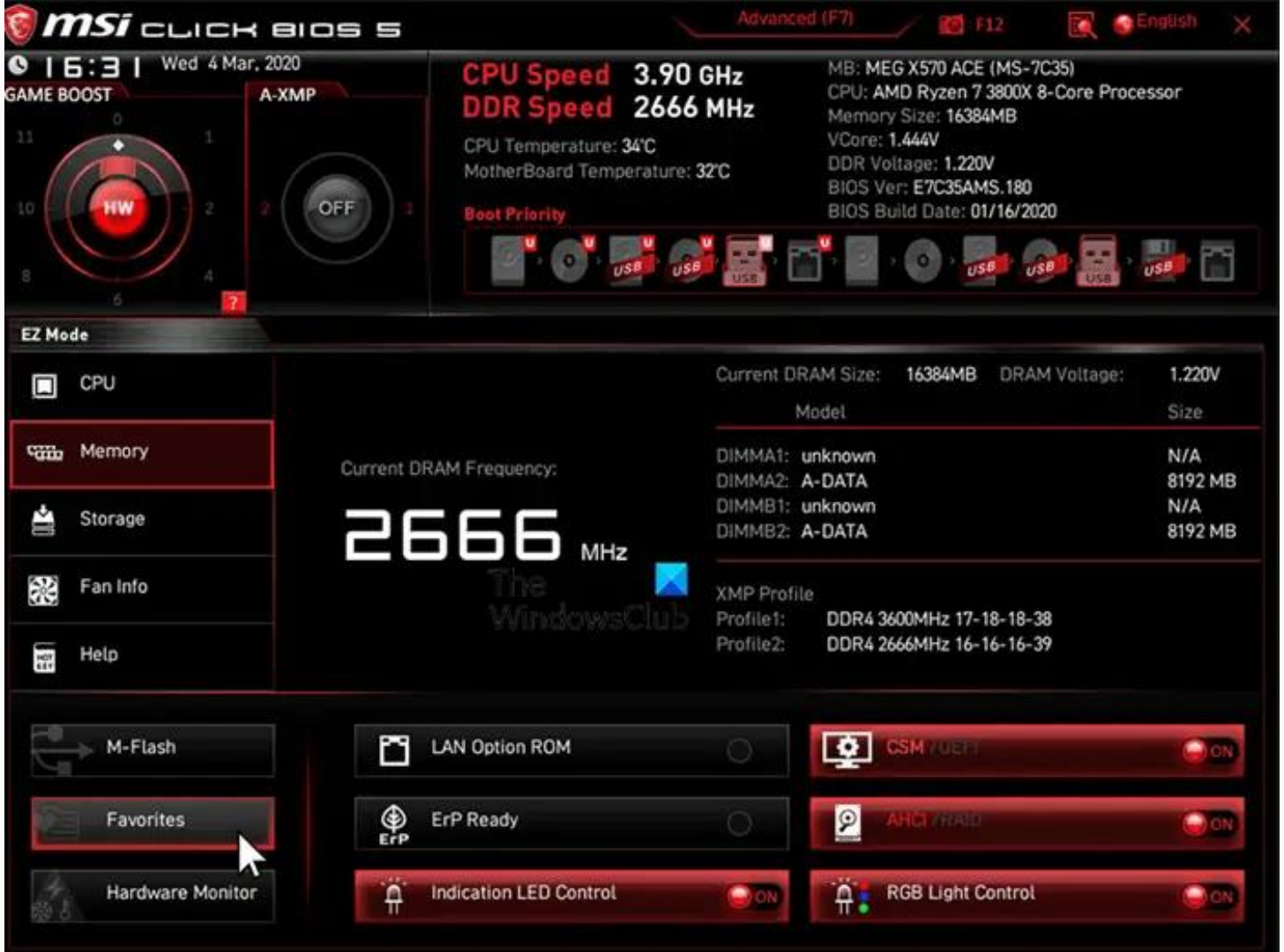
- BIOS (Basic Input/Output System) (1975)
  - initialize hardware, boot OS
  - 16 bit



- UEFI (Unified Extensible Firmware Interface) (2004)
  - initialize hardware, boot OS
  - 32/64 bit
  - support GPT
  - support mouse, network, FAT, (NTFS), secure boot*
  - boot from (ESP)/EFI/boot/bootx64.efi
  - support legacy boot using CSM


CMOS Setup Utility - Copyright (C) 1984-1999 Award Software
Standard CMOS Features
Advanced BIOS Features
Advanced Chipset Features
Integrated Peripherials
Power Management Setup
PnP/PCI Configurations
PC Health Status
Frequency/Voltage Control
Load Fail-Safe Defaults
Load Optimized Defaults
Set Supervisor Password
Set User Password
Save & Exit Setup
Exit Without Saving
Esc : Quit
F10 : Save & Exit Setup
↑ ↓ → ← : Select Item
Time, Date, Hard Disk Type...


Aptio Setup – AMI
Main Advanced AMD CBS AMD PBS Option Chipset Server Mgmt Security Boot Save & Exit
BIOS Information
Project Name MZ72-HB0-00
Project Version M02
Build Date and Time 02/05/2021 18:22:06
BMC Information
BMC Firmware Version 12.50.09
Processor Information
CPU 0 Brand String AMD EPYC 7763 64-Core Processor
CPU 1 Brand String AMD EPYC 7763 64-Core Processor
CPU Speed 2450 MHz
Processor Core 64
Microcode Patch A001114
Total Memory 524288 MB
Memory Speed 3200 MT/s
VR Information
Version 8160
AGESA PI Version
PI Version 1.0.0.0
→←: Select Screen
↑↓: Select Item
Enter: Select
+/-: Change Opt.
F1: General Help
F3: Previous Values
F9: Optimized Defaults
F10: Save & Exit
ESC: Exit
Version 2.21.1279 Copyright (C) 2021 AMI


msi CLICK BIOS 5
Advanced (F7)
F12
English
16:31 Wed 4 Mar, 2020
GAME BOOST
HW
A-XMP
OFF
CPU Speed 3.90 GHz
DDR Speed 2666 MHz
CPU Temperature: 34°C
MotherBoard Temperature: 32°C
Boot Priority
MB: MEG X570 ACE (MS-7C35)
CPU: AMD Ryzen 7 3800X 8-Core Processor
Memory Size: 16384MB
VCore: 1.444V
DDR Voltage: 1.220V
BIOS Ver: E7C35AMS.180
BIOS Build Date: 01/16/2020
EZ Mode
CPU
Memory
Storage
Fan Info
Help
Current DRAM Frequency:
2666 MHz
Current DRAM Size: 16384MB
DRAM Voltage: 1.220V
Model
Size
DIMMA1: unknown N/A
DIMMA2: A-DATA 8192 MB
DIMMB1: unknown N/A
DIMMB2: A-DATA 8192 MB
XMP Profile
Profile1: DDR4 3600MHz 17-18-18-38
Profile2: DDR4 2666MHz 16-16-16-39
M-Flash
Favorites
Hardware Monitor
LAN Option ROM
ErP Ready
Indication LED Control
CSM (UEFI)
AHCI /RAID
RGB Light Control
ON

Install Linux: a demonstration

copy + paste text

Bash (**B**ourne **A**gain **SH**ell)

- ls
- man
- cd
- echo
- touch
- mkdir
- touch
- grep
- pwd
- cp
- mv
- rmdir
- rm
- type
- cmp
- diff
- head
- tail
- cat
- more
- less
- sleep
- history
- clear
- ps
- kill
- nano
- ln
- whoami
- useradd (adduser可)
- sudo
- usermod
- userdel
- su
- exit
- passwd
- whatis
- which
- ssh
- curl
- wget
- zip
- unzip
- tar
- find
- chmod
- chown
- ip
- ping
- nslookup
- date
- time
- users
- groups
- uname
- free
- df
- top
- systemctl
- reboot
- shutdown

https://www.youtube.com/watch?v=gd7BXuUQ91w

(bash) shell script

```
#!/bin/bash
```

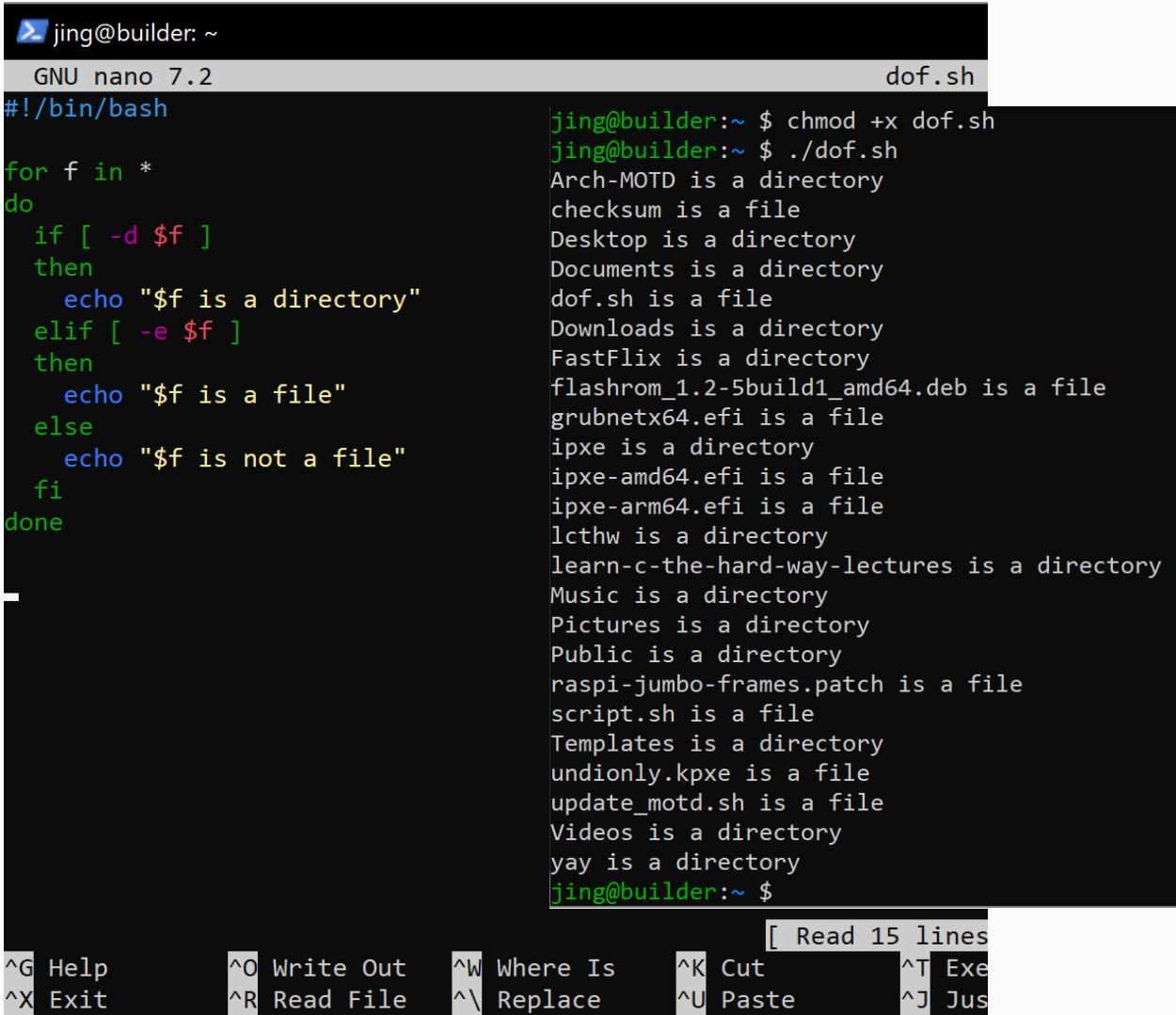
script.sh

```
for (( c=1; c<=5; c++ ))
do
   echo "Welcome $c"
done
```

```
for c in {1..5..1}
do
   echo "Welcome $c"
done
```

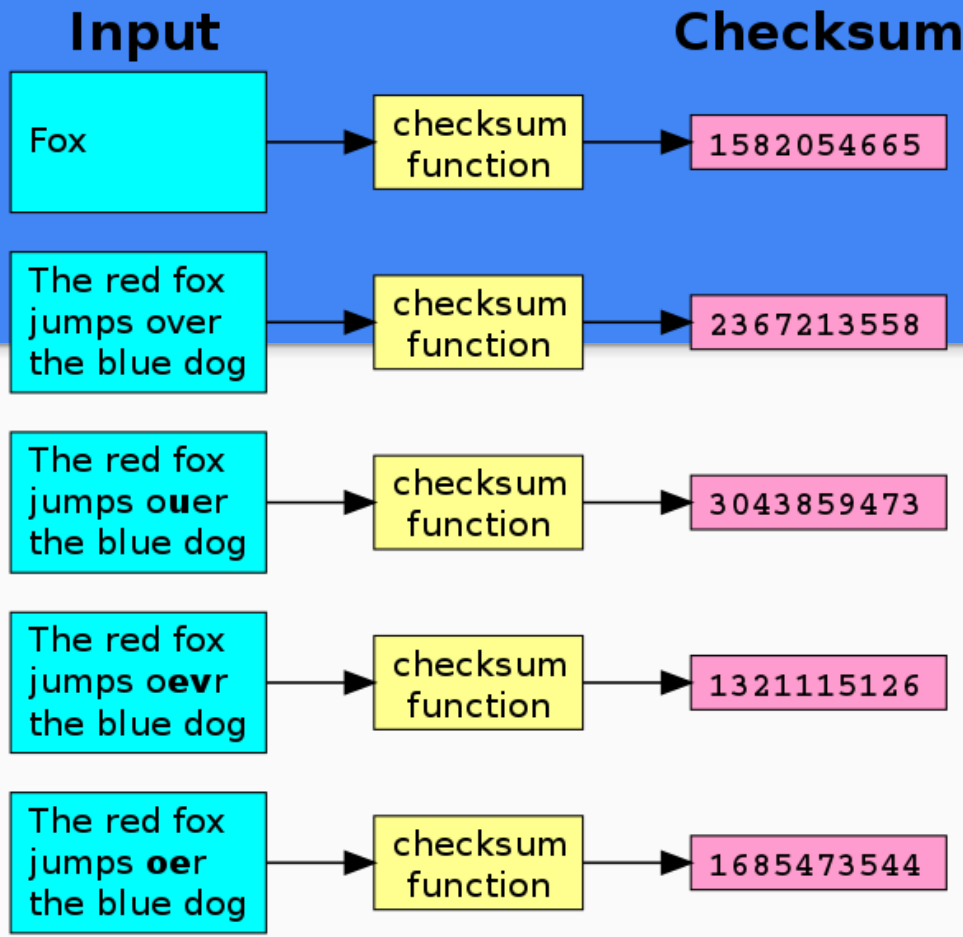
```
#!/bin/bash

for f in *
do
  if [ -d $f ]
  then
    echo "$f is a directory"
  elif [ -e $f ]
  then
    echo "$f is a file"
  else
    echo "$f is not a file"
  fi
done
```

The Linux Document Project
https://tldp.org/LDP/Bash-Beginners-Guide/html/sect_07_01.html



