

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

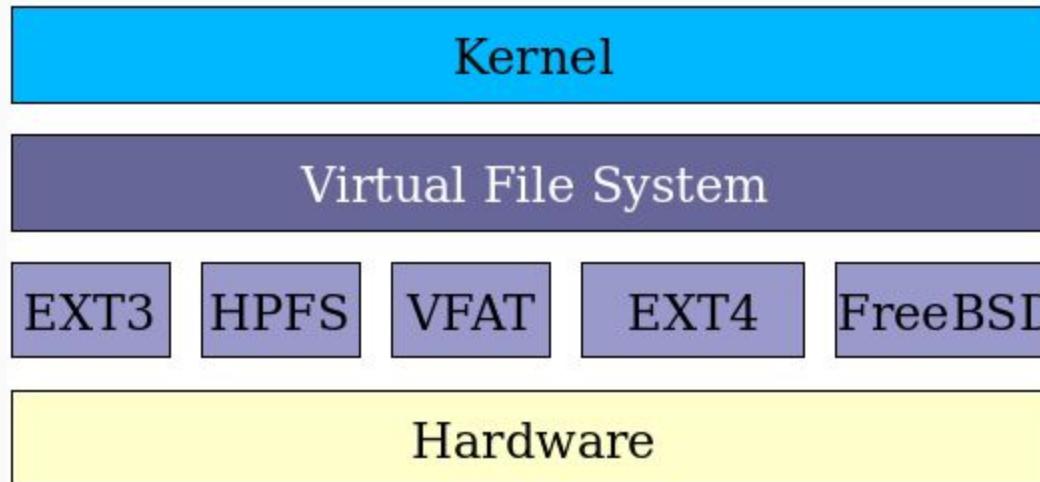


File Allocation Table (FAT) (1977~)

- 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
 - FILEA~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

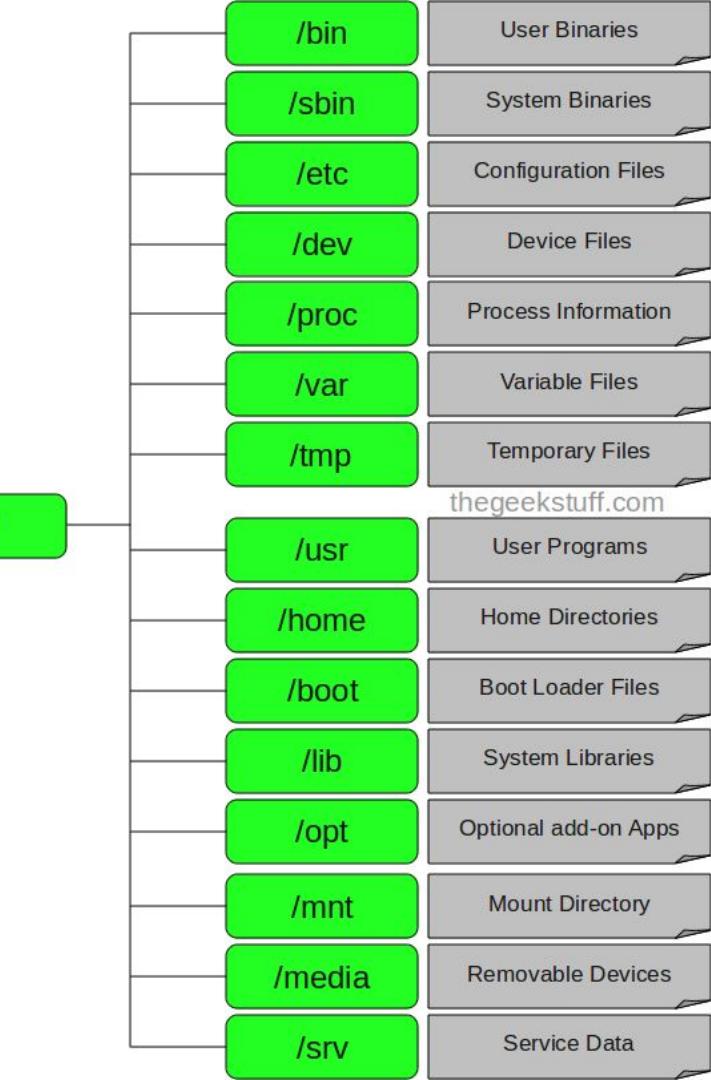


Directory/folder

```
$ ls /
```

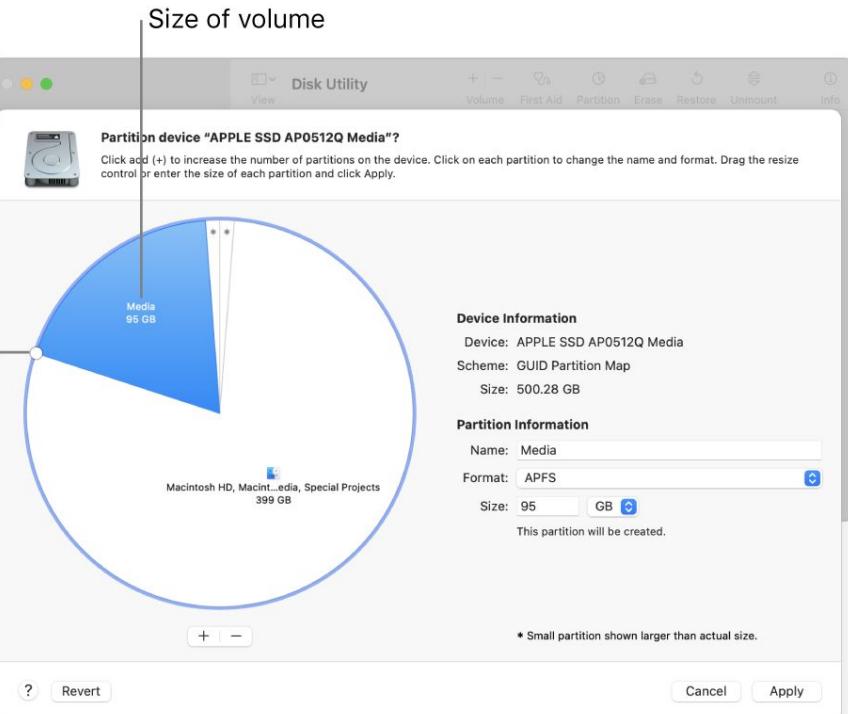
Filesystem Hierarchy Standard

<https://www.pathname.com/fhs/pub/fhs-2.3.pdf>



Partition vs volume

Drag to resize a volume.



Volume	Layout	Type	File System	Status	Capacity	Free Spa...	% Free
(H:)	Simple	Basic	NTFS	Healthy (P...)	192.08 GB	180.56 GB	94 %
(J:)	Simple	Basic	NTFS	Healthy (P...)	63.29 GB	63.12 GB	100 %
New Volume (F:)	Striped	Dynamic	NTFS	Healthy	20.27 GB	20.16 GB	99 %
New Volume (G:)	Simple	Dynamic	NTFS	Healthy	10.24 GB	10.15 GB	99 %
New Volume (I:)	Mirror	Dynamic	NTFS	Healthy	1003.62 GB	1002.25 ...	100 %
System Reserved	Simple	Basic	NTFS	Healthy (S...)	100 MB	64 MB	64 %
System Reserved (...)	Simple	Basic	NTFS	Healthy (A...)	628 MB	376 MB	60 %

Disk 0
Basic
60.00 GB
Online

System 100 MB Healthy	(C): 30.60 GB NTFS Healthy (Boot, Page)	(E): 10.08 GB NTFS Healthy (Primary)	19.21 GB Unallocated
-----------------------------	---	--	-------------------------

Disk 1
Dynamic
1024.00 GB
Online

New Volume (G): 10.24 GB NTFS Healthy	New Volume (F): 10.14 GB NTFS Healthy	New Volume (I): 1003.62 GB NTFS Healthy
---	---	---

Disk 2
Dynamic
2048.00 GB

New Volume (F): 10.14 GB NTFS	New Volume (I): 1003.62 GB NTFS	1034.24 GB
----------------------------------	------------------------------------	------------

Legend: Unallocated (Black), Primary partition (Blue), Simple volume (Green), Striped volume (Teal), Mirrored volume (Red).

