A Deep Dive into Computer Networking for Web Development

Presented By: Yingquan Li
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About Me

Name: Yingquan Li

- Full-time Student @ **Virginia Tech** (M.S. in IT expected in 08/23)

Bio: I'm an engineer who has worked in both the private & public sectors. Most recently, I worked in academia. Long time networking hobbyist!

Work: U. of Pennsylvania, Deloitte, PwC, Gartner, HPE

Should a web developer learn about networking?

- Frontend Developer

- Backend Developer

Talk Outline

- Fundamental Concepts: TCP/IP Model, IPv4/IPv6 addresses, subnetting, routing, TCP/UDP, Sockets/Ports, DNS, HTTP Protocol

- Networking with the **command-line interface**.

- Networking with **Python**.

Fundamental Concepts

OSI Model → TCP/IP Model

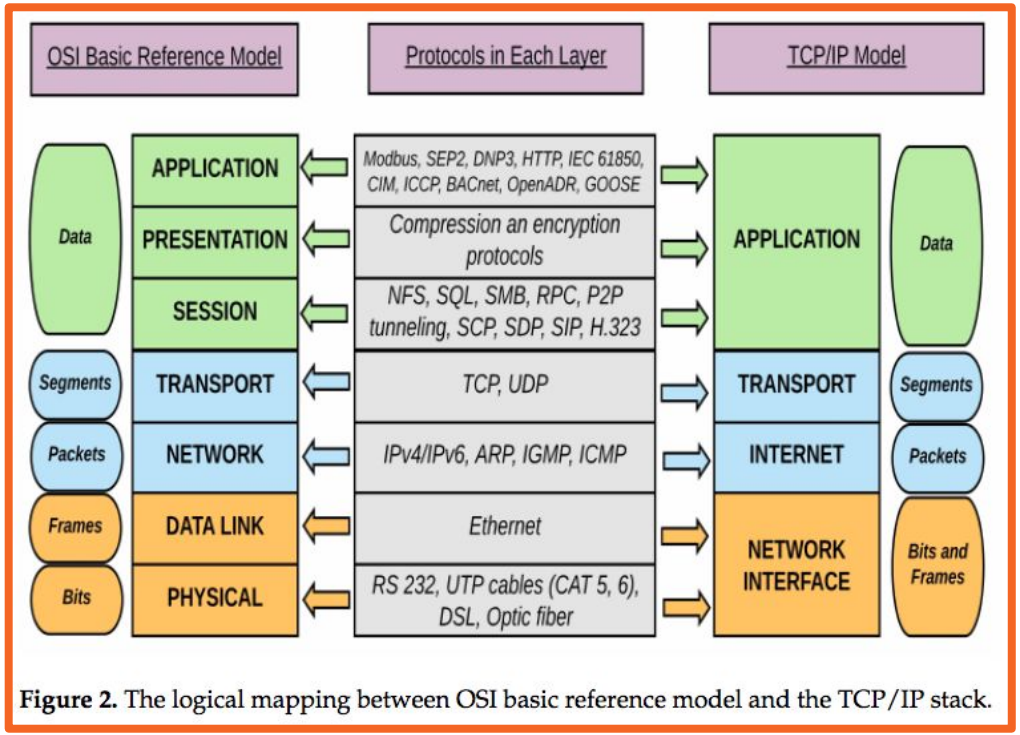

Figure 2. The logical mapping between OSI basic reference model and the TCP/IP stack.

- **APPLICATION**: Work with interfaces, protocols, software.
- **TRANSPORT**: Error-free data delivery between host → destination nodes.
- **INTERNET**: Package data into IP packets; transmit packets across the network.
- **NETWORK INTERFACE**: Transmit bits across the network.

Image Source

IPv4 & IPv6 Addresses

IPv4 Address (32-bits): **18.154.277.99**

IPv4	1st Octet	2nd Octet	3rd Octet	4th Octet
Dotted-Decimal	18	154	227	99
Binary Digits	00010010	10011010	11100011	01100011

IPv6 Address (128-bits): **2001:0DB8:AC10:FE01::**

IPv6	Hex #s	Hex #s	Hex #s	Hex #s	Hex #s	Hex #s	Hex #s	Hex #s
Colon-Hex	2001	0DB8	AC10	FE01	0000	0000	0000	0000
Binary Digits	00100000 00000001	00001101 10111000	10101100 00010000	11111110 00000001	00000000 00000000	00000000 00000000	00000000 00000000	00000000 00000000

IPv4 Subnetting (Part 1)

A **routable IPv4**'s address class:

Address Class	Value in First Octet	Classful Mask (Dotted Decimal)	CIDR** Notation
Class A	1 - 126	255.0.0.0	/8
Class B	128 - 191	255.255.0.0	/16
Class C	192 - 223	255.255.255.0	/24
Class D	224 - 239	-	-

* We skip 127 because 127.0.0.1 is reserved (i.e. **loopback address**).