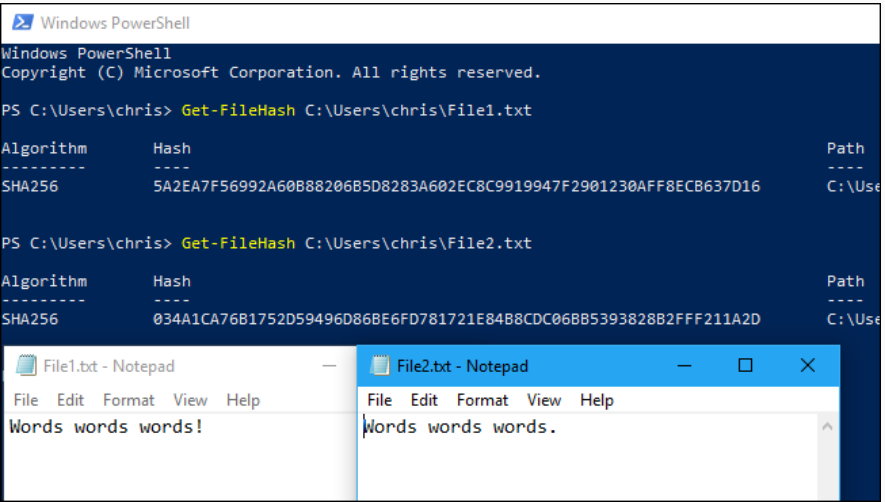
Checksum & Hash algorithm

- CRC
- CRC64
- MD5
- SHA1
- SHA256
- SHA512
- …



SHA256

- `Get-FileHash C:\file.txt -Algorithm SHA256`

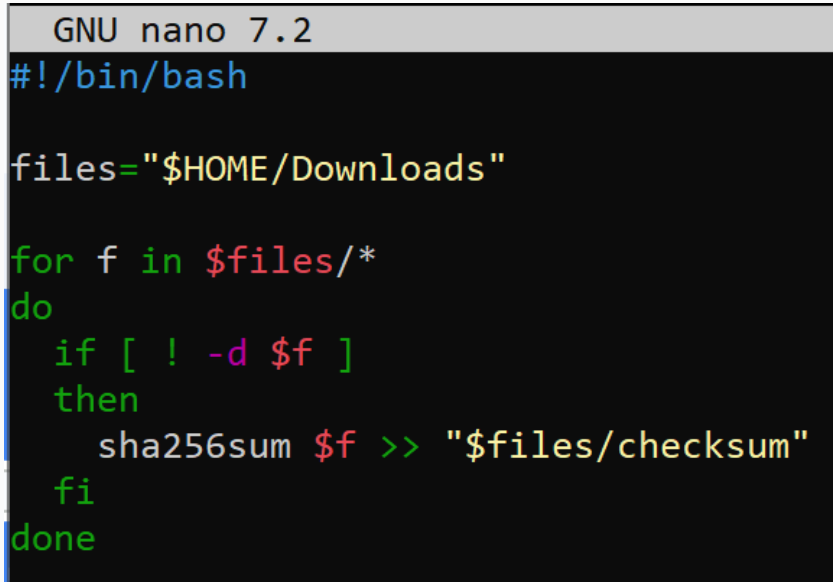


https://man7.org/linux/man-pages/man1/sha256sum.1.html

```
$ sha256sum file.txt

$ echo -n "foobar" | sha256sum


$ sha256sum file.txt > file.txt.checksum

$ sha256sum -c file.txt.checksum
```

Exercise: write a shell script

Calculate the SHA256 hash of every file in a directory, and store the hash in a file.

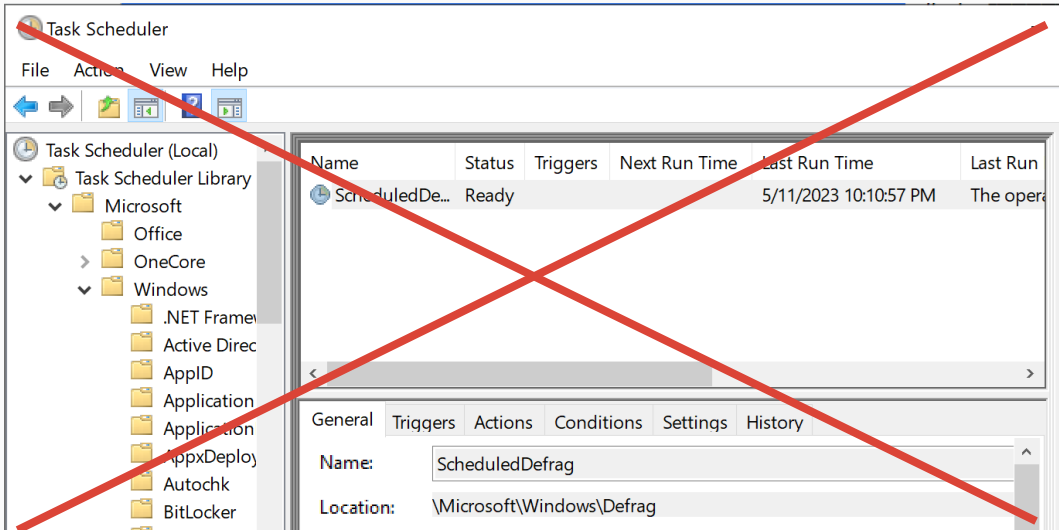


cron

```
# ┌──────────── minute (0 - 59)
# │ ┌────────── hour (0 - 23)
# │ │ ┌──────── day of the month (1 - 31)
# │ │ │ ┌────── month (1 - 12)
# │ │ │ │ ┌──── day of the week (0 - 6) (Sunday to Saturday;
# │ │ │ │ │                                7 is also Sunday on some systems)
# │ │ │ │ │
# │ │ │ │ │
# * * * * * <command to execute>
```

```
$ sudo crontab -e
```

```
# For example, you can run a backup of
# at 5 a.m every week with:
# 0 5 * * 1 tar -zcf /var/backups/home
#
# For more information see the manual
#
# m h  dom mon dow   command
* * 1 * * /root/scrub.sh

^G Help        ^O Write Out   ^W Where
^X Exit        ^R Read File   ^\ Repla
```



Solid state drive (SSD)

3.5 inch SATA HDD

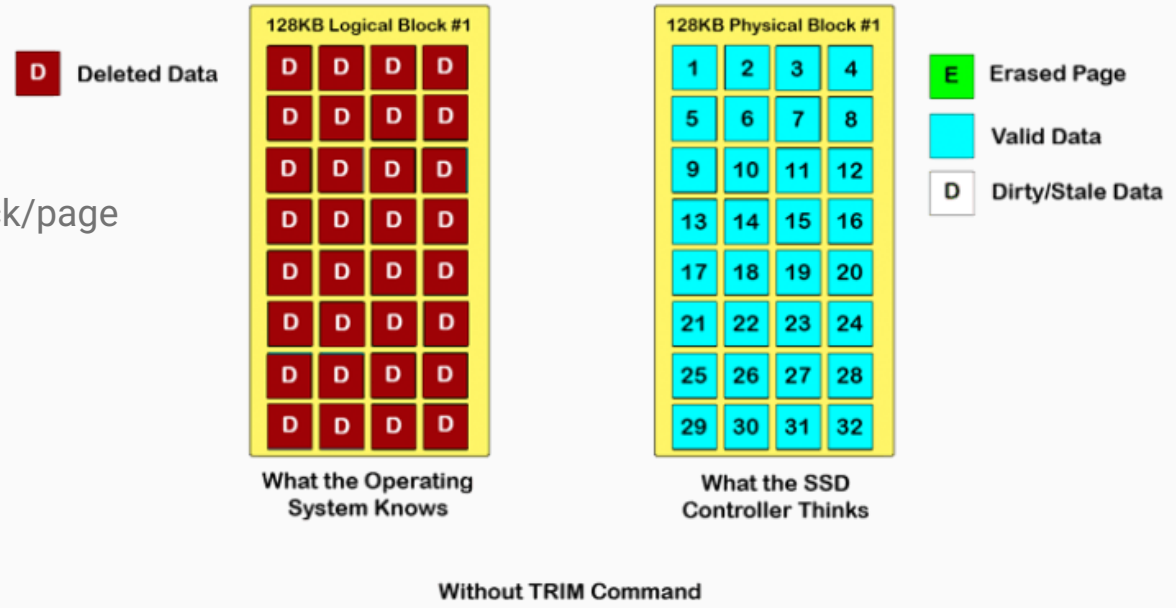
2.5 inch SATA HDD

2.5 inch SATA SSD

22mm x 80mm M.2 NVMe SSD

no TRIM

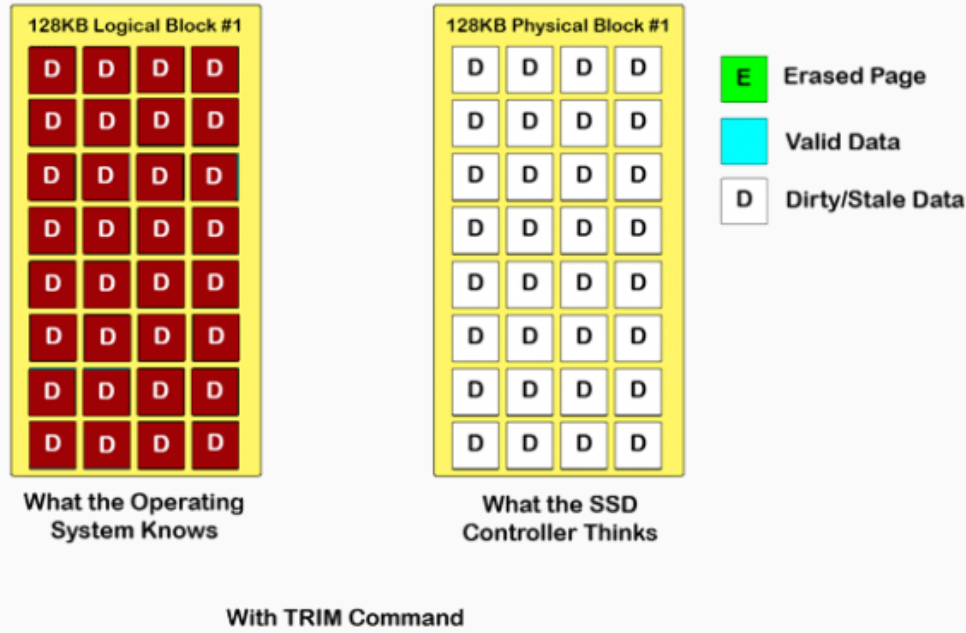
1. delete a file in OS
2. file deleted from filesystem
   a. not from SSD
   b. can be recovered
3. write a new file in the same block/page
   a. erase the page first
   b. write new data



TRIM

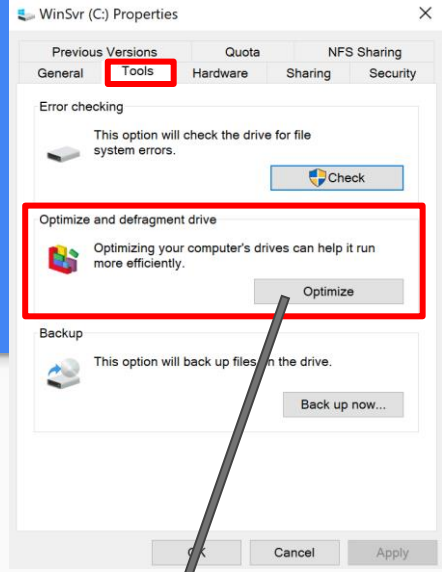
[What is Trim? | Crucial.com]

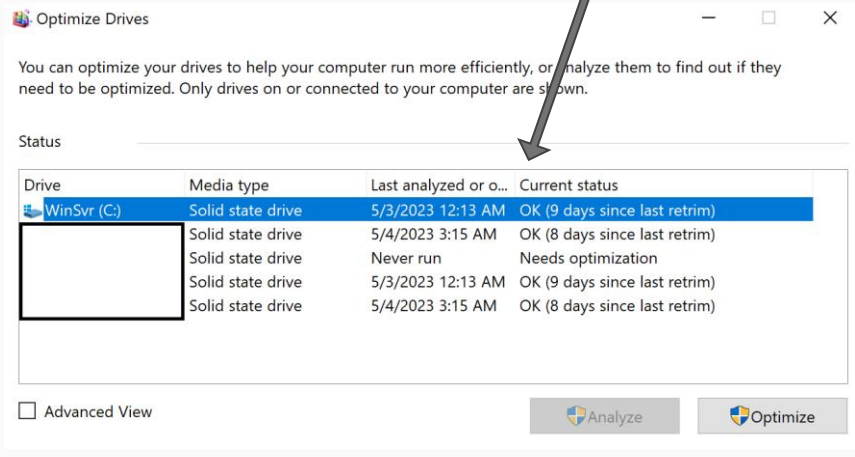
1. delete a file in OS
2. TRIM (auto or manual)
   a. data marked deleted
   b. active garbage collection when SSD idle
3. file cannot be recovered
4. write new data into the same block/page
   a. write only, no erase, faster



fstrim

```
Usage:
 fstrim [options] <mount point>

Discard unused blocks on a mounted filesystem.

Options:
 -a, --all               trim mounted filesystems
 -A, --fstab             trim filesystems from /etc/fstab
 -I, --listed-in <list>  trim filesystems listed in specified files
 -o, --offset <num>      the offset in bytes to start discarding from
 -l, --length <num>      the number of bytes to discard
 -m, --minimum <num>     the minimum extent length to discard
 -v, --verbose           print number of discarded bytes
     --quiet-unsupported suppress error messages if trim unsupported
 -n, --dry-run           does everything, but trim

 -h, --help          display this help
 -V, --version       display version

Arguments:
 <num> arguments may be followed by the suffixes for
   GiB, TiB, PiB, EiB, ZiB, and YiB (the "iB" is optional)

For more details see fstrim(8).
jing@h12ssl-nt:~$ sudo fstrim -v /
/: 553.9 MiB (580763648 bytes) trimmed
```





Exercise: a cron job to TRIM the SSD

Write a cron job to TRIM the SSD once a week, at 00:00 every Sunday.
Bonus: save the output to a log file.