Master Boot Record (MBR) (1983)

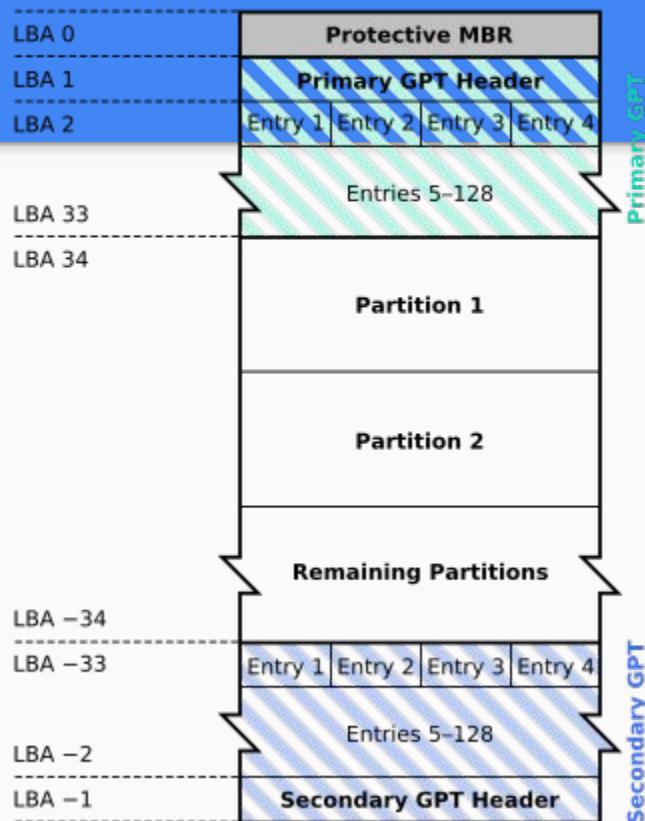
- Boot code
 - 16 bit
 - beginning of the disk
- Partition table
 - 4 primary partitions
 - or 3 primary partitions and 1 extended partition (many logical partitions inside)
 - max 2TB disk

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

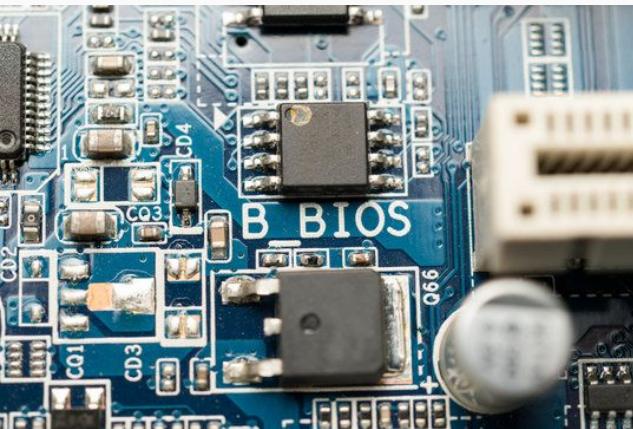
GUID Partition Table Scheme



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



- ▶ Standard CMOS Features
- ▶ Advanced BIOS Features
- ▶ Advanced Chipset Features
- ▶ Integrated Peripherals
- ▶ 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

↑ ↓ → ← : Select Item

F10 : Save & Exit Setup

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



⌚ 16:31 | Wed 4 Mar, 2020

GAME BOOST

A-XMP



CPU Speed 3.90 GHz
DDR Speed 2666 MHz

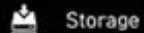
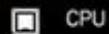
CPU Temperature: 34°C
MotherBoard Temperature: 32°C

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



Current DRAM Size: 16384MB DRAM Voltage: 1.220V

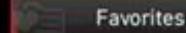
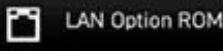
Model	Size
DIMMA1: unknown	N/A
DIMMA2: A-DATA	8192 MB
DIMMB1: unknown	N/A
DIMMB2: A-DATA	8192 MB

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



Install Linux

copy + paste text

Bash (Bourne Again SHeLL)

- 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也可)
- 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

(bash) shell script

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

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

```
script.sh
```

```
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
```

jing@builder: ~

GNU nano 7.2

dof.sh

```
#!/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
```

jing@builder:~ \$ chmod +x dof.sh
jing@builder:~ \$./dof.sh

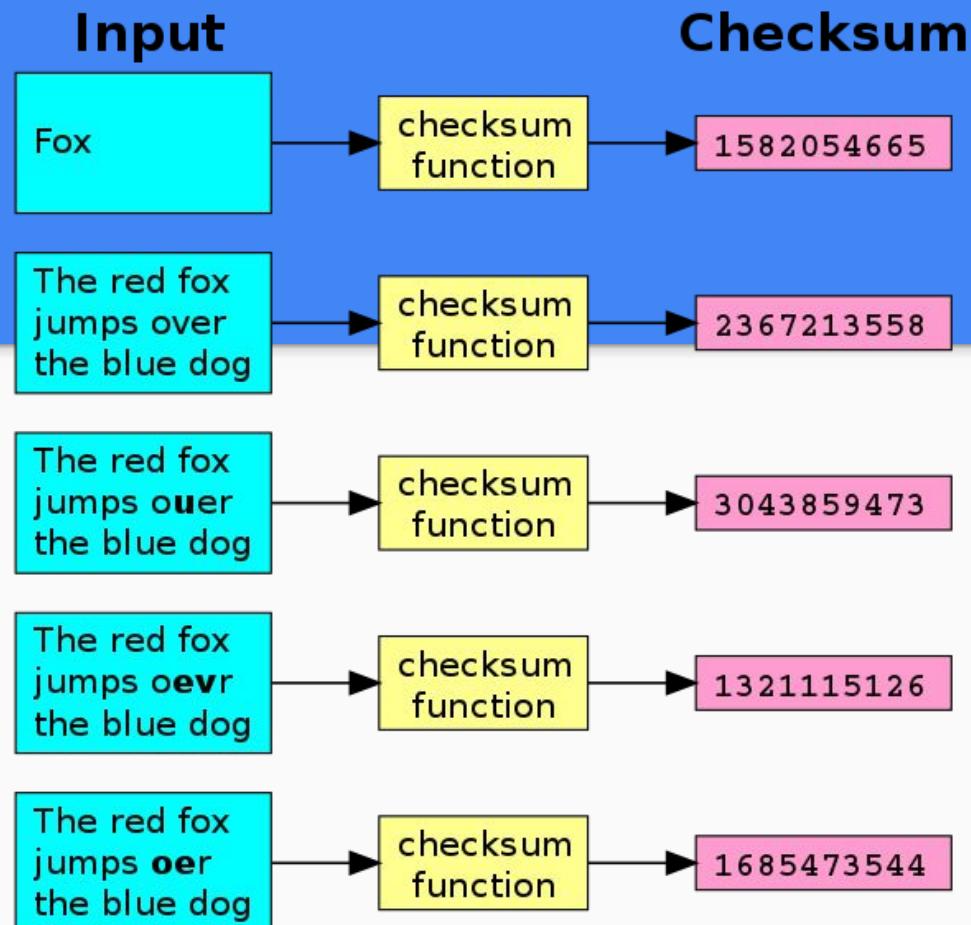
Arch-MOTD is a directory
checksum is a file
Desktop is a directory
Documents is a directory
dof.sh is a file
Downloads is a directory
FastFlix is a directory
flashrom_1.2-5build1_amd64.deb is a file
grubnetx64.efi is a file
ipxe is a directory
ipxe-amd64.efi is a file
ipxe-arm64.efi is a file
lcthw is a directory
learn-c-the-hard-way-lectures is a directory
Music is a directory
Pictures is a directory
Public is a directory
raspi-jumbo-frames.patch is a file
script.sh is a file
Templates is a directory
undionly.kpxe is a file
update_motd.sh is a file
Videos is a directory
yay is a directory

