National University of Computer & Emerging Sciences

CS 3001 – COMPUTER NETWORKS

Lecture 17

Chapter 4

25th March, 2025

Nauman Moazzam Hayat

nauman.moazzam@lhr.nu.edu.pk

Office Hours: 11:30 am till 01:00 pm (Every Tuesday & Thursday)

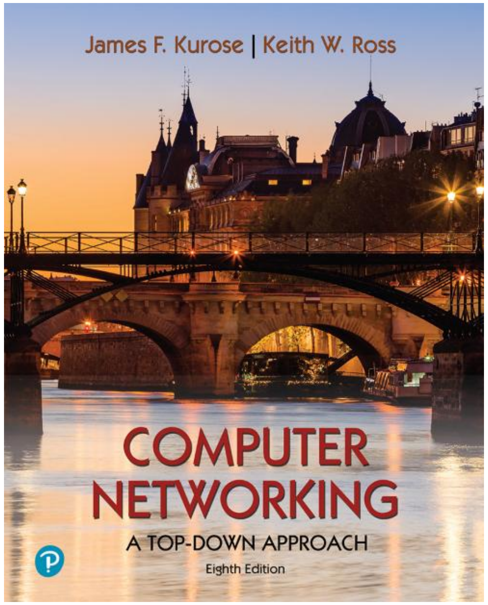
Chapter 4
Network Layer: Data Plane

A note on the use of these PowerPoint slides:
We're making these slides freely available to all (faculty, students, readers). They're in PowerPoint form so you see the animations; and can add, modify, and delete slides (including this one) and slide content to suit your needs. They obviously represent a *lot* of work on our part. In return for use, we only ask the following:

- If you use these slides (e.g., in a class) that you mention their source (after all, we'd like people to use our book!)
- If you post any slides on a www site, that you note that they are adapted from (or perhaps identical to) our slides, and note our copyright of this material.

For a revision history, see the slide note for this page.

Thanks and enjoy! JFK/KWR



Computer Networking: A Top-Down Approach
8th edition
Jim Kurose, Keith Ross
Pearson, 2020

IP addresses: how to get one?

That's actually two questions:

1. Q: How does a *host* get IP address within its network (host part of address)?
2. Q: How does a *network* get IP address for itself (network part of address)

How does *host* get IP address?

- hard-coded by sysadmin in config file (e.g., /etc/rc.config in UNIX)
- DHCP: Dynamic Host Configuration Protocol: dynamically get address from as server
  - "plug-and-play"

Q1: How does a *host* get IP address within its network (host part of address)?

DHCP: Dynamic Host Configuration Protocol

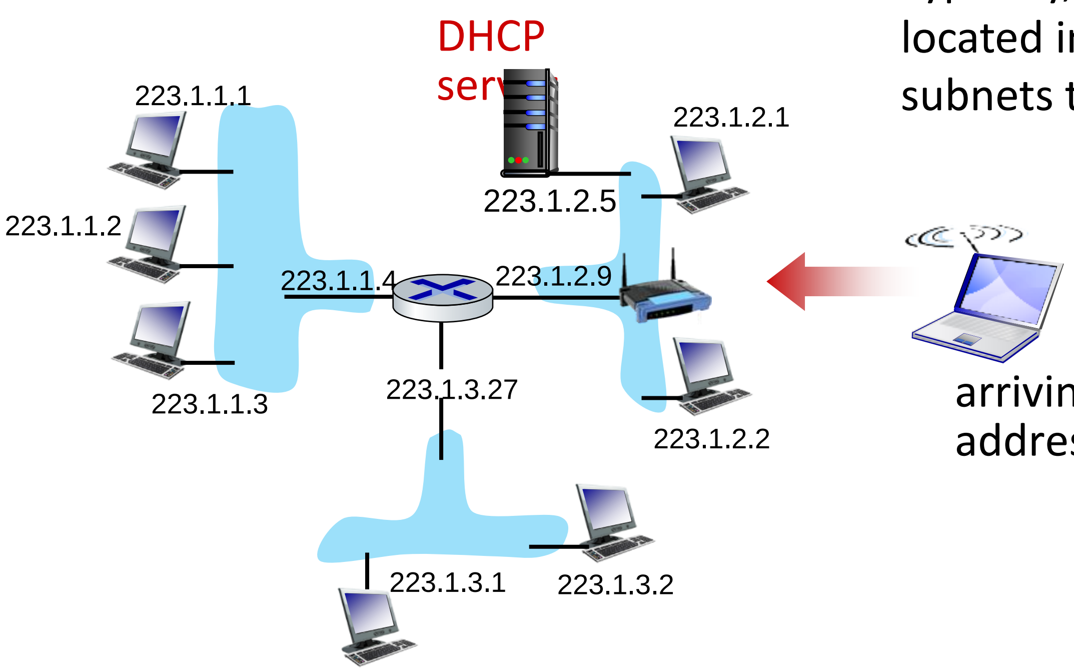
goal: host *dynamically* obtains IP address from network server when it "joins" network

- can renew its lease on address in use
- allows reuse of addresses (only hold address while connected/on)
- support for mobile users who join/leave network
  - App layer protocol used by the Network Layer
  - DHCP uses UDP at the Transport Layer

DHCP overview: (DHCP Summary)

- host broadcasts DHCP discover msg [optional]
- DHCP server(s) responds with DHCP offer msg [optional]
- host requests IP address: DHCP request msg
- DHCP server sends address: DHCP ack msg