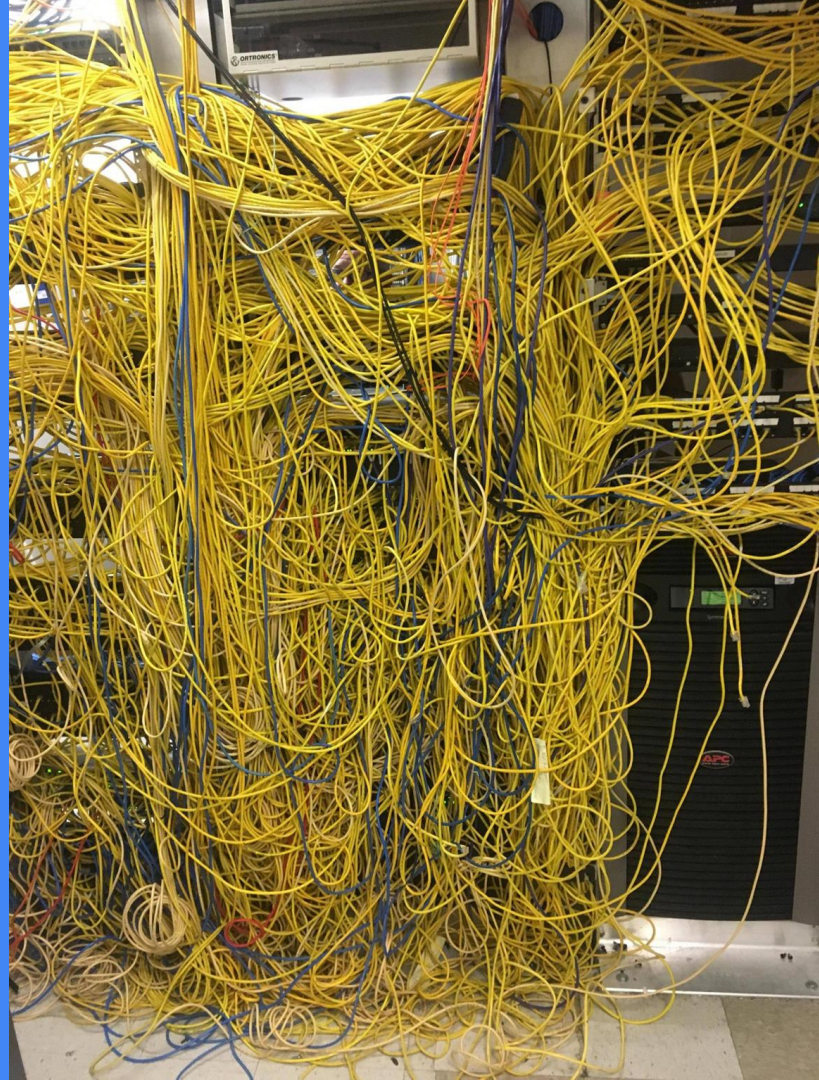
Hint: schedule the cron job as root so that it runs as root

Exercise: cron job 2

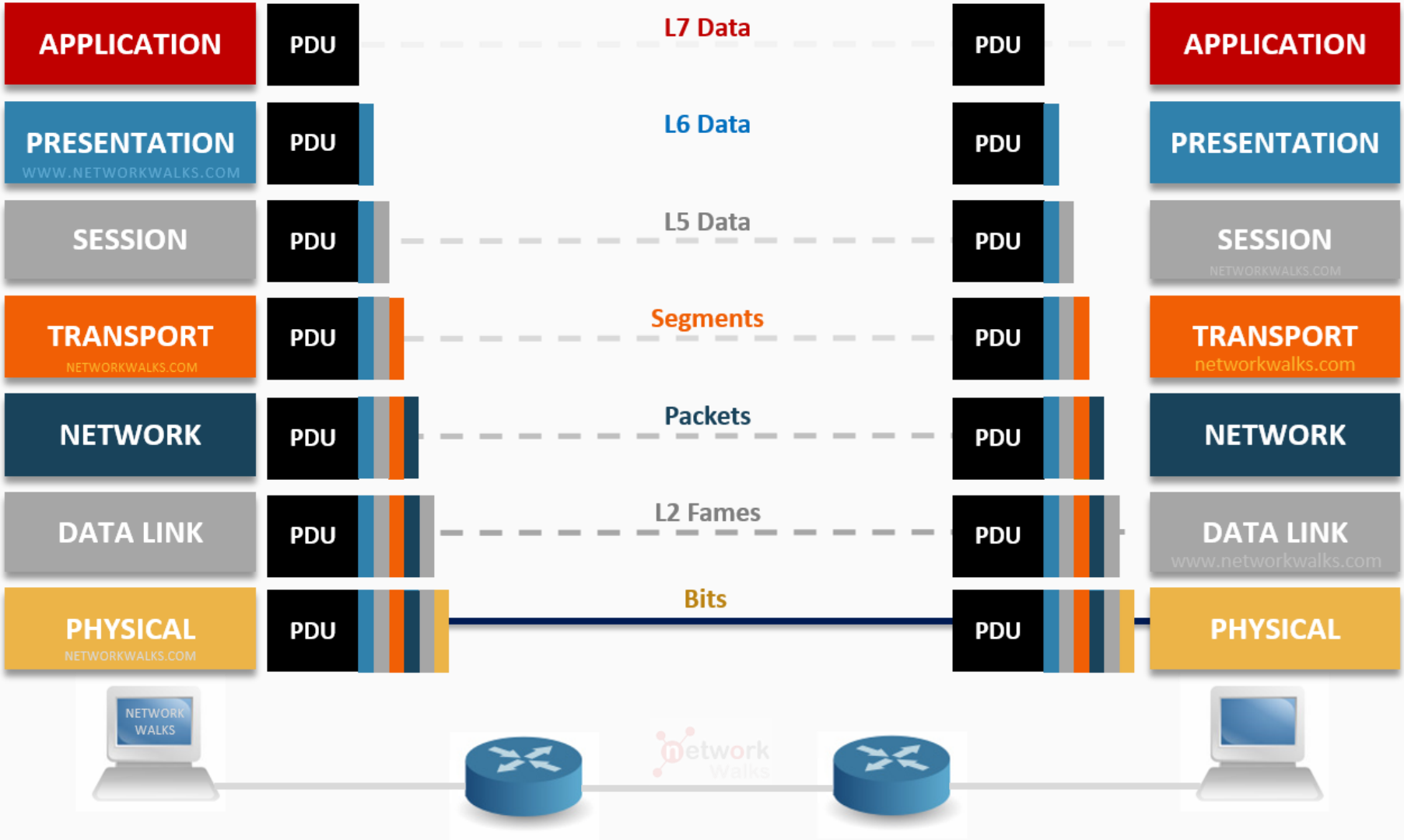
Create a cron job to backup your home directory or all users' home directory.

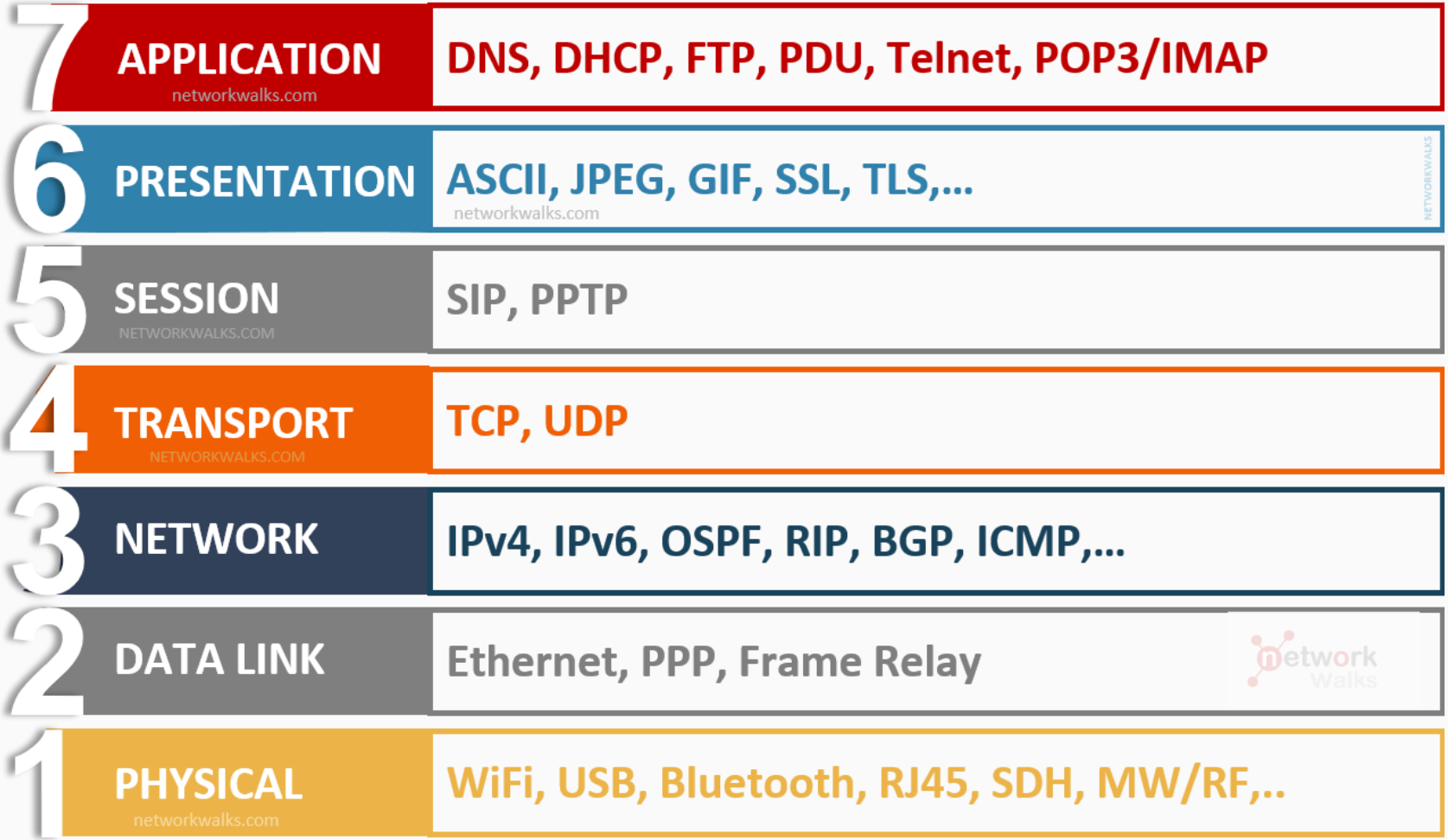
Hint: use `` `tar -zcvf` `` to compress a file or a directory.

Networking



r/forbiddensnacks

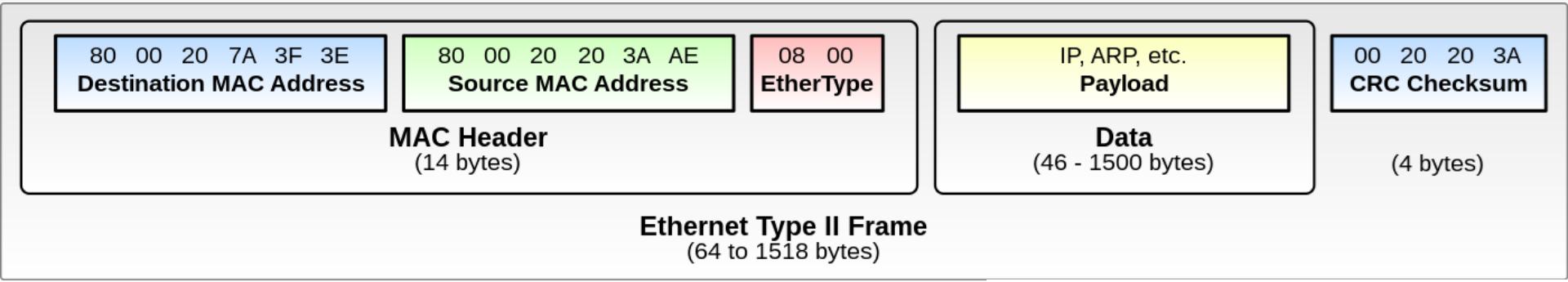

APPLICATION
PDU
L7 Data
PDU
APPLICATION
PRESENTATION
WWW.NETWORKWALKS.COM
PDU
L6 Data
PDU
PRESENTATION
SESSION
PDU
L5 Data
PDU
SESSION
NETWORKWALKS.COM
TRANSPORT
NETWORKWALKS.COM
PDU
Segments
PDU
TRANSPORT
networkwalks.com
NETWORK
PDU
Packets
PDU
NETWORK
DATA LINK
PDU
L2 Fames
PDU
DATA LINK
www.networkwalks.com
PHYSICAL
NETWORKWALKS.COM
PDU
Bits
PDU
PHYSICAL
NETWORK
WALKS
network
Walks


7
APPLICATION
networkwalks.com
DNS, DHCP, FTP, PDU, Telnet, POP3/IMAP
6
PRESENTATION
networkwalks.com
ASCII, JPEG, GIF, SSL, TLS,...
NETWORKWALKS
5
SESSION
NETWORKWALKS.COM
SIP, PPTP
4
TRANSPORT
NETWORKWALKS.COM
TCP, UDP
3
NETWORK
IPv4, IPv6, OSPF, RIP, BGP, ICMP,...
2
DATA LINK
Ethernet, PPP, Frame Relay
network Walks
1
PHYSICAL
networkwalks.com
WiFi, USB, Bluetooth, RJ45, SDH, MW/RF,..

Please **D**o **N**ot **T**hrow **S**ausage **P**izza **A**way

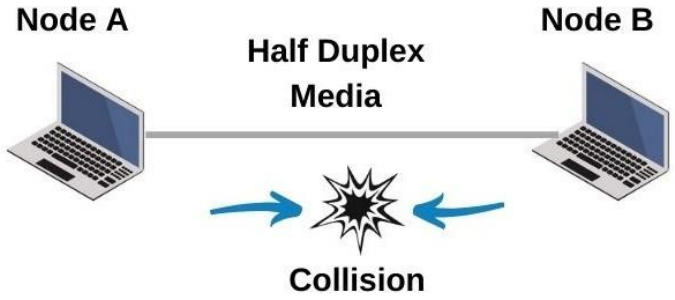
All **P**eople **S**eem **T**o **N**eed **D**ata **P**rocessing