[Read 15 lines

^G Help ^O Write Out ^W Where Is ^K Cut ^T Execute
^X Exit ^R Read File ^\ Replace ^U Paste ^J Justify

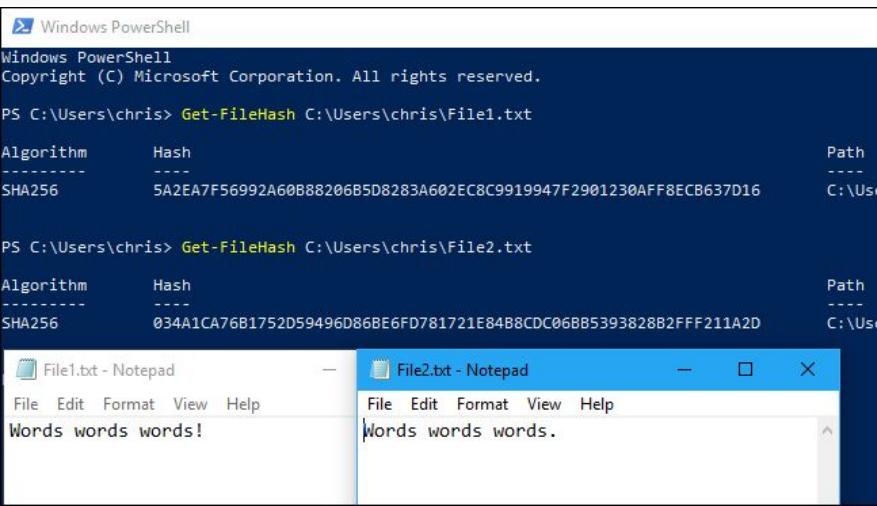
Checksum & Hash algorithm

- CRC
- CRC64
- MD5
- SHA1
- SHA256
- SHA512
- ...



SHA256

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



Windows PowerShell
Copyright (C) Microsoft Corporation. All rights reserved.
PS C:\Users\chris> **Get-FileHash C:\Users\chris\File1.txt**
Algorithm Hash Path
---- ----
SHA256 5A2EA7F56992A60B88206B5D8283A602EC8C9919947F2901230AFF8ECB637D16

PS C:\Users\chris> **Get-FileHash C:\Users\chris\File2.txt**
Algorithm Hash Path
---- ----
SHA256 034A1CA76B1752D59496D86BE6FD781721E84B8CDC06BB5393828B2FFF211A2D

File1.txt - Notepad File2.txt - Notepad
File Edit Format View Help File Edit Format View Help
Words words words! Words words words.

<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.

```
GNU nano 7.2
#!/bin/bash

files="$HOME/Downloads"

for f in $files/*
do
    if [ ! -d $f ]
    then
        sha256sum $f >> "$files/checksum"
    fi
done
```

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>
```

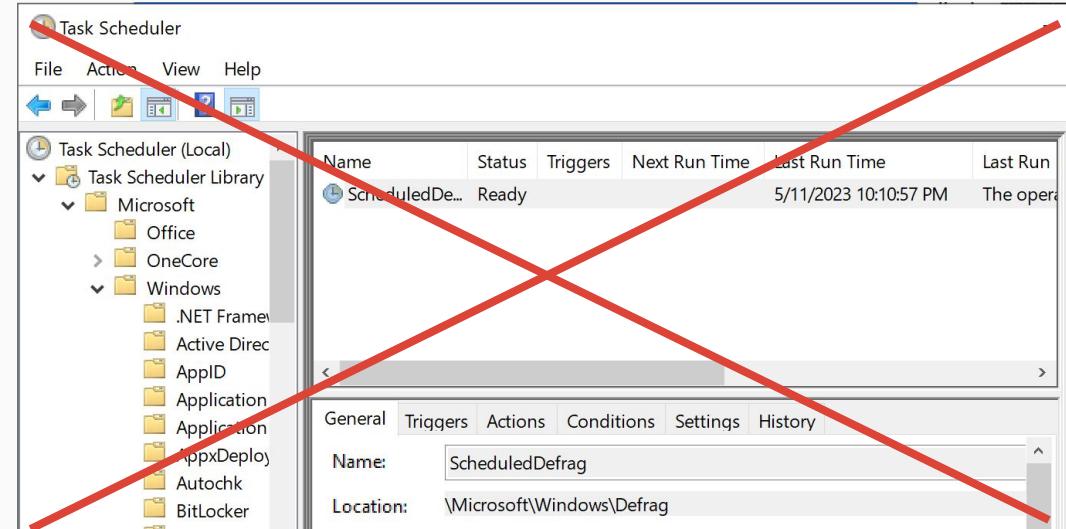
```
$ sudo crontab -e
```

```
# 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
^X Exit

^O Write Out
^R Read File

^W Where
^\\ Replace



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

D Deleted Data

128KB Logical Block #1			
D	D	D	D
D	D	D	D
D	D	D	D
D	D	D	D
D	D	D	D
D	D	D	D
D	D	D	D

What the Operating System Knows

128KB Physical Block #1			
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	32

What the SSD Controller Thinks

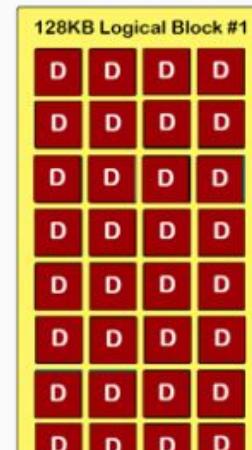
E Erased Page
V Valid Data
D Dirty/Stale Data

Without TRIM Command

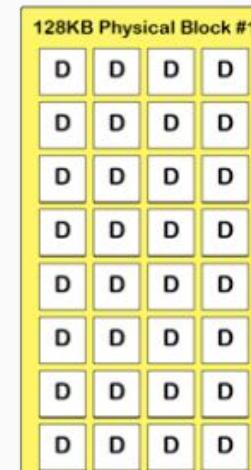
TRIM

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

D Deleted Data



What the Operating System Knows



What the SSD Controller Thinks



With TRIM Command

[What is Trim? | Crucial.com](#)

fstrim

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

Discard unused blocks on a mounted filesystem.

Options:

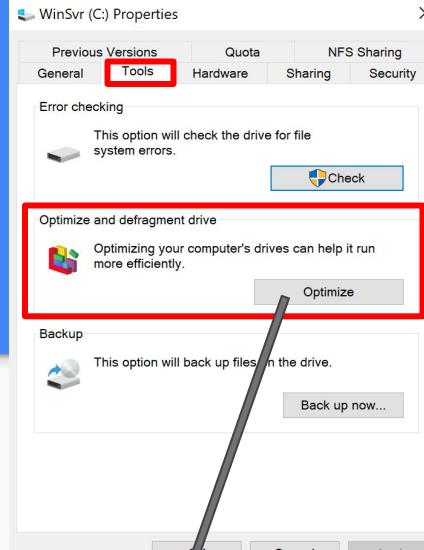
-a, --all	trim mounted filesystems
-A, --fstab	trim filesystems from /etc/fstab
-I, --listed-in <list>	trim filesystems listed in specified files
-o, --offset <num>	the offset in bytes to start discarding from
-l, --length <num>	the number of bytes to discard
-m, --minimum <num>	the minimum extent length 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
```



Optimize Drives

You can optimize your drives to help your computer run more efficiently, or analyze them to find out if they need to be optimized. Only drives on or connected to your computer are shown.

Status

Drive	Media type	Last analyzed or o...	Current status
WinSrv (C:)	Solid state drive	5/3/2023 12:13 AM	OK (9 days since last retrim)
[redacted]	Solid state drive	5/4/2023 3:15 AM	OK (8 days since last retrim)
Solid state drive	Never run		Needs optimization
Solid state drive	5/3/2023 12:13 AM	OK (9 days since last retrim)	
Solid state drive	5/4/2023 3:15 AM	OK (8 days since last retrim)	

Advanced View

Analyze

Optimize

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

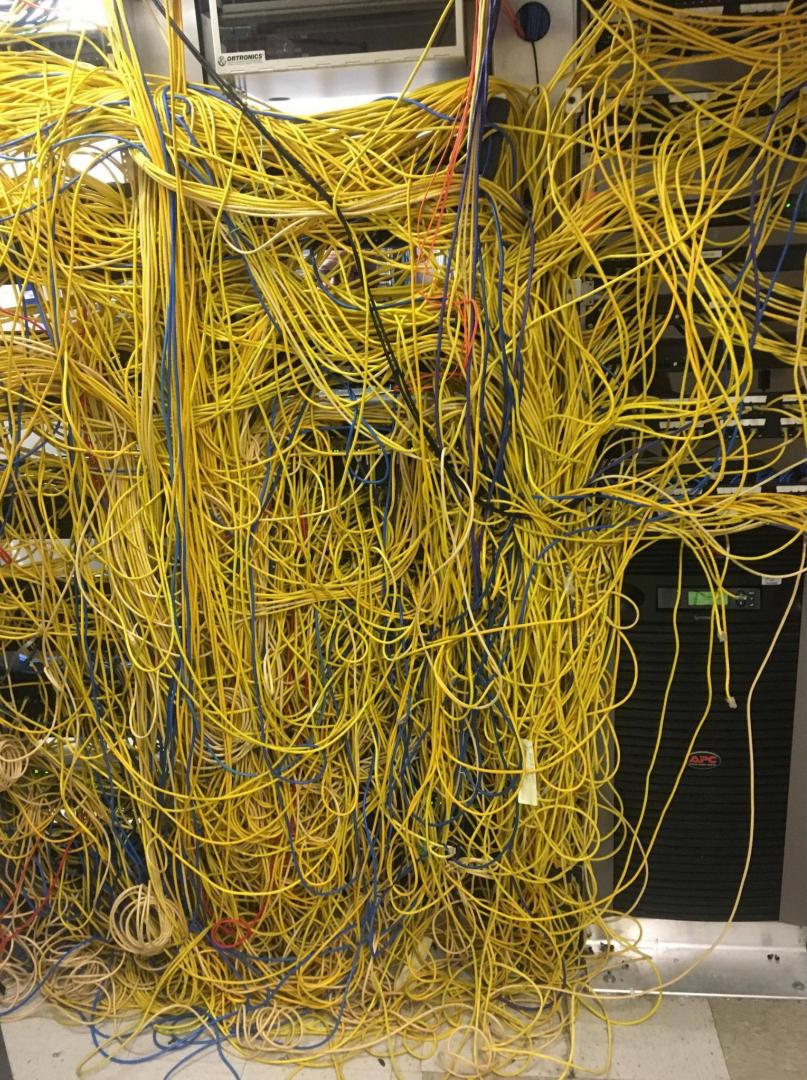
Exercise: cron job 2

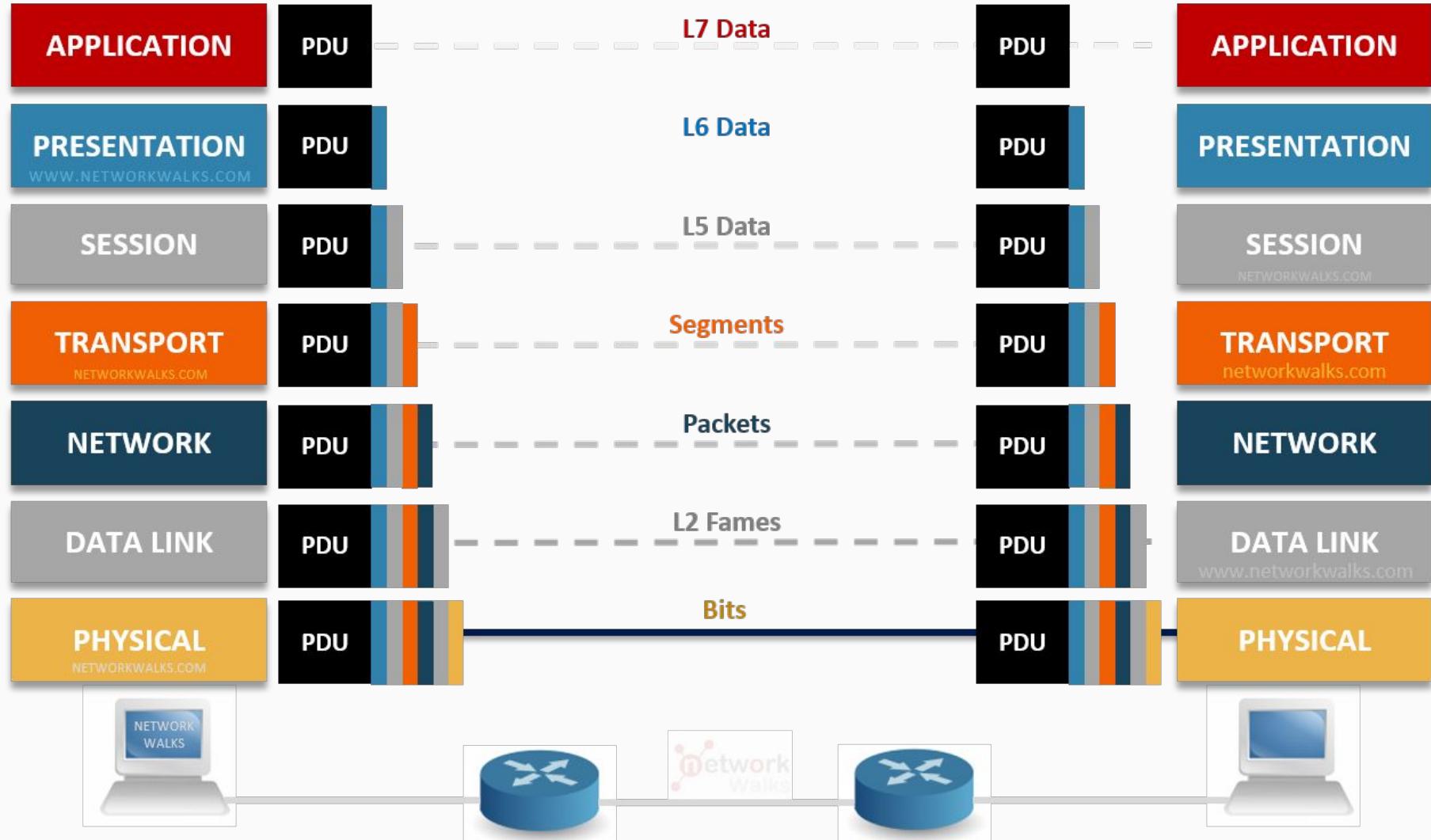
Create a cron job to backup your home directory or all users' home directory.

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

Networking

r/forbiddensnacks





7

APPLICATION

networkwalks.com

DNS, DHCP, FTP, PDU, Telnet, POP3/IMAP

6

PRESENTATION

ASCII, JPEG, GIF, SSL, TLS,...

networkwalks.com

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



1

PHYSICAL

networkwalks.com

WiFi, USB, Bluetooth, RJ45, SDH, MW/RF,..

APPLICATION

networkwalks.com

PRES
ESENTATION

SESSION

networkwalks.com

TRANSPORT

networkwalks.com

NETWORK

DATA LINK

PHYSICAL

networkwalks.com

Please Do Not Throw Sausage Pizza Away

All People Seem To Need Data Processing



Ethernet



80 00 20 7A 3F 3E
Destination MAC Address

80 00 20 20 3A AE
Source MAC Address

08 00
EtherType

IP, ARP, etc.
Payload

00 20 20 3A
CRC Checksum

MAC Header
(14 bytes)

Data
(46 - 1500 bytes)

(4 bytes)

Ethernet Type II Frame
(64 to 1518 bytes)

MAC (media access control) address

Full duplex vs half duplex

Node A



Half Duplex
Media

Node B



→  ←
Collision

Command Prompt