** **CIDR**: Classless Inter-Domain Routing

A **routable IPv4**'s address can be broken into the network and host portion:

Image Source

IPv4 Subnetting (Part 2)

Subnetting: Take large network a split it into smaller networks.

1	2	4	8	16	32	64	128
2^0	2^1	2^2	2^3	2^4	2^5	2^6	2^7

Subnetting Masks:

- Modify subnets so that they are scoped properly.
- Default classful subnet mask may not give optimal subnet size.

Classful subnets →

Classless subnets →

Dotted-Decimal Notation	CIDR	Binary Notation
255.0.0.0	/8	11111111.00000000.00000000.00000000
255.255.0.0	/16	11111111.11111111.00000000.00000000
255.255.255.0	/24	11111111.11111111.11111111.00000000
255.255.255.128	/25	11111111.11111111.11111111.10000000
255.255.255.192	/26	11111111.11111111.11111111.11000000
255.255.255.224	/27	11111111.11111111.11111111.11100000
255.255.255.240	/28	11111111.11111111.11111111.11110000
255.255.255.248	/29	11111111.11111111.11111111.11111000
255.255.255.252	/30	11111111.11111111.11111111.11111100

Jason Dion, Network+

IPv4 Subnetting Example

Formula #1: Number of Created Subnets = 2^s (**s** is the number of borrowed bits)

Formula #2: Number of Allocable IP Addresses per Subnet = $2^h - 2$ (**h** is the number of host bits)

- *Subtract 2 for the network and broadcast addresses!*

Example: 192.186.3.0/26

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Binary: 11000000.10111010.00000011.00000000

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Number of Created Subnets = $2^2 \Rightarrow 4$

Number of Allocable IP Addresses / Subnet = $2^6 - 2 \Rightarrow 62$

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Number of Created Subnets = $2^2 \Rightarrow 4$

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- **1st Subnet:** 192.186.3.0 → 192.186.3.63
- **2nd Subnet**: 192.186.3.64 → 192.186.3.127
- **3rd Subnet**: 192.186.3.128 → 192. 186.3.191
- **4th Subnet**: 192.186.3.192 → 192.186.3.255

- **Network ID (First IP)**: 0, 64, 128, 192
- **Broadcast (Last IP)**: 63, 127, 191, 255

Routing

- Facilitates communication between subnets/networks.
- Separates **broadcast domains**.
- Operates at OSI Model - Level 3 (**Network**) and TCP/IP Model - Level 2 (**Internet**).

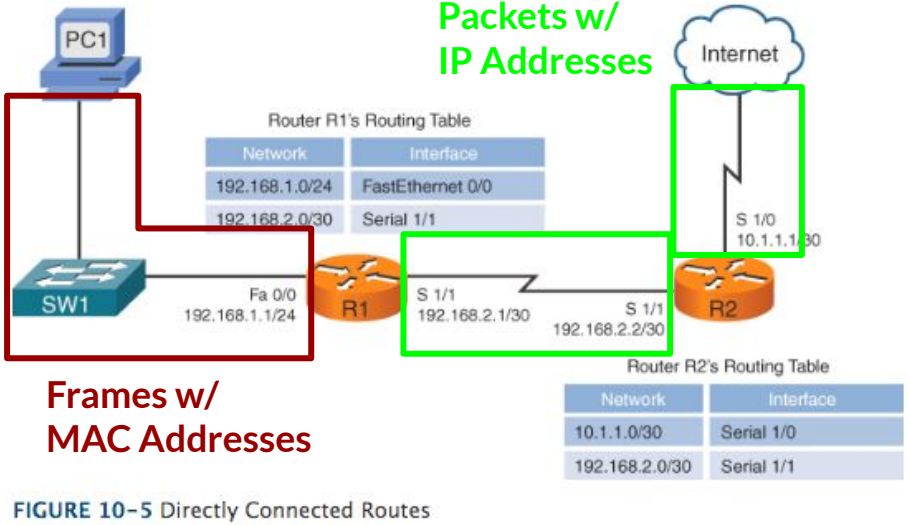


FIGURE 10-5 Directly Connected Routes

Image Source

Routing + Network Address Translation (NAT)