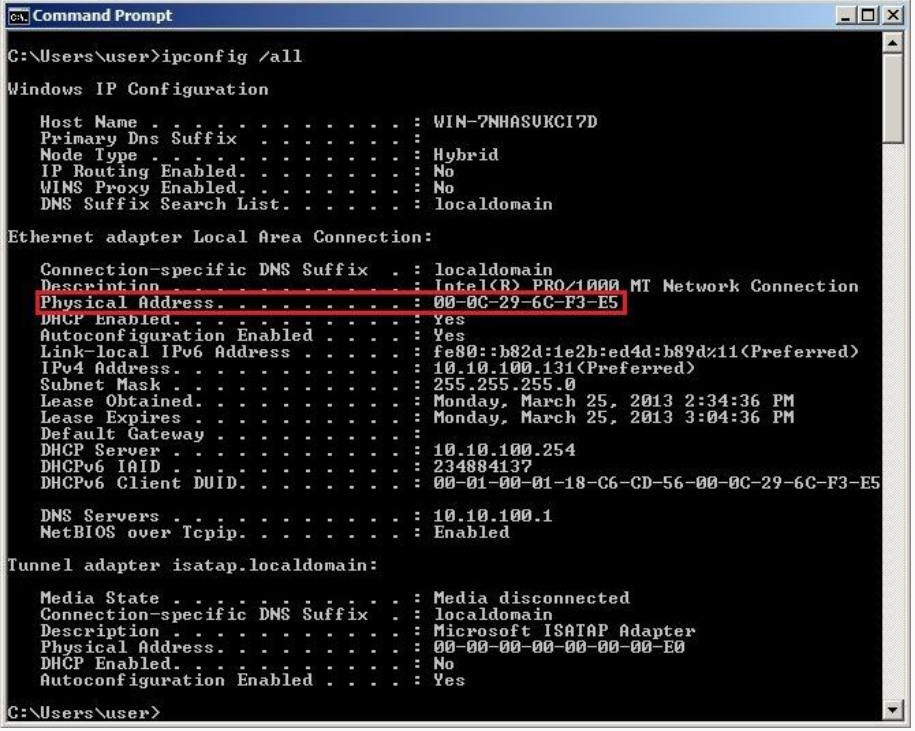
Ethernet

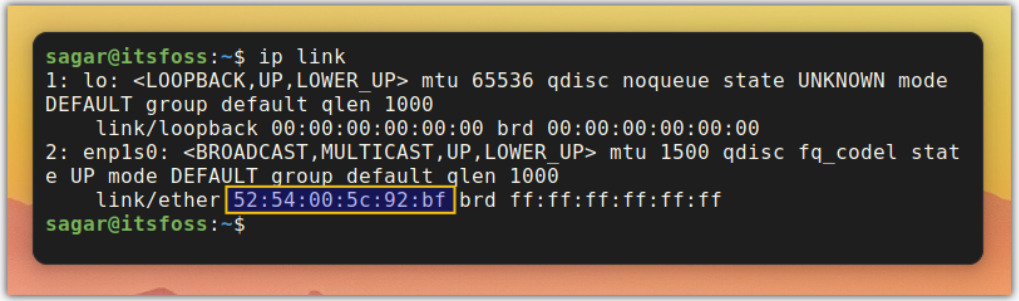


MAC (media access control) address

Full duplex vs half duplex



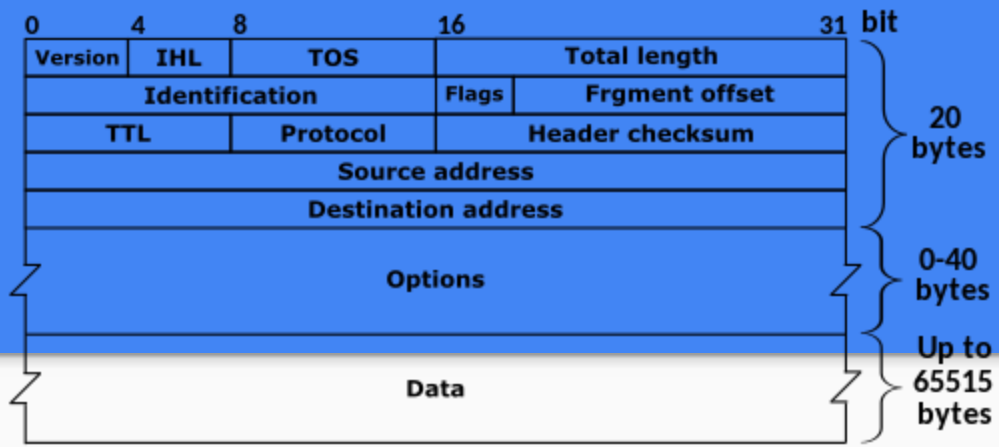

Command Prompt
C:\Users\user>ipconfig /all
Windows IP Configuration
Host Name . . . . . : WIN-7NHASVKCI7D
Primary Dns Suffix . . . . . :
Node Type . . . . . : Hybrid
IP Routing Enabled. . . . . : No
WINS Proxy Enabled. . . . . : No
DNS Suffix Search List. . . . . : localdomain
Ethernet adapter Local Area Connection:
Connection-specific DNS Suffix . : localdomain
Description . . . . . : Intel(R) PRO/1000 MT Network Connection
Physical Address. . . . . : 00-0C-29-6C-F3-E5
DHCP Enabled. . . . . : Yes
Autoconfiguration Enabled . . . . : Yes
Link-local IPv6 Address . . . . . : fe80::b82d:1e2b:ed4d:b89d%11(Preferred)
IPv4 Address. . . . . : 10.10.100.131(Preferred)
Subnet Mask . . . . . : 255.255.255.0
Lease Obtained. . . . . : Monday, March 25, 2013 2:34:36 PM
Lease Expires . . . . . : Monday, March 25, 2013 3:04:36 PM
Default Gateway . . . . . :
DHCP Server . . . . . : 10.10.100.254
DHCPv6 IAID . . . . . : 234884137
DHCPv6 Client DUID. . . . . : 00-01-00-01-18-C6-CD-56-00-0C-29-6C-F3-E5
DNS Servers . . . . . : 10.10.100.1
NetBIOS over Tcpip. . . . . : Enabled
Tunnel adapter isatap.localdomain:
Media State . . . . . : Media disconnected
Connection-specific DNS Suffix . : localdomain
Description . . . . . : Microsoft ISATAP Adapter
Physical Address. . . . . : 00-00-00-00-00-00-00-E0
DHCP Enabled. . . . . : No
Autoconfiguration Enabled . . . . : Yes
C:\Users\user>

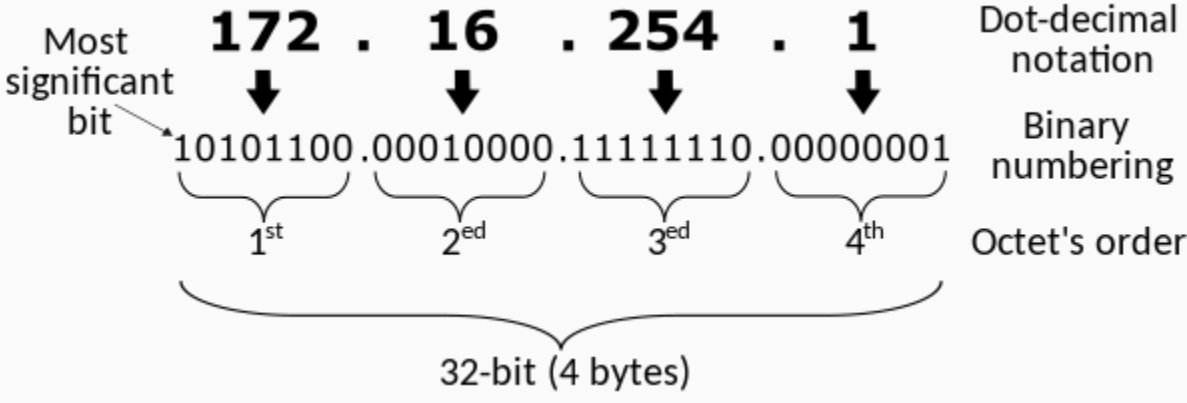

sagar@itsfoss:~$ ip link
1: lo: <LOOPBACK,UP,LOWER_UP> mtu 65536 qdisc noqueue state UNKNOWN mode DEFAULT group default qlen 1000
link/loopback 00:00:00:00:00:00 brd 00:00:00:00:00:00
2: enp1s0: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc fq_codel state UP mode DEFAULT group default qlen 1000
link/ether 52:54:00:5c:92:bf brd ff:ff:ff:ff:ff:ff
sagar@itsfoss:~$


Settings
WiFi
Properties
SSID:
Protocol: Wi-Fi 4 (802.11n)
Security type: WPA2-Personal
Network band: 2.4 GHz
Network channel: 11
Link speed (Receive/Transmit): 26/26 (Mbps)
Link-local IPv6 address:
IPv4 address:
IPv4 DNS servers:
Manufacturer: Intel Corporation
Description: Intel(R) Dual Band Wireless-N 7265
Driver version:
Physical address (MAC): 60-57-18-E1-34-0D
Copy

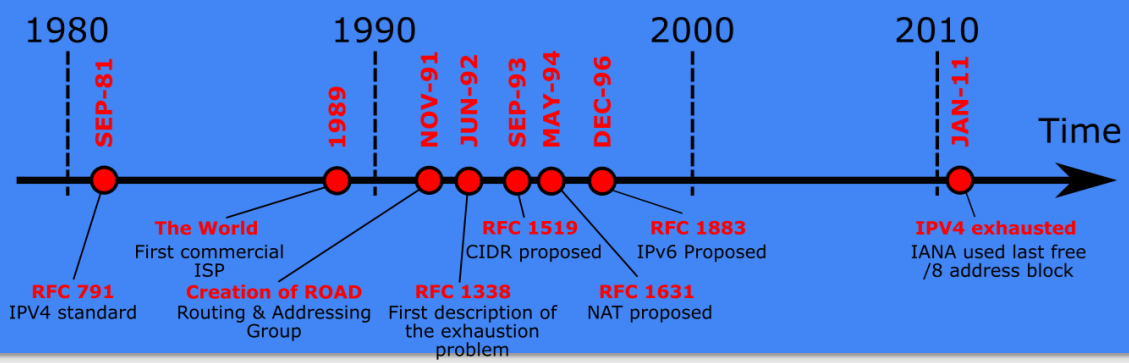
Layer 3

IP (Internet Protocol)





IPv4



- 0.0.0.0 Entire Internet
- 127.0.0.0/8 Host loopback
- 169.254.0.0/16 Link-local

public(グローバル) IP address vs private IP address:

Reserved private IPv4 network ranges[8]

Name	CIDR block	Address range	Number of addresses	*Classful* description
24-bit block	10.0.0.0/8	10.0.0.0 – 10.255.255.255	16 777 216	Single Class A.
20-bit block	172.16.0.0/12	172.16.0.0 – 172.31.255.255	1 048 576	Contiguous range of 16 Class B blocks.
16-bit block	192.168.0.0/16	192.168.0.0 – 192.168.255.255	65 536	Contiguous range of 256 Class C blocks.

Type	Binary form	Dot-decimal notation
Network space	11000000.10101000.00000101.00000000	192.168.5.0
Broadcast address	11000000.10101000.00000101.11111111	192.168.5.255
In red, is shown the host part of the IP address; the other part is the network prefix. The host gets inverted (logical NOT), but the network prefix remains intact.		

IPv4 Subnet

Home LAN: 192.168.0.0 ~ 192.168.255.255

Router/gateway: 192.168.0.1

PC1: 192.168.0.2 (192.168.0.2/16)

PC2: 192.168.0.3

Subnet mask: 255.255.0.0

Broadcast address: 192.168.255.255

Classless Inter-Domain Routing (CIDR) notation

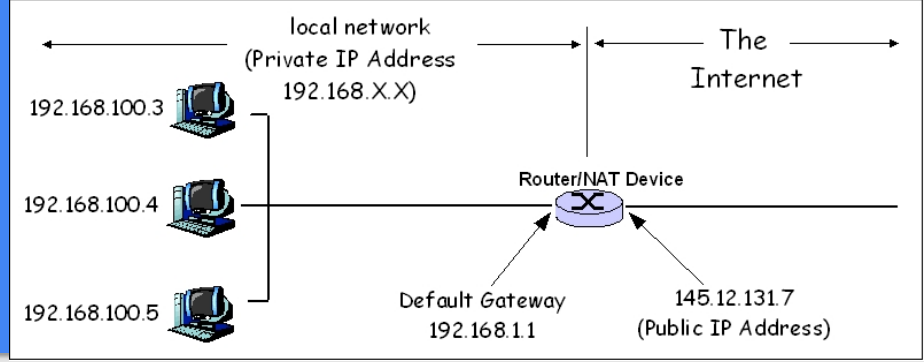
https://www.calculator.net/ip-subnet-calculator.html

IPv4 Subnet Calculator

Result

IP Address:	192.168.0.2
Network Address:	192.168.0.0
Usable Host IP Range:	192.168.0.1 - 192.168.255.254
Broadcast Address:	192.168.255.255
Total Number of Hosts:	65,536
Number of Usable Hosts:	65,534
Subnet Mask:	255.255.0.0
Wildcard Mask:	0.0.255.255
Binary Subnet Mask:	11111111.11111111.00000000.00000000
IP Class:	B
CIDR Notation:	/16
IP Type:	Private
Short:	192.168.0.2 /16
Binary ID:	11000000101010000000000000000010

IPv4 Subnets



Router0: 192.168.0.1/16

Router1: 192.168.1.1/24

PC1: 192.168.1.2

PC2: 192.168.1.3

Subnet mask: 255.255.255.0

Broadcast address: 192.168.1.255

Router2: 192.168.2.1/24

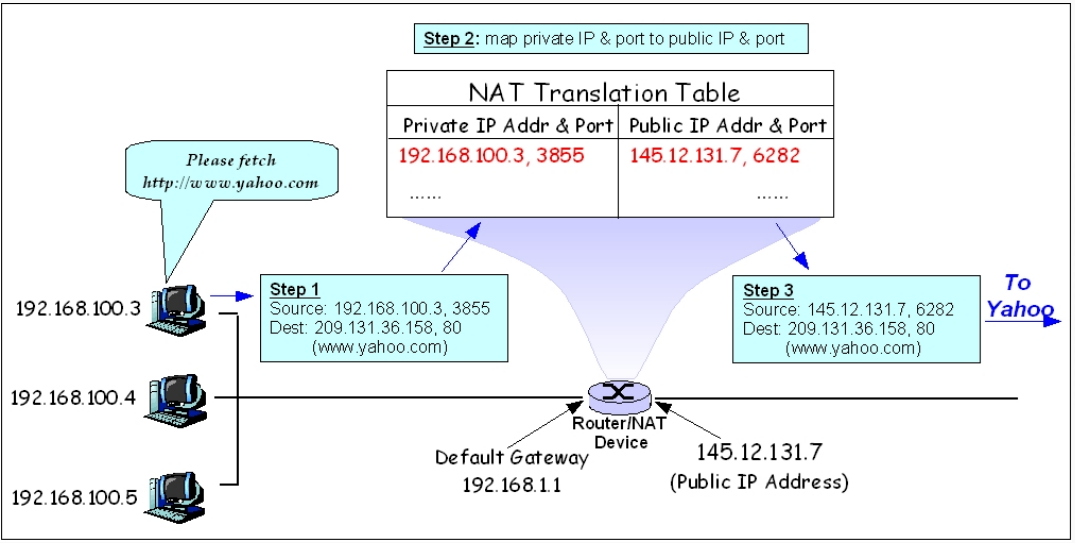
Server1: 192.168.2.2

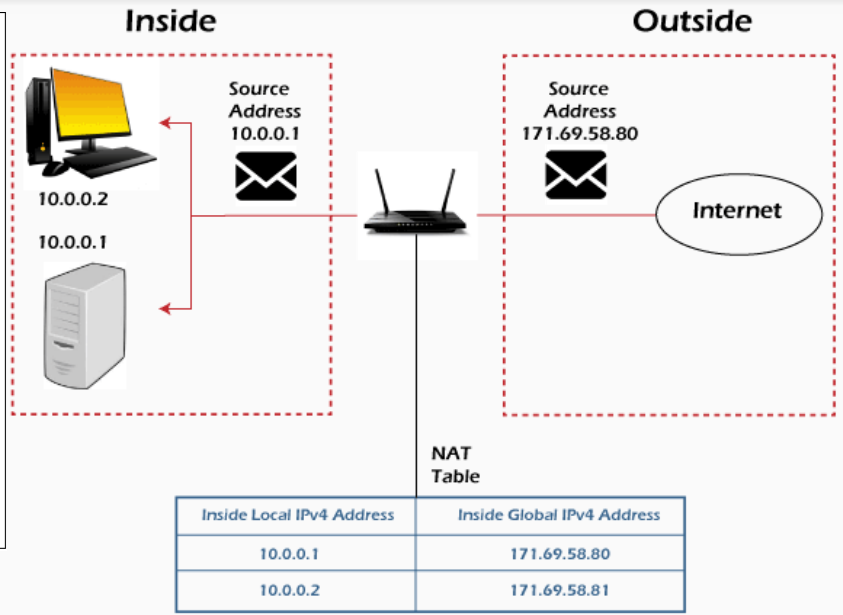
Server2: 192.168.2.3

Subnet mask: 255.255.255.0

Broadcast address: 192.168.2.255

NAT (network address translation)



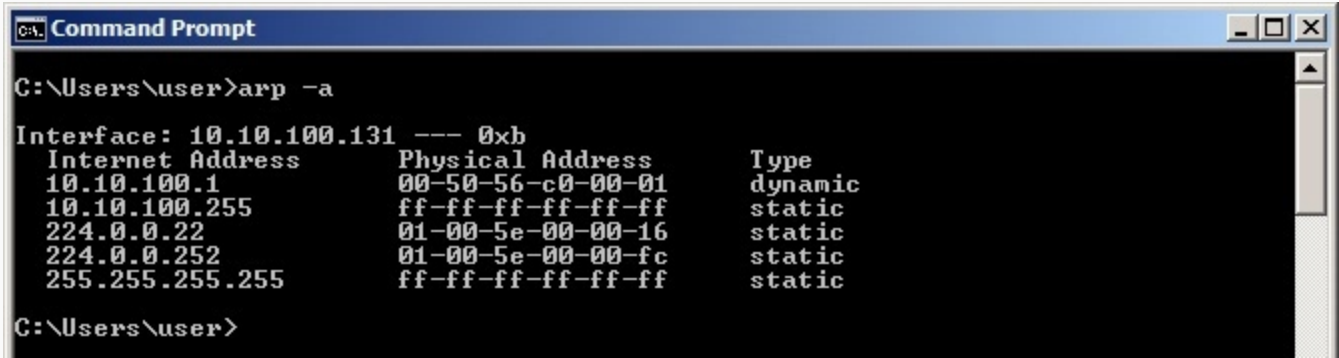


Address Resolution Protocol (ARP)

The MAC address of 192.168.0.2?