```
C:\Users\user>ipconfig /all
Windows IP Configuration

Host Name . . . . . : WIN-7NHASUKCI7D
Primary Dns Suffix . . . . . : localdomain
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

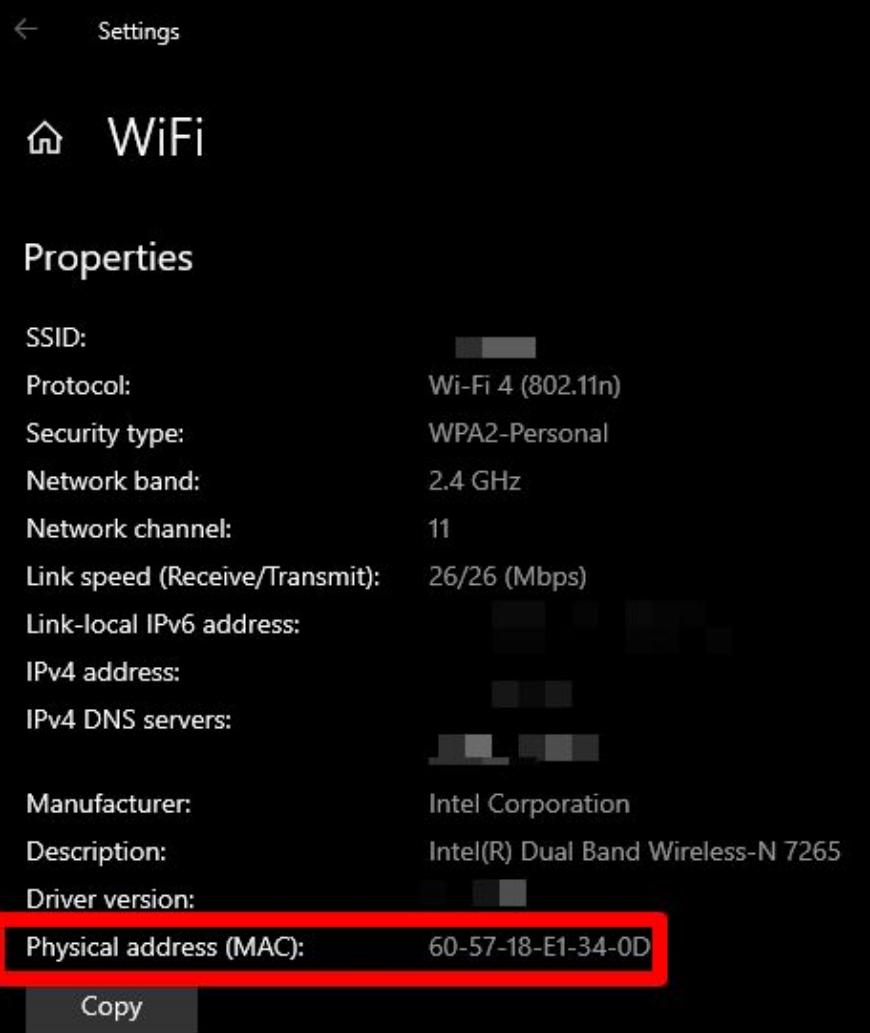
DNS Servers . . . . . : 10.10.100.1
NetBIOS over Tcpip . . . . . : Enabled

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-E0
DHCP Enabled . . . . . : No
Autoconfiguration Enabled . . . . . : Yes

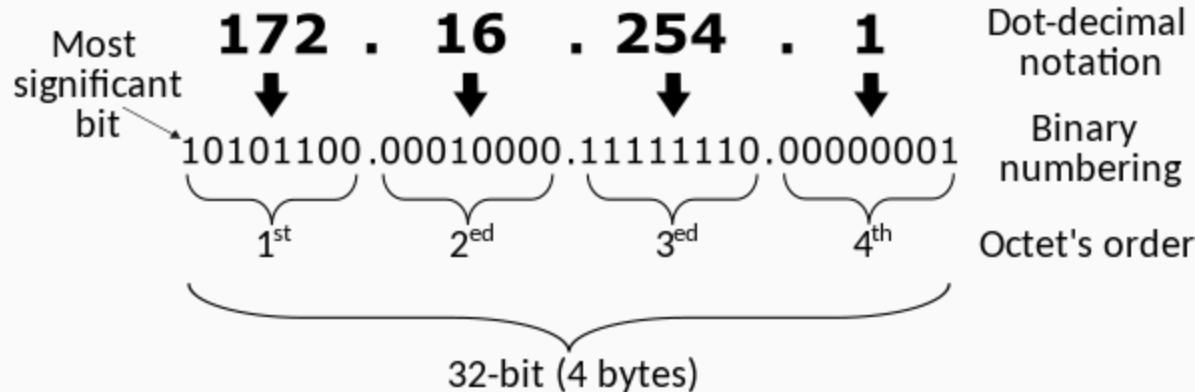
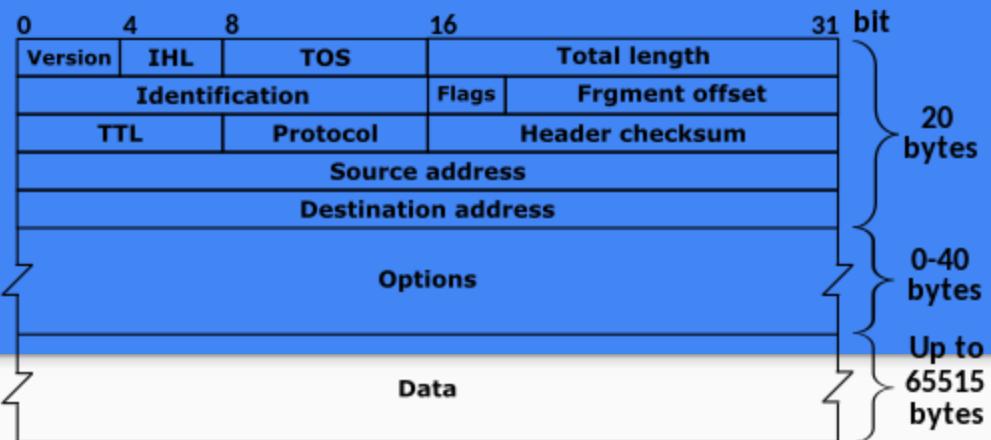
C:\Users\user>
```