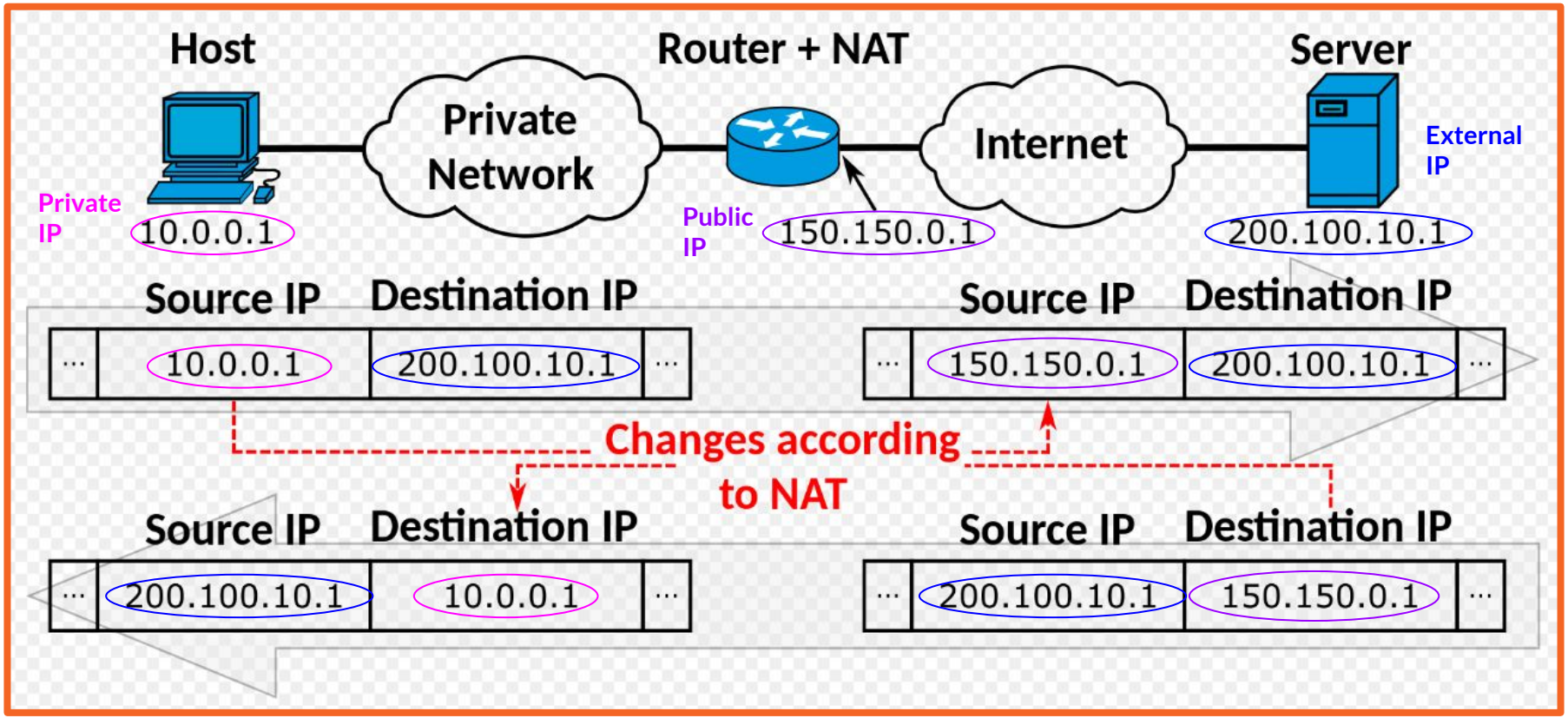


Image Source

TCP vs. UDP

- Operates at OSI Model - Level 4 (**Transport**) and TCP/IP Model - Level 3 (**Transport**).
- Host-to-host communication via the Internet.
- I've met **Vint Cerf** personally twice!

TCP	UDP
• Connection-oriented • Data remains intact; arrives in the same order • Slower • Heavyweight • Use cases: Email, web browsing	• Connectionless • Not guaranteed that packets will reach destination at all • Faster • Lightweight • Use cases: VoIP, music streaming

Socket

- **Sockets** are what most web libraries work with.
- Sockets are also known as a connection's **endpoint** across a network.