12:33:DB:8G:0F:E3

FF:FF:FF:FF:FF:FF broadcast



ICMP (Internet Control Message Protocol)

Layer 3. (ping)

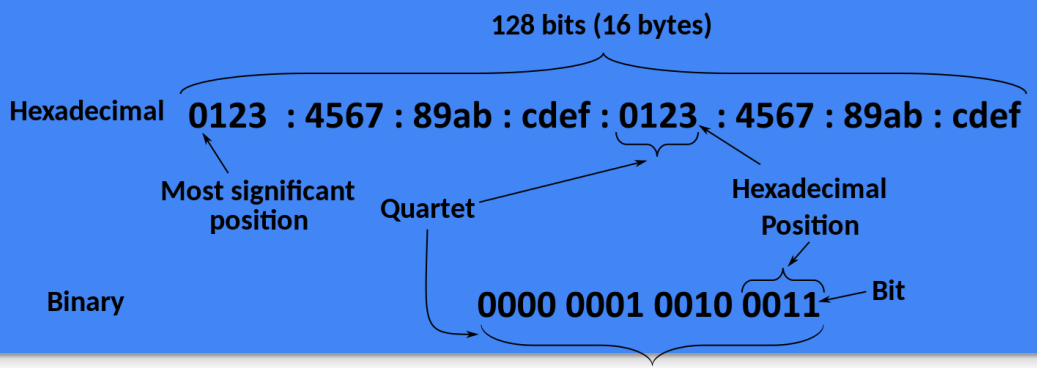
```
jing@builder:~ $ ping -c 2 yahoo.co.jp
PING yahoo.co.jp (182.22.16.251) 56(84) bytes of data.
64 bytes from 182.22.16.251 (182.22.16.251): icmp_seq=1 ttl=53 time=4.69 ms
64 bytes from 182.22.16.251 (182.22.16.251): icmp_seq=2 ttl=53 time=5.09 ms

--- yahoo.co.jp ping statistics ---
2 packets transmitted, 2 received, 0% packet loss, time 1002ms
rtt min/avg/max/mdev = 4.694/4.891/5.089/0.197 ms
jing@builder:~ $
```

```
PS C:\Users\jing> ping yahoo.co.jp

Pinging yahoo.co.jp [182.22.25.252] with 32 bytes of data:
Reply from 182.22.25.252: bytes=32 time=4ms TTL=56
Reply from 182.22.25.252: bytes=32 time=5ms TTL=56
Reply from 182.22.25.252: bytes=32 time=5ms TTL=56
Reply from 182.22.25.252: bytes=32 time=4ms TTL=56

Ping statistics for 182.22.25.252:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
    Minimum = 4ms, Maximum = 5ms, Average = 4ms
PS C:\Users\jing>
```

ICMP header format

Offsets	Octet	0								1								2								3							
Octet	Bit	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
0	0	Type								Code								Checksum															
4	32	Rest of header																															

IPv6



- :: Entire Internet
- ::1/128 localhost
- fe80::/64 link local (non-routable)
- fc00::/7 unique local address (ULA)
  - fc00::/8 undefined
  - fd00::/8
  - = IPv4 private address

RFC 4193 block	Prefix/*L*	Global ID (random)	Subnet ID	Number of addresses in subnet
	48 bits		16 bits	64 bits
fd00::/8	fd	xx:xxxx:xxxx	yyyy	18 446 744 073 709 551 616

Abbreviation

1. 0042→42, 0000→0, 0880→880
2. (use only once) consecutive zeros→::

- 0000:0000:0000:0000:0000:0000:0000:0001→::1
- 2001:0db8:0000:0000:0000:ff00:0042:8329→2001:db8::ff00:42:8329
- fc80:0000:0000:0001:0000:0000:0ff0:ffff→fc80::1:0:0:ff0:ffff

https://en.wikipedia.org/wiki/IPv6_address

Link-local address format

bits	10	54	64
field	*prefix*	*zeroes*	*interface identifier*

IPv6

Global Unicast Address (GUA)

2000::/3

= IPv4 public address

- Don’t use NAT6

- 2001::/16 IPv6 Internet
- 2002::/16 6to4 (deprecated)
- 2400::/12 APNIC IPv6 Internet
- 2600::/12 ARIN IPv6 Internet
- 2800::/12 LACNIC IPv6 Internet
- 2c00::/12 AFRINIC IPv6 Internet
- …

https://www.iana.org/assignments/ipv6-unicast-address-assignments/ipv6-unicast-address-assignments.xhtml

General unicast address format (routing prefix size varies)

bits	48 (or more)	16 (or fewer)	64
field	*routing prefix*	*subnet id*	*interface identifier*

Example: Arch Linux

```
jing@builder:~ $ ip a
1: lo: <LOOPBACK,UP,LOWER_UP> mtu 65536 qdisc noqueue state UNKNOWN group default qlen 1000
    link/loopback 00:00:00:00:00:00 brd 00:00:00:00:00:00
    inet 127.0.0.1/8 scope host lo
       valid_lft forever preferred_lft forever
    inet6 ::1/128 scope host
       valid_lft forever preferred_lft forever
2: ens18: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 9014 qdisc fq_codel state UP group default qlen 1000
    link/ether 00:15:5d:0b:[redacted] brd ff:ff:ff:ff:ff:ff
    altname enp0s18
    inet 192.168.0.[redacted]/16 metric 20 brd 192.168.255.255 scope global ens18
       valid_lft forever preferred_lft forever
    inet6 240b:10:[redacted]/128 scope global dynamic noprefixroute
       valid_lft 1035079sec preferred_lft 1035079sec
    inet6 fd69::[redacted]/128 scope global dynamic noprefixroute
       valid_lft 1035079sec preferred_lft 1035079sec
    inet6 fe80::215:5dff:fe0b:[redacted]/64 scope link
       valid_lft forever preferred_lft forever
jing@builder:~ $
```

GUA

ULA

link local

IPv4 vs IPv6

- IPv4: address exhaustion
- IPv4: simple address pattern
- IPv6: built-in IPsec
- IPv6: built-in Quality of Service (QoS)
- IPv6: everyone gets an address, no need for NAT
- IPv6: no checksum
- speed: ?

ICMPv6

```
jing@builder:~ $ ping -6 -c 10 google.co.jp
PING google.co.jp(nrt13s52-in-x03.1e100.net (2404:6800:4004:823::2003)) 56 data bytes
64 bytes from nrt13s52-in-x03.1e100.net (2404:6800:4004:823::2003): icmp_seq=1 ttl=115 time=15.1 ms
64 bytes from nrt13s52-in-x03.1e100.net (2404:6800:4004:823::2003): icmp_seq=2 ttl=115 time=8.89 ms
64 bytes from nrt13s52-in-x03.1e100.net (2404:6800:4004:823::2003): icmp_seq=3 ttl=115 time=8.23 ms
64 bytes from nrt13s52-in-x03.1e100.net (2404:6800:4004:823::2003): icmp_seq=4 ttl=115 time=8.61 ms
64 bytes from nrt13s52-in-x03.1e100.net (2404:6800:4004:823::2003): icmp_seq=5 ttl=115 time=8.87 ms
64 bytes from nrt13s52-in-x03.1e100.net (2404:6800:4004:823::2003): icmp_seq=6 ttl=115 time=8.15 ms
64 bytes from nrt13s52-in-x03.1e100.net (2404:6800:4004:823::2003): icmp_seq=7 ttl=115 time=7.78 ms
64 bytes from nrt13s52-in-x03.1e100.net (2404:6800:4004:823::2003): icmp_seq=8 ttl=115 time=7.91 ms
64 bytes from nrt13s52-in-x03.1e100.net (2404:6800:4004:823::2003): icmp_seq=9 ttl=115 time=8.20 ms
64 bytes from nrt13s52-in-x03.1e100.net (2404:6800:4004:823::2003): icmp_seq=10 ttl=115 time=9.19 ms

--- google.co.jp ping statistics ---
10 packets transmitted, 10 received, 0% packet loss, time 9014ms
rtt min/avg/max/mdev = 7.781/9.087/15.050/2.034 ms
jing@builder:~ $
```

MTU (maximum transmission unit)

L2: Ethernet frame: 1514 bytes

L3: 1500 bytes

IPv4: min 576 bytes / max 65536 bytes

IPv6: min 1280 bytes / max 4GB*

Jumbo frames: 1501 bytes~

Name:	Ethernet 2
Description:	Marvell AQti Adapter
Physical address (MAC):	60:32:b1:06:e
Status:	Operational
Maximum transmission unit:	1500
Link speed (Receive/Transmit):	10/10 (Gbps)

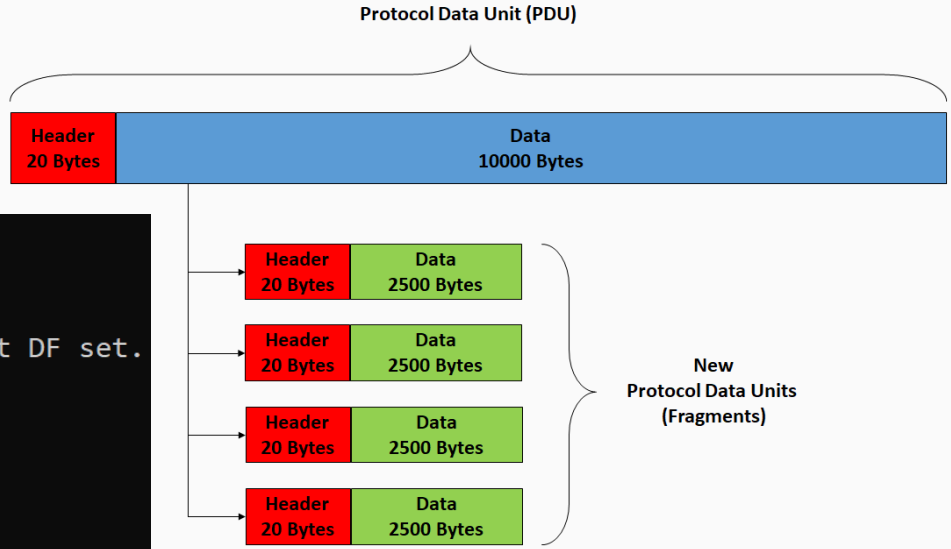
```
PS C:\Users\jing> Get-NetIPInterface

ifIndex InterfaceAlias                 AddressFamily NlMtu(Bytes) InterfaceMetric Dhcp     ConnectionState PolicyStore
------- --------------                 ------------- ------------ --------------- ----     --------------- -----------
14      Ethernet 3                     IPv6                  1500              25 Enabled  Connected       ActiveStore
5       Ethernet 2                     IPv6                  1500              15 Enabled  Connected       ActiveStore
12      Local Area Connection* 11      IPv6                  1500              25 Disabled Disconnected    ActiveStore
18      Local Area Connection* 10      IPv6                  1500              25 Disabled Disconnected    ActiveStore
10      Ethernet                       IPv6                  1500              20 Enabled  Connected       ActiveStore
11      Wi-Fi                          IPv6                  1500              30 Enabled  Connected       ActiveStore
1       Loopback Pseudo-Interface 1    IPv6            4294967295              75 Disabled Connected       ActiveStore
14      Ethernet 3                     IPv4                  9000              25 Enabled  Connected       ActiveStore
5       Ethernet 2                     IPv4                  9000              15 Enabled  Connected       ActiveStore
12      Local Area Connection* 11      IPv4                  1500              25 Enabled  Disconnected    ActiveStore
18      Local Area Connection* 10      IPv4                  1500              25 Enabled  Disconnected    ActiveStore
10      Ethernet                       IPv4                  1500              20 Enabled  Connected       ActiveStore
11      Wi-Fi                          IPv4                  1500              30 Enabled  Connected       ActiveStore
1       Loopback Pseudo-Interface 1    IPv4            4294967295              75 Disabled Connected       ActiveStore
```

IP packet fragmentation

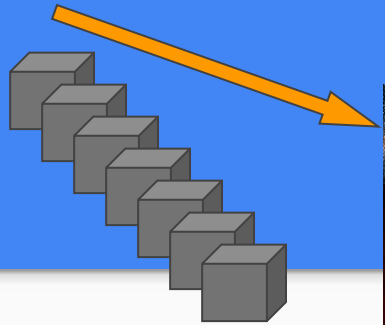
IPv4: fragment at the router

```
PS C:\Users\jing> ping 8.8.8.8 -f -l 1600

Pinging 8.8.8.8 with 1600 bytes of data:
Reply from 192.168.0.1: Packet needs to be fragmented but DF set.
Packet needs to be fragmented but DF set.
Packet needs to be fragmented but DF set.
Packet needs to be fragmented but DF set.

Ping statistics for 8.8.8.8:
    Packets: Sent = 4, Received = 1, Lost = 3 (75% loss),
```