```
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 stat
e UP mode DEFAULT group default qlen 1000
    link/ether 52:54:00:5c:92:bf brd ff:ff:ff:ff:ff:ff
sagar@itsfoss:~$
```

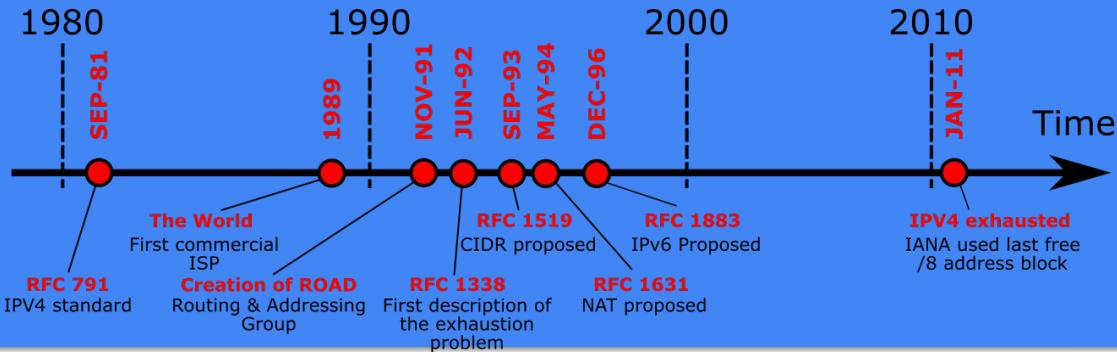


Layer 3

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

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

▼

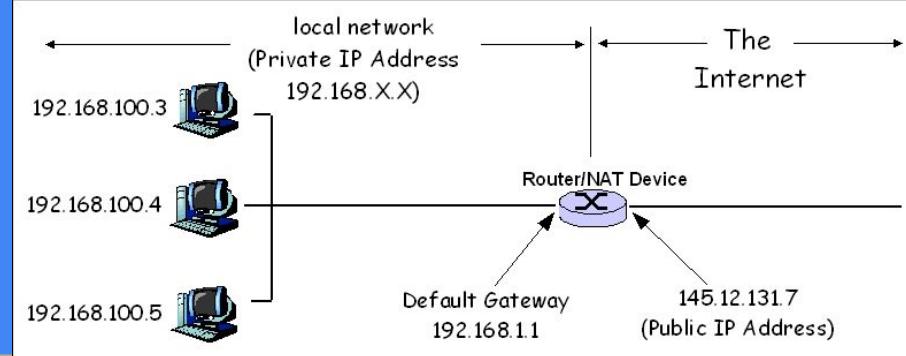
Classless Inter-Domain Routing (CIDR) notation

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

Router2: 192.168.2.1/24

Router1: 192.168.1.1/24

Server1: 192.168.2.2

PC1: 192.168.1.2

Server2: 192.168.2.3

PC2: 192.168.1.3

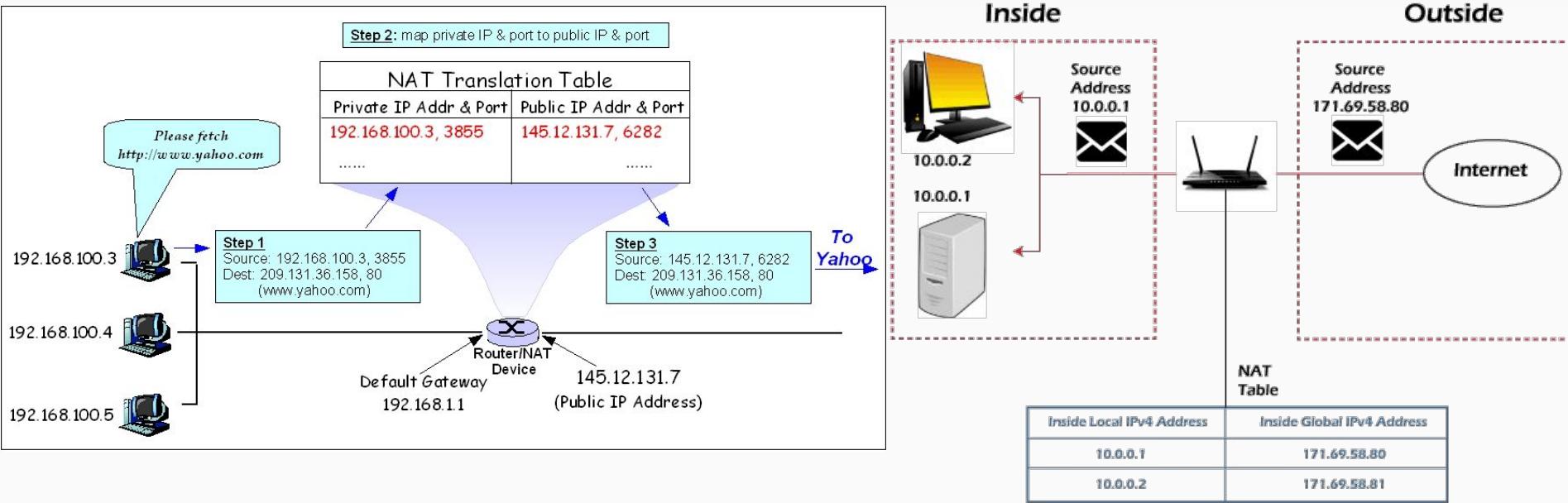
Subnet mask: 255.255.255.0

Subnet mask: 255.255.255.0

Broadcast address: 192.168.2.255

Broadcast address: 192.168.1.255

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

```
Command Prompt
C:\Users\user>arp -a
Interface: 10.10.100.131 --- 0xb
  Internet Address          Physical Address      Type
  10.10.100.1                00-50-56-c0-00-01    dynamic
  10.10.100.255              ff-ff-ff-ff-ff-ff    static
  224.0.0.22                  01-00-5e-00-00-16    static
  224.0.0.252                01-00-5e-00-00-fc    static
  255.255.255.255            ff-ff-ff-ff-ff-ff    static
C:\Users\user>
```

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

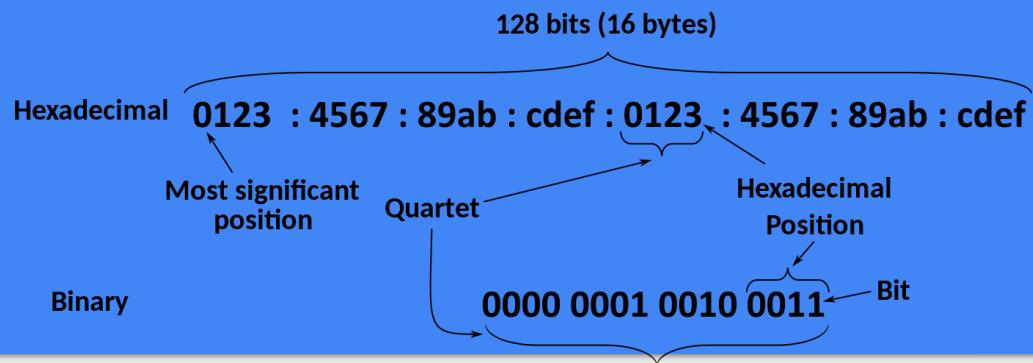
Ping statistics for 182.22.25.252:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
    Minimum = 4ms, Maximum = 5ms, Average = 4ms
PS C:\Users\jing>
```

ICMP header format

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→::
- 0000:0000:0000:0000:0000:0000:0001→::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: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	<i>routing prefix</i>	<i>subnet id</i>	<i>interface identifier</i>

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:██████ brd ff:ff:ff:ff:ff:ff
    altname enp0s18
        inet 192.168.0.████/16 metric 20 brd 192.168.255.255 scope global ens18
            valid_lft forever preferred_lft forever
        inet6 240b:10:████████/128 scope global dynamic noprefixroute      GUA
            valid_lft 1035079sec preferred_lft 1035079sec
        inet6 fd69:████████/128 scope global dynamic noprefixroute      ULA
            valid_lft 1035079sec preferred_lft 1035079sec
        inet6 fe80::215:5dff:fe0b:████/64 scope link
            valid_lft forever preferred_lft forever
link local
jing@builder:~ $
```

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~

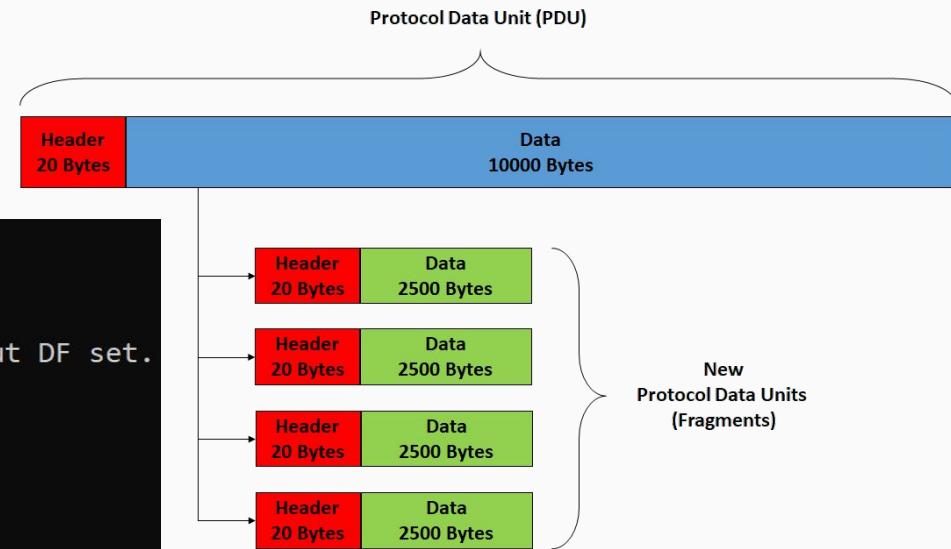
Name:	Ethernet 2
Description:	Marvell AQtic Adapter
Physical address (MAC):	60:32:b1:06:e
Status:	Operational
Maximum transmission unit:	1500
Link speed (Receive/Transmit):	10/10 (Gbps)

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

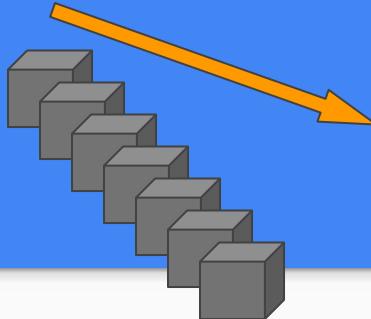
IPv6: fragment at source