Consists of:

1. A *transport protocol* (TCP, UDP).
2. An *IP address* (IPv4 or IPv6).
3. A *port* (Port 80 is web server default).

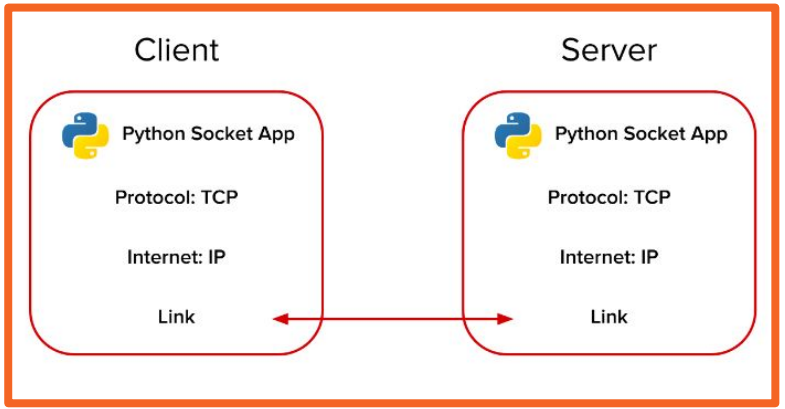


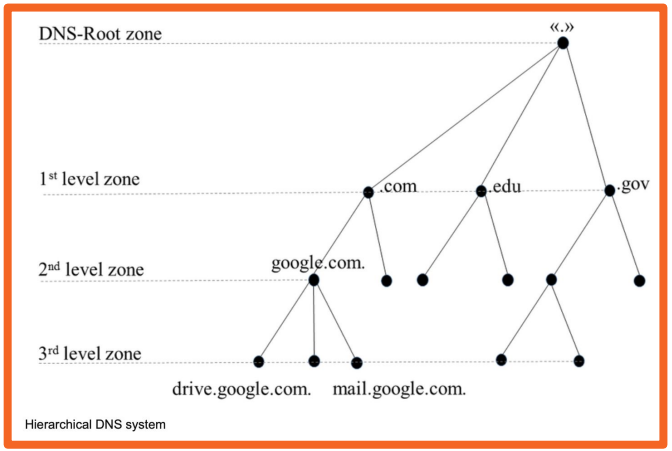
Image Source

Domain Name System (DNS)

Domain Names: labels separated by dots.

- **www.yahoo.com**
  - *.com* is the root domain.
  - *yahoo.com* is a subdomain of com.
  - *www.yahoo.com* is a subdomain of yahoo.com

1. DNS Hierarchy



2. DNS Query Process

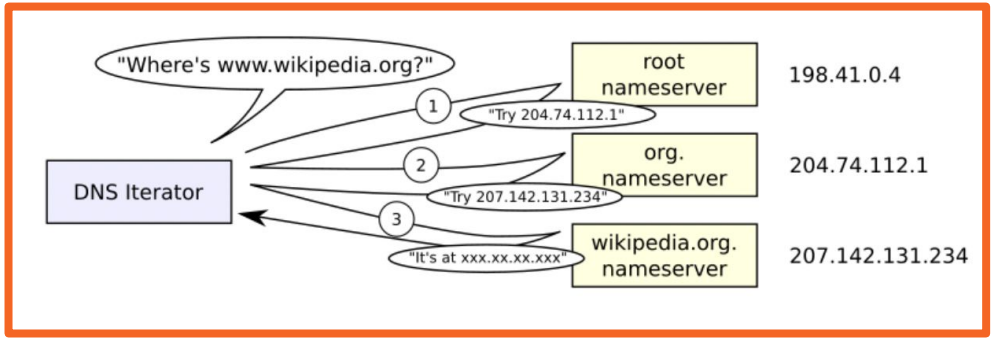


Image Source 1
Image Source 2

Networking with the Command-Line Interface

Key Networking Commands

Mac:

- arp / arp -a
- ifconfig
- ping
- traceroute
- netstat
- nslookup / host
- dig
- route

Windows:

- arp / arp -a
- Ipconfig / ipconfig /all
- ping
- tracert
- nbtstat
- netstat
- nslookup
- route

Networking with Python

Python Networking Resources

- https://docs.python.org/3/library/ipc.html
- https://www.yeahhub.com/top-7-python-libraries-networking-programming/

References:

- Jason Dion - (Udemy - Network+ Class)
  - https://docs.google.com/document/d/1ghng228GURwrnHaTSSE8uVZErRumFDP-Rg5mKo7hsAk/edit
- Kendall Giles - (ECE5480 - Network Security)
  - https://docs.google.com/document/d/1oX3vwq-AktI4aR1pPEXhiHbFk1BlPf3yowdkXq4r17I/edit
- Gregory Kulczycki - (CS5244 - Software Engineering)
  - https://docs.google.com/document/d/1-3c81BQjsmGG1MlRYJPoFXRaTIdKUj3c3D2Zj4qp680/edit

Thank you!

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Phone: 301-204-3957

Slides that will not be presented.

Additional Tasks

- ~~Finish subnetting slides~~
- ~~Make decision on DNS~~
- ~~Spell check!~~
- ~~Add picture sources~~
- ~~Finish Networking with Python section~~
- Think about concluding message.