IPv6: fragment at source



MTU black hole

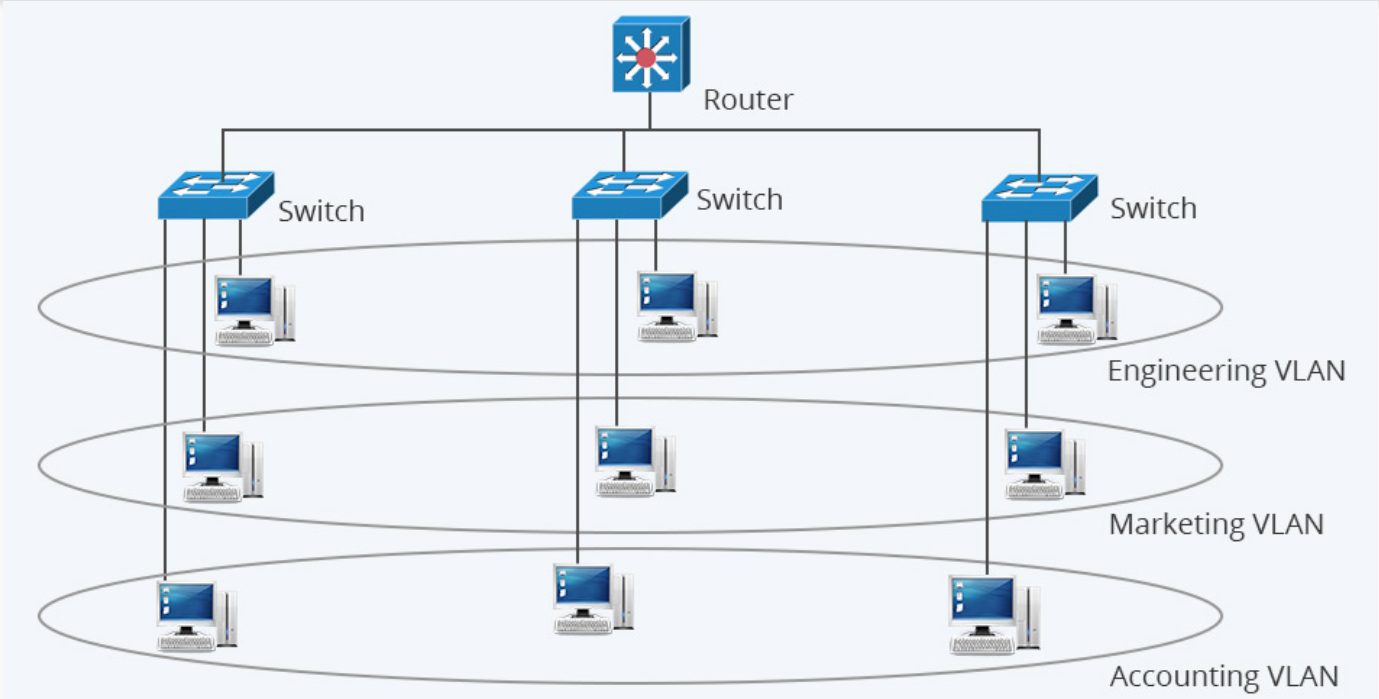


Path MTU Discovery

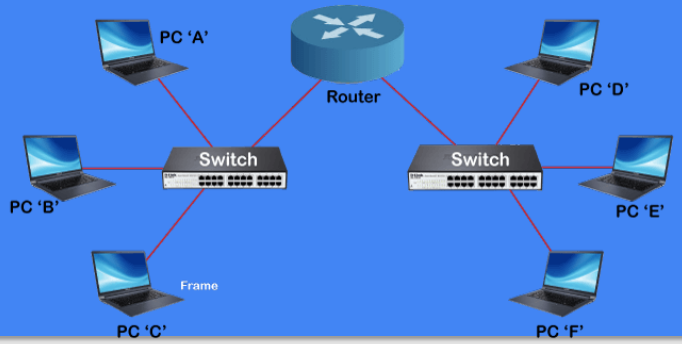
https://en.wikipedia.org/wiki/Path_MTU_Discovery

```
jing@builder:~ $ ping -6 -v -a -s 1492 google.com
ping: sock4.fd: -1 (socktype: 0), sock6.fd: 3 (socktype: SOCK_DGRAM), hints.ai_family: AF_INET6

ai->ai_family: AF_INET6, ai->ai_canonname: 'google.com'
PING google.com(nrt12s58-in-x0e.1e100.net (2404:6800:4004:828::200e)) 1492 data bytes
^C
--- google.com ping statistics ---
9 packets transmitted, 0 received, 100% packet loss, time 8109ms

jing@builder:~ $
```

VLAN


Router
Switch
Switch
Switch
Engineering VLAN
Marketing VLAN
Accounting VLAN
VLAN tag
VLAN10
VLAN11
VLAN4095

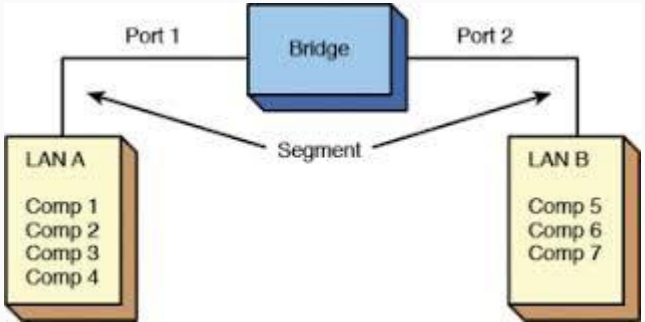
Switch vs router



Connection of networks through Router

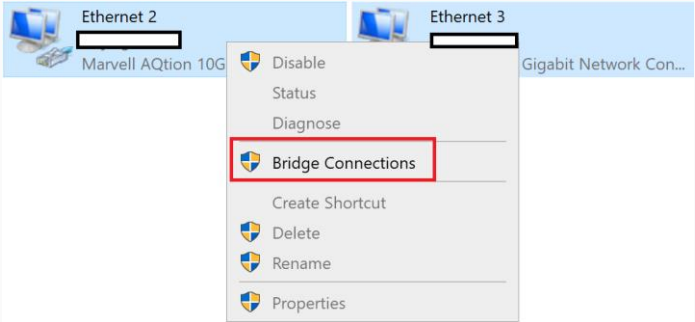
Switch

- Layer 2 (typically)
- Uses MAC address to forward data
- multiport bridge (connects network segments)
- no NAT



Router

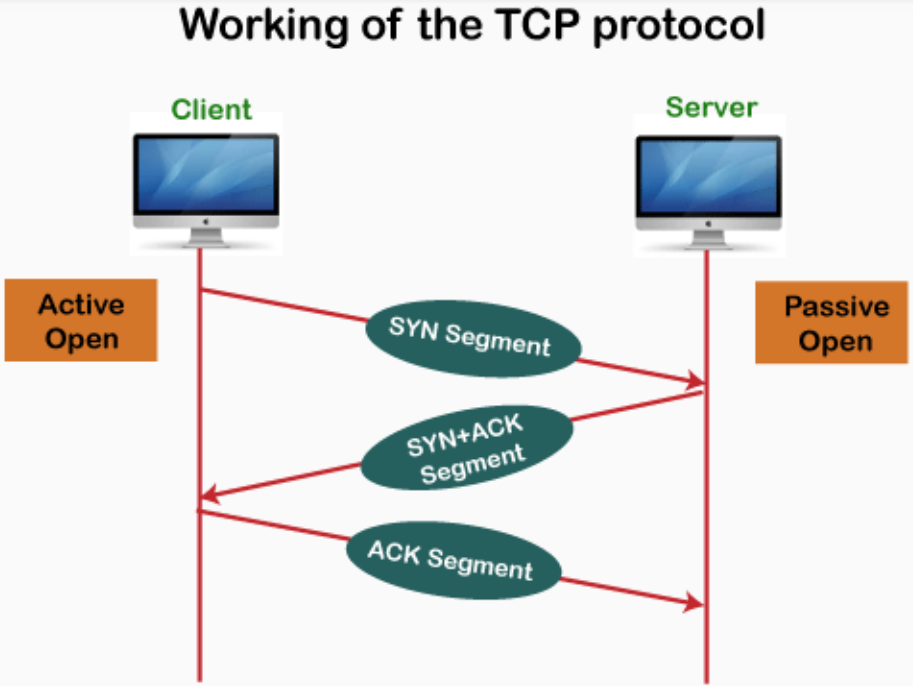
- Layer 3
- Uses IP address
- Routes traffic between different subnets
- can have NAT



TCP (Transmission Control Protocol)

Layer 4

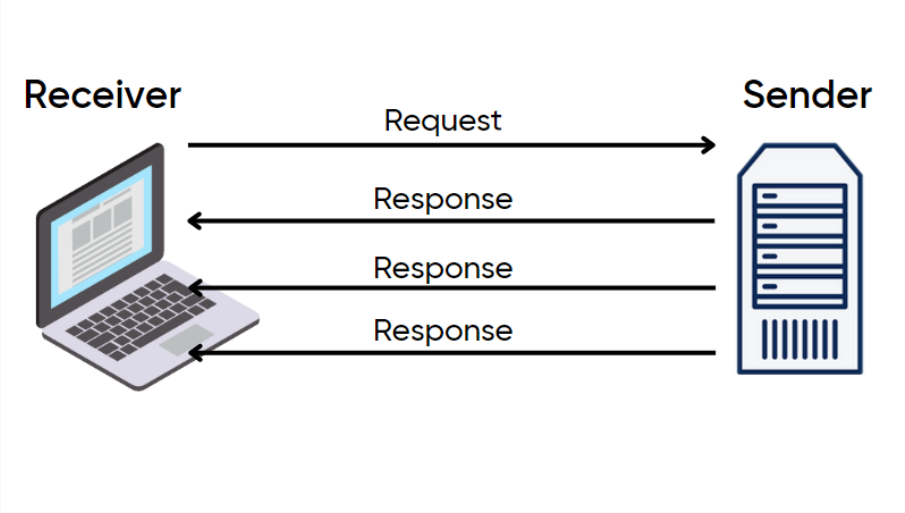
- 3 way handshakes
- retransmission
- 65536 ports
- Connection-oriented
- reliable, has error detection, has checksum
- unicast



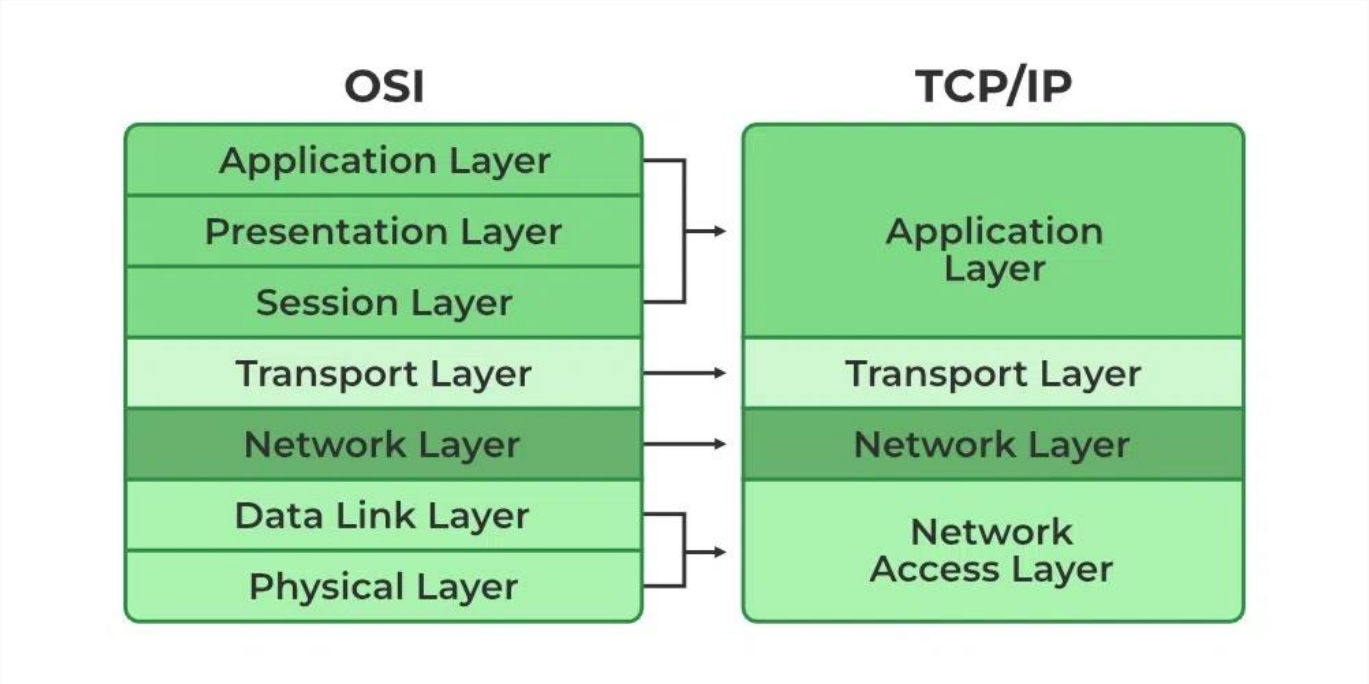
UDP (User Datagram Protocol)

Layer 4

- connectionless
- no retransmission delay
- 65536 ports
- unreliable but low latency
- has checksum
- unicast, multicast, and broadcast



TCP/IP model


OSI
TCP/IP
Application Layer
Presentation Layer
Session Layer
Transport Layer
Network Layer
Data Link Layer
Physical Layer
Application Layer
Transport Layer
Network Layer
Network Access Layer

HTTP, HTTPS

Hypertext Transfer Protocol (HTTP): layer 7

HTTP request: GET, PUT, POST, DELETE, …

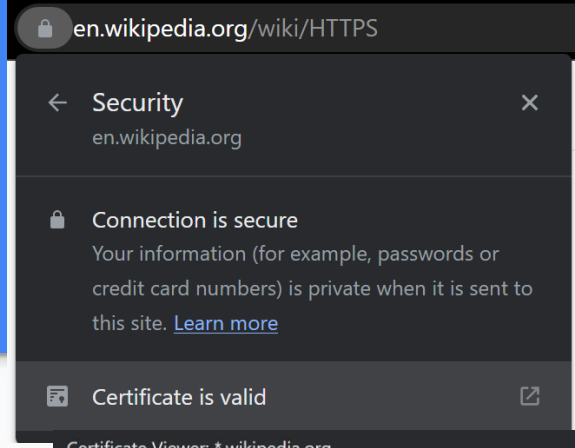
HTTP status: 200 (OK), 301 (moved permanently), 403 (forbidden), 404 (not found), 502 (bad gateway), 503 (service not available), …

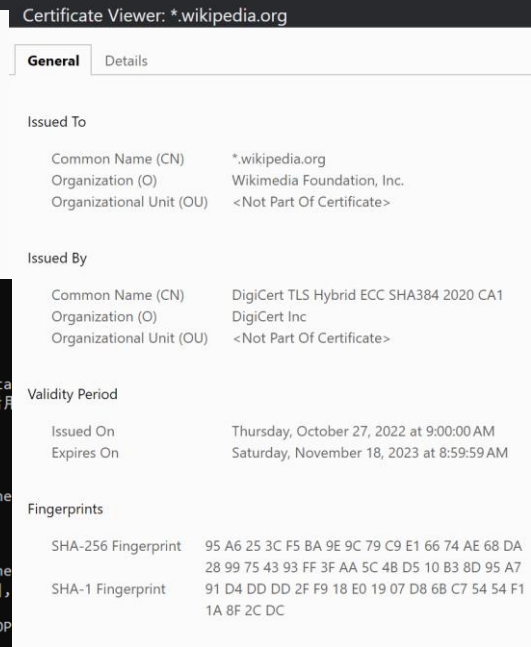
HTTP: port 80

HTTPS: port 443

HTTP/2

HTTP/3






```
PS C:\Users\jing> curl http://google.com


StatusCode        : 200
StatusDescription : OK
Content           : <!doctype html><html itemscope="" itemtype="http://schema.org/WebPage" lang="ja"><head><meta
                    content="世界中のあらゆる情報を検索するためのツールを提供しています。さまざまな検索機能を活用
お探しの情報を見つけてください。" name="description"><meta
                    content="n...
RawContent        : HTTP/1.1 200 OK
                    Content-Security-Policy-Report-Only: object-src 'none';base-uri 'self';script-src
                    'nonce-PgT03qFNjvuTt4TVFyG06g' 'strict-dynamic' 'report-sample' 'unsafe-eval' 'unsafe-inline
                    https: ...
Forms             : {f}
Headers           : {[Content-Security-Policy-Report-Only, object-src 'none';base-uri 'self';script-src
                    'nonce-PgT03qFNjvuTt4TVFyG06g' 'strict-dynamic' 'report-sample' 'unsafe-eval' 'unsafe-inline
                    https: http:;report-uri https://csp.withgoogle.com/csp/gws/other-hp], [X-XSS-Protection, 0],
                    [X-Frame-Options, SAMEORIGIN], [Cache-Control, private, max-age=0]...}
Images            : {@{innerHTML=; innerText=; outerHTML=<IMG id=hplogo style="PADDING-BOTTOM: 14px; PADDING-TOP
                    28px; PADDING-LEFT: 0px; PADDING-RIGHT: 0px" alt=Google
```

SSH (Secure Shell), Telnet

Layer 7

SSH: port 22

Telnet: port 23

```
$ ssh username@hostname:port
$ ssh -l username hostname
```

SCP, SFTP

openssh-server

Secure Copy Protocol (SCP)

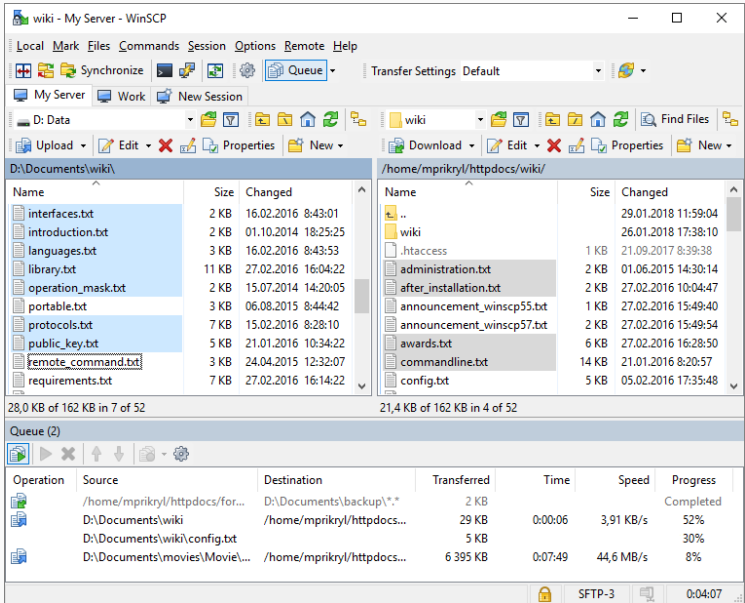
```
$ scp file.txt username@hostname:/path
```

local → remote

```
$ scp username@hostname:/path /localpath
```

remote → local

SSH File Transfer Protocol (SFTP)



WinSCP

DNS (Domain Name System)

The IP address of google.com?

2404:6800:4004:828::200e
142.250.198.14

Layer 7

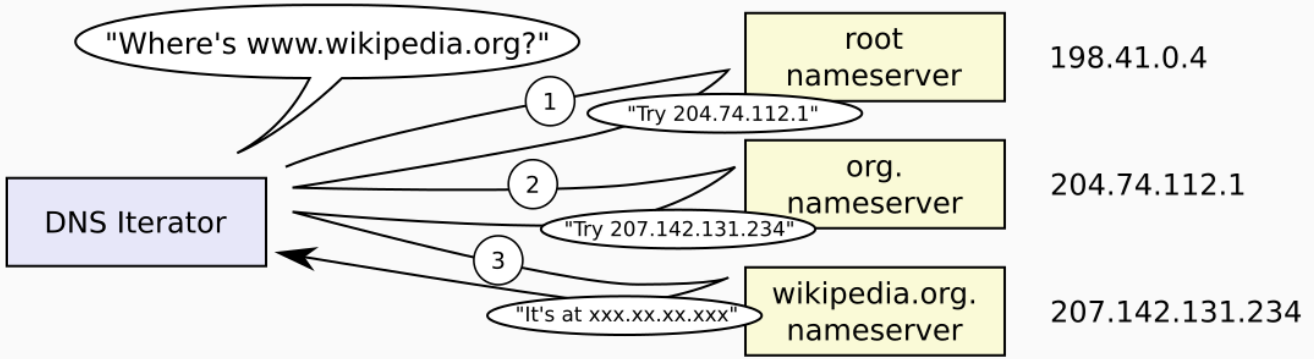
port: 53

nslookup, dig, …

A record: IPv4

AAAA record: IPv6

CNAME record: alias



DHCP (Dynamic Host Configuration Protocol)

Everyone, I need an IP address

offer: 192.168.0.2

gimme 192.168.0.2

ACK

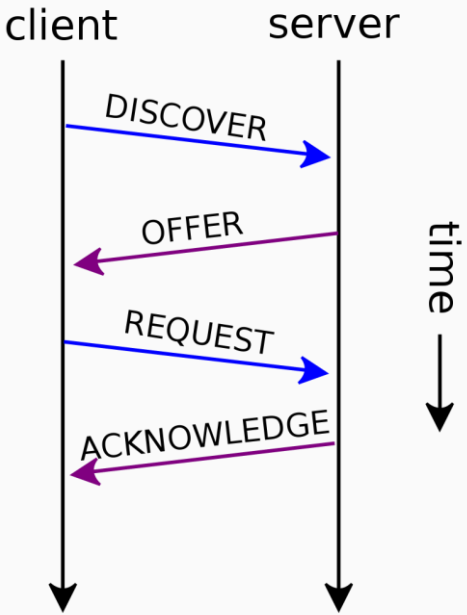
DHCP options:
1: subnet mask
3: router
6: DNS server
26: interface MTU
50: requested IP address
51: lease time
...

Layer 7

client: UDP port 68

server: UDP port 67

- static allocation



- Client sends a *solicit* from [*fe80::aabb:ccff:fedd:eeff*]:546 to multicast address [*ff02::1:2*]:547.[3]
- Server replies with an *advertise* from [*fe80::0011:22ff:fe33:5566*]:547 to [*fe80::aabb:ccff:fedd:eeff*]:546.
- Client replies with a *request* from [*fe80::aabb:ccff:fedd:eeff*]:546 to [*ff02::1:2*]:547.
- Server finishes with a *reply* from [*fe80::0011:22ff:fe33:5566*]:547 to [*fe80::aabb:ccff:fedd:eeff*]:546.

DHCPv6, SLAAC

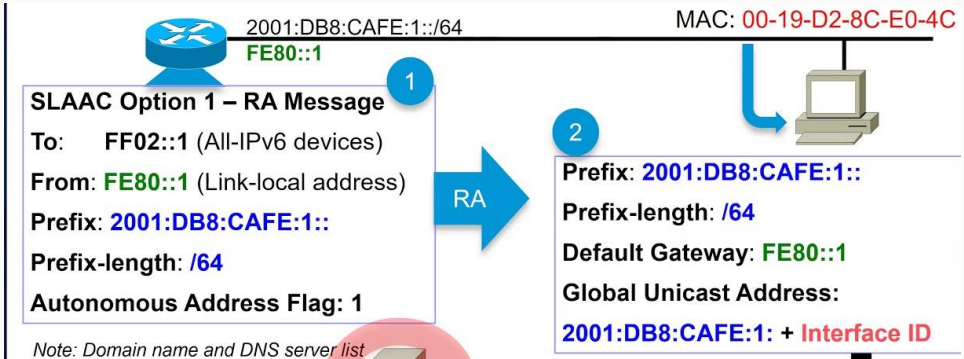
DHCPv6: layer 7
client: UDP port 546
server: UDP port 547

No more MAC address:
DUID (**D**HCP **U**nique **Id**entifier)

- Link-layer address plus time (DUID-LLT)
- Vendor-assigned unique ID based on enterprise number (DUID-EN)
- Link-layer address (DUID-LL)
- UUID-based DUID (DUID-UUID)
- MAC address (RFC 6939)

Stateless address autoconfiguration (SLAAC)

1. router solicitation: who's the router?
2. router advertisement: I'm the router and you can set your own address



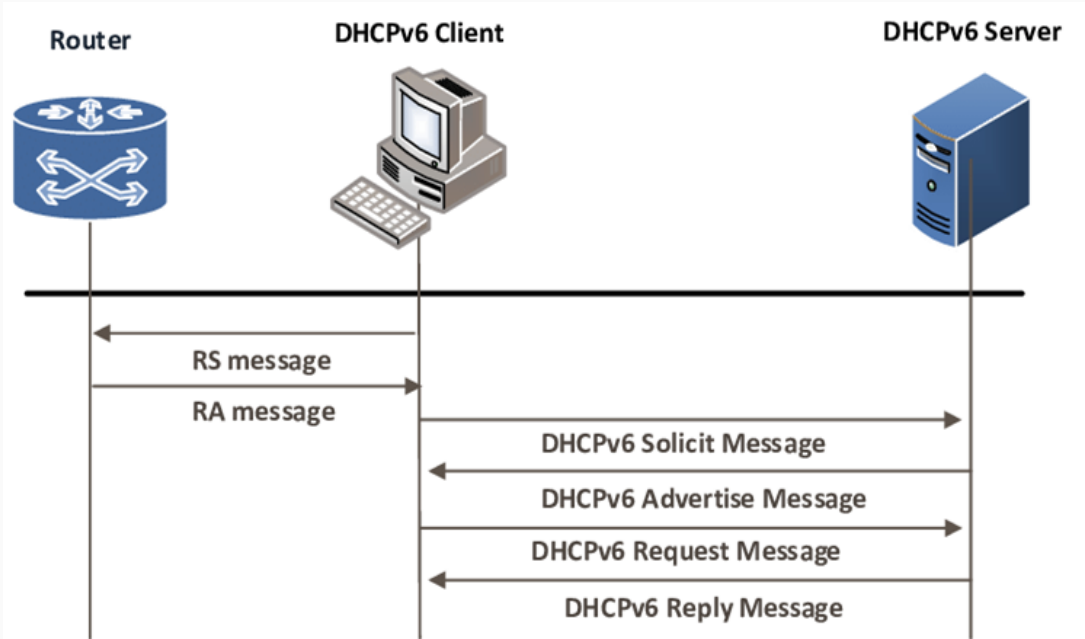
Router advertisement (RA)
Neighbor Discovery Protocol (NDP)

Every X seconds: I'm a router, here's the prefix, router address, and DNS server list…

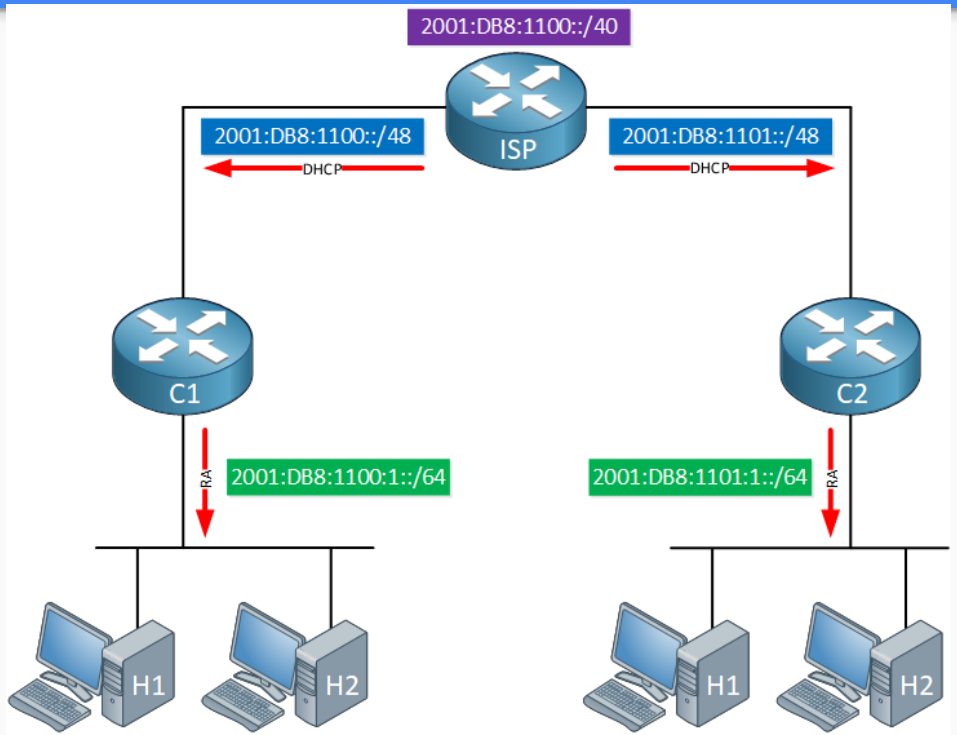
NDP:

- Router Solicitation
- Router Advertisement
- Neighbor Solicitation
- Neighbor Advertisement
- Redirect

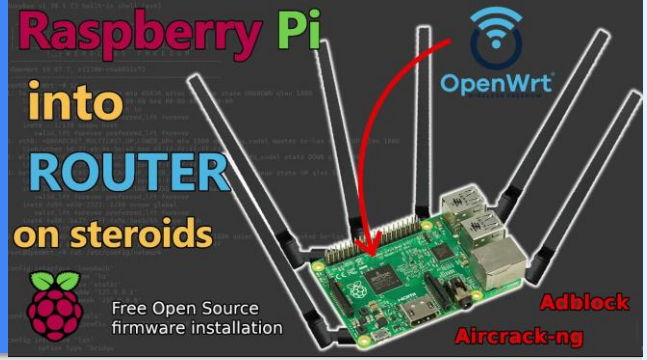
DOI:10.1109/ACCESS.2019.2919966



Prefix delegation (DHCPv6-PD)

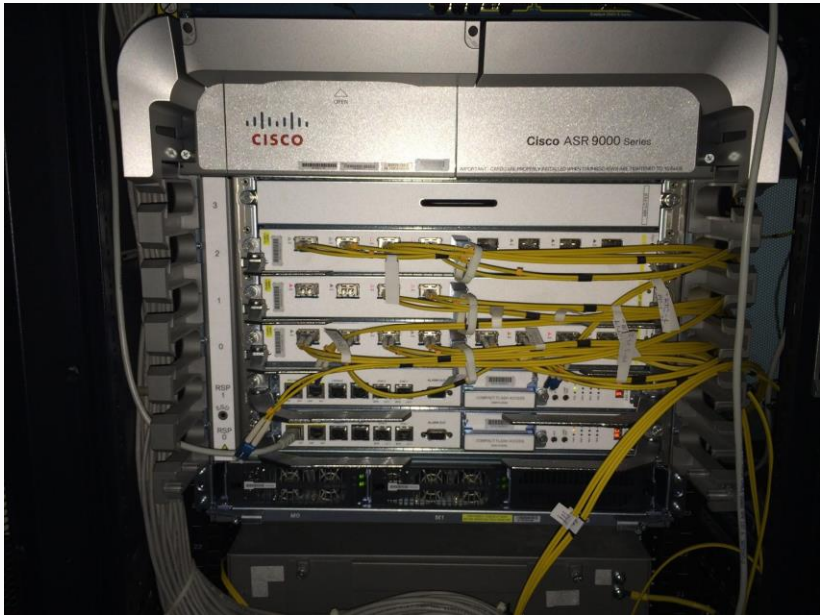


What is a "router"



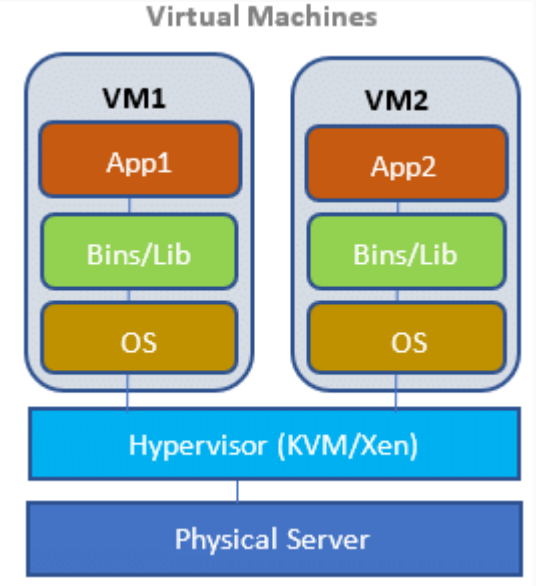
https://www.youtube.com/watch?v=PuBTE0xmdIk

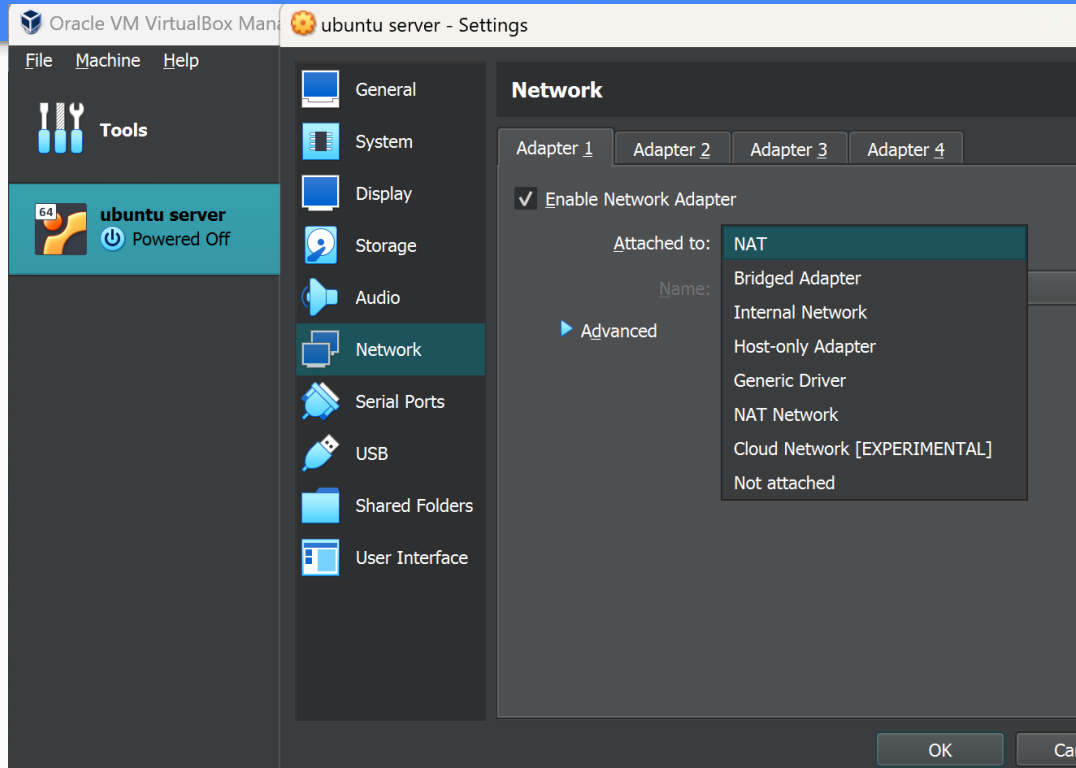
- router
- switch
- wireless access point (AP)
- DHCP server
- DHCPv6 server
- DNS server
- NAT (NAT44)
- firewall?



VMs and VM network

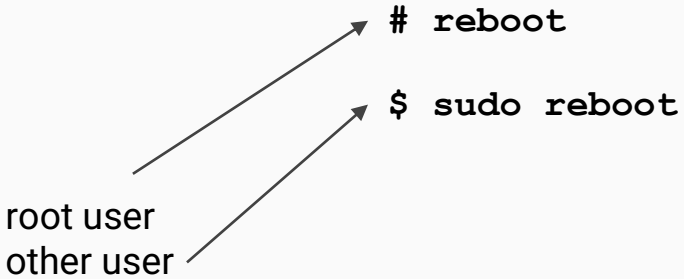
DOI:10.30534/ijatcse/2020/220942020





root user

- sudo: superuser do
- With great power comes great responsibility
- Are you a sudoer? /etc/sudoers
- `sudo -l` ←**Letter L** check/list sudo permission
- `su -` = `su root` (switch user)
- `sudo -i` (interactive sudo)
- exercise: create a sudo and a non-sudo user
- exercise: lock and unlock root user password



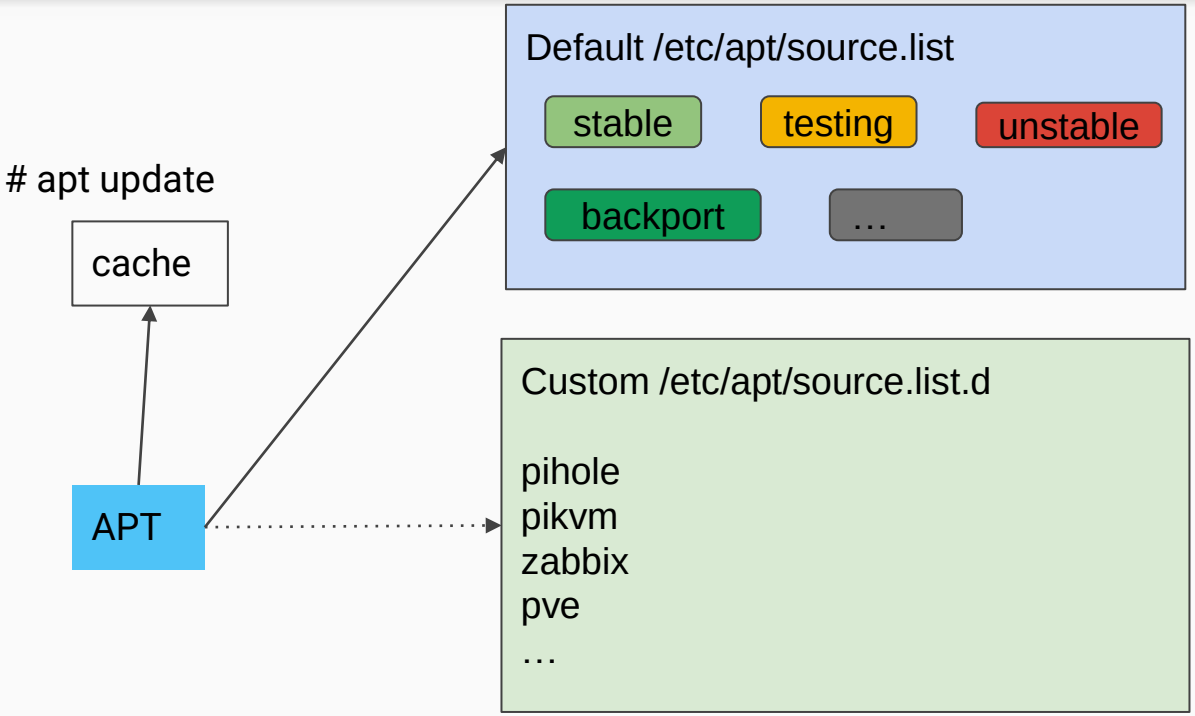
Package manager

DPKG – Debian Package Management System
| \ \
APT Synaptic Aptitude
(frontend)

RPM (Red Hat Package Manager)
| \ \
YUM DNF ZYpp

pacman homebrew npm yarn pip RubyGems Maven Gradle…

Example: APT


apt update
cache
APT
Default /etc/apt/source.list
stable
testing
unstable
backport
…
Custom /etc/apt/source.list.d
pihole
pikvm
zabbix
pve
…

Lottery!

Configure static IP address and DHCP

1. Debian/Ubuntu
    a. /etc/network/interfaces

```
auto eth0
iface eth0 inet static
  address XXX.XXX.XXX.XXX/XX
  gateway
```

    a. /etc/resolv.conf

```
nameserver 8.8.8.8
nameserver 8.8.4.4
```

```
# systemctl restart networking
```

```
auto eth0
iface eth0 inet dhcp
iface eth0 inet6 dhcp # (or auto)
```

Configure static IP address and DHCP

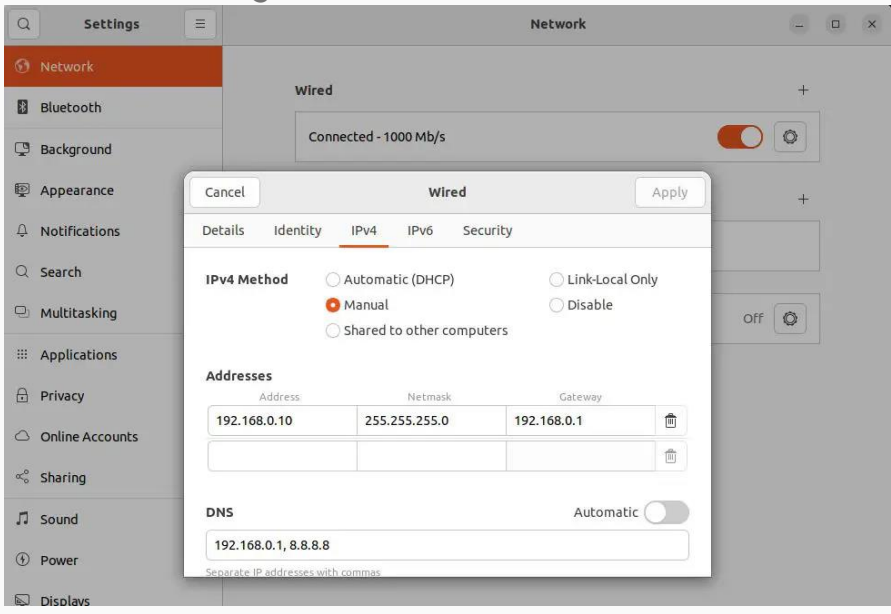
2. ip (iproute2) # loses config after reboot

```
$ ip addr add XXX.XXX.XXX.XXX dev eth0
$ ip route add 192.168.XXX.XXX/24 dev eth0
$ ip route add default via 192.168.X.1
```

/etc/resolv.conf

```
nameserver 8.8.8.8
nameserver 8.8.4.4
```

3. NetworkManager



Configure static IP address and DHCP

4.1 systemd-networkd

/etc/systemd/network/20-wired.network

```
[Match]
Name=enp1s0

[Network]
Address=10.1.10.9/24
Gateway=10.1.10.1
DNS=10.1.10.1
```

4.2 systemd-resolved

```
# ln -rsf /run/systemd/resolve/stub-resolv.conf
/etc/resolv.conf
```

/etc/systemd/network/25-wireless.network

```
[Match]
Name=wlp2s0

[Network]
DHCP=yes
IgnoreCarrierLoss=3s
```

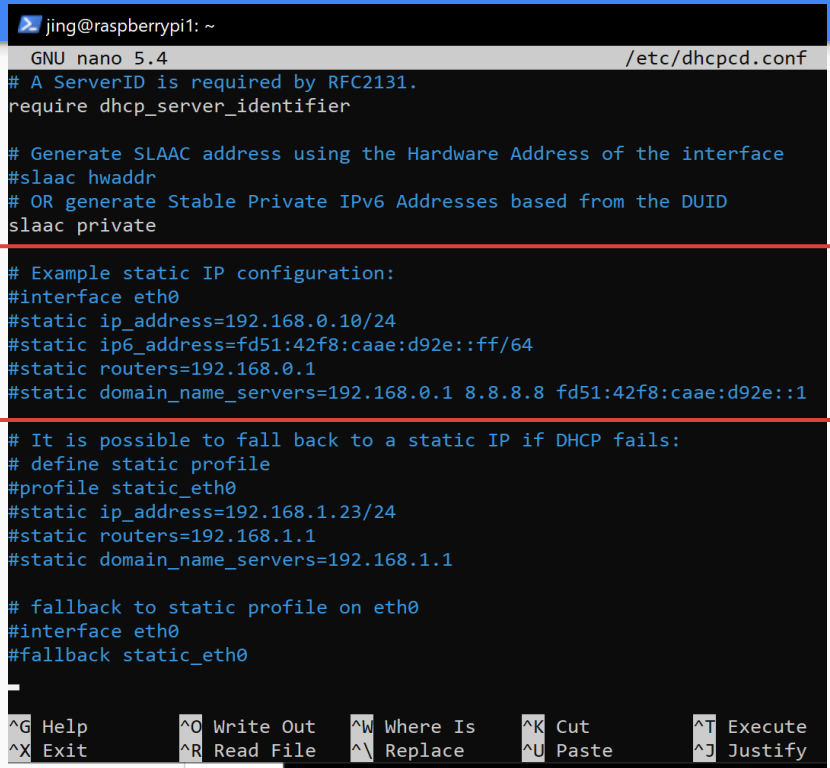
```
# systemctl restart <service-name>
```

https://wiki.archlinux.org/title/Systemd-networkd

Configure static IP address and DHCP

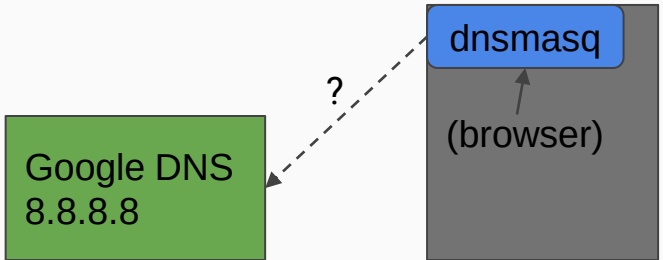
5. dhcpcd /etc/dhcpcd.conf

```
# systemctl restart dhcpcd
```



Exercise: setup your own DNS server

1. Install **`dnsmasq`**
2. /etc/dnsmasq.conf
   a. server=8.8.8.8
   b. server=1.1.1.1
3. Change network manager DNS address
4. Start (/enable) dnsmasq



3.1 systemd-resolved
/etc/systemd/resolved.conf
DNS=127.0.0.1 ::1

3.2 dhcpcd
/etc/dhcpcd.conf
static domain_name_servers=127.0.0.1 ::1

3.3 NetworkManager

Browsers to surf the net

```
####### update cache first #######
# apt update
# apt upgrade


# apt install firefox
######### or ########
# apt install chromium-browser
```

yum...

Homework

1. 日本語、中国語入力方法のインストール
   。
2. (bonus) mount SFTP over CLI