```
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.

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

MTU black hole



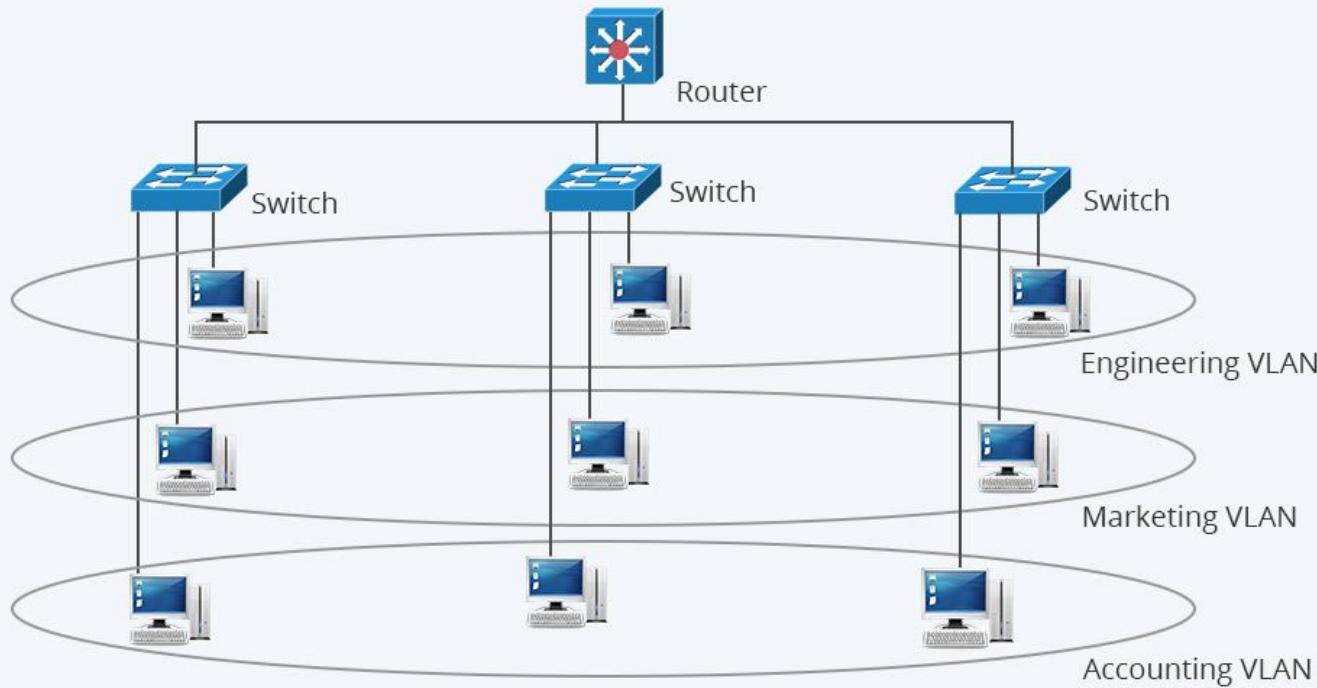
Path MTU Discovery

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



VLAN tag

VLAN10

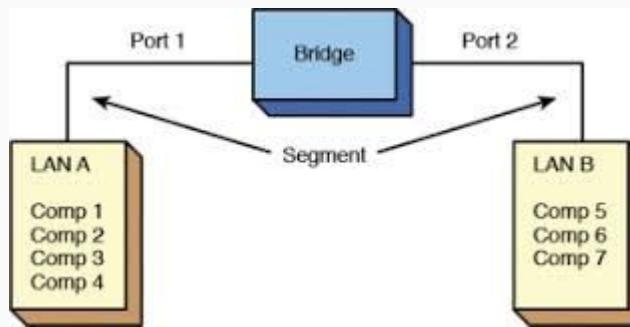
VLAN11

VLAN4095

Switch vs router

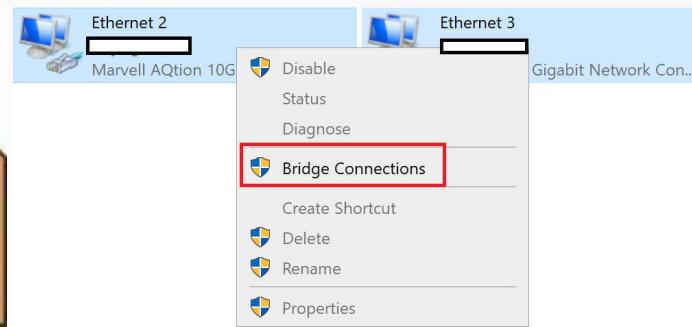
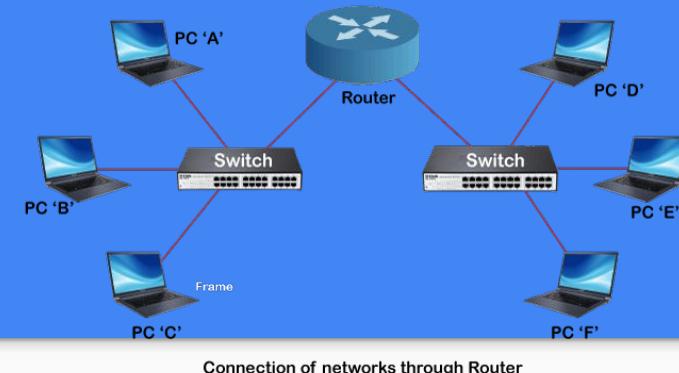
Switch

- 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

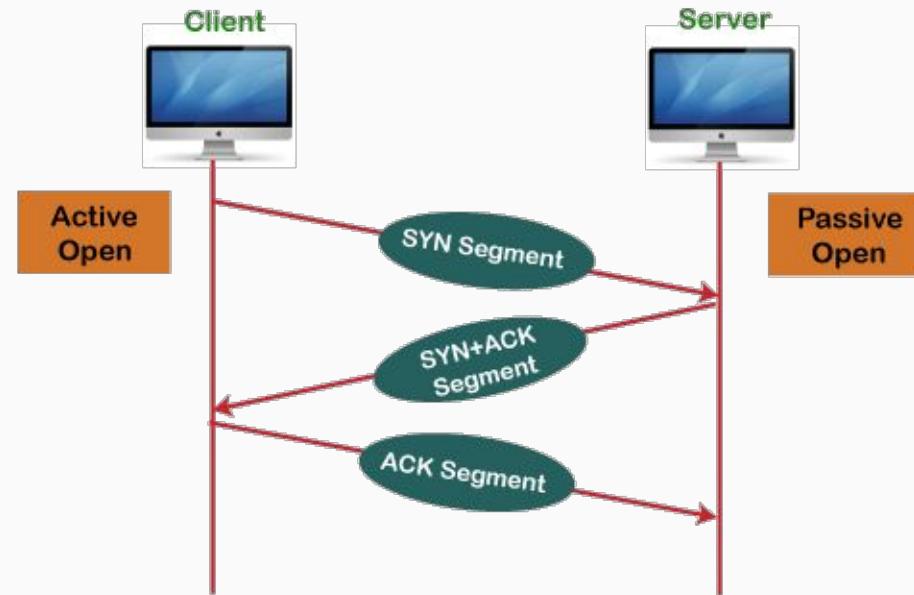


TCP (Transmission Control Protocol)

Layer 4

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

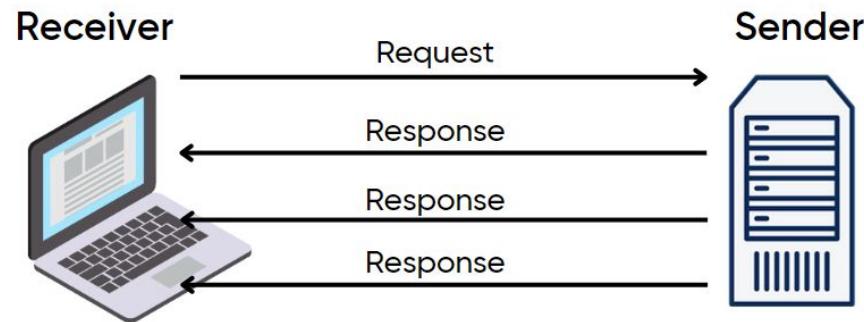
Working of the TCP protocol



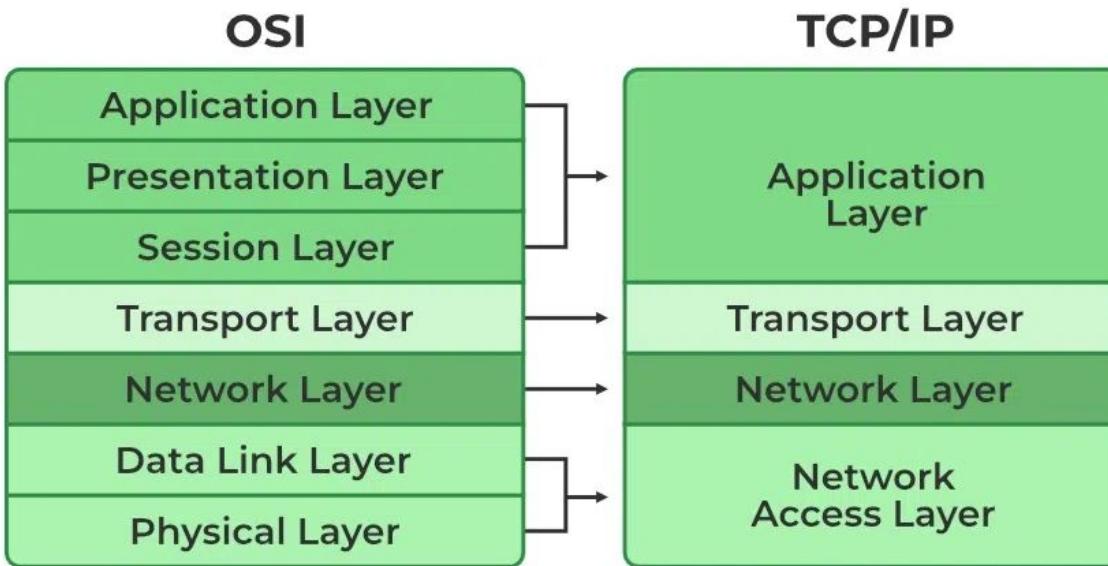
UDP (User Datagram Protocol)

Layer 4

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



TCP/IP model



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

```
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して、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-PgT03qFNjvuIt4TVFyG06g' 'strict-dynamic' 'report-sample' 'unsafe-eval' 'unsafe-inline'
https: ...
Forms
Headers
Images
```

HTTP/2

HTTP/3

en.wikipedia.org/wiki/HTTPS

← Security
en.wikipedia.org

Connection is secure
Your information (for example, passwords or credit card numbers) is private when it is sent to this site. [Learn more](#)

Certificate is valid

Certificate Viewer: *.wikipedia.org

General Details

Issued To

Common Name (CN) *.wikipedia.org
Organization (O) Wikimedia Foundation, Inc.
Organizational Unit (OU) <Not Part Of Certificate>

Issued By

Common Name (CN) DigiCert TLS Hybrid ECC SHA384 2020 CA1
Organization (O) DigiCert Inc
Organizational Unit (OU) <Not Part Of Certificate>

Validity Period

Issued On Thursday, October 27, 2022 at 9:00:00 AM
Expires On Saturday, November 18, 2023 at 8:59:59 AM

Fingerprints

SHA-256 Fingerprint 95 A6 25 3C F5 BA 9E 9C 79 C9 E1 66 74 AE 68 DA
28 99 75 43 93 FF 3F AA 5C 4B D5 10 B3 8D 95 A7
SHA-1 Fingerprint 91 D4 DD DD 2F F9 18 E0 19 07 D8 6B C7 54 54 F1
1A 8F 2C DC

SSH (Secure Shell), Telnet

Layer 7

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

SSH: port 22

Telnet: port 23

```
jing@ansible-control-node:~$ ssh 192.168.0.234  
Linux dnsmasq4 5.15.107-1-pve #1 SMP PVE 5.15.107-1 (2023-04-20T10:05Z) x86_64  
  
The programs included with the Debian GNU/Linux system are free software;  
the exact distribution terms for each program are described in the  
individual files in /usr/share/doc/*copyright.  
  
Debian GNU/Linux comes with ABSOLUTELY NO WARRANTY, to the extent  
permitted by applicable law.  
Last login: Thu May 11 22:07:12 2023 from 192.168.1.53  
jing@dnsmasq4:~$
```

SCP, SFTP

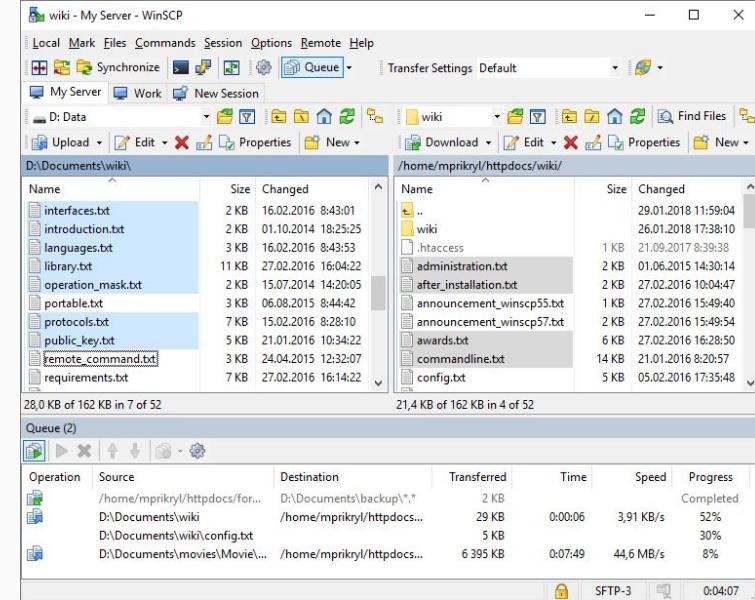
Secure Copy Protocol (SCP)

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

```
$ scp username@hostname:/path /localpath  
remote → local
```

openssh-server

SSH File Transfer Protocol (SFTP)



WinSCP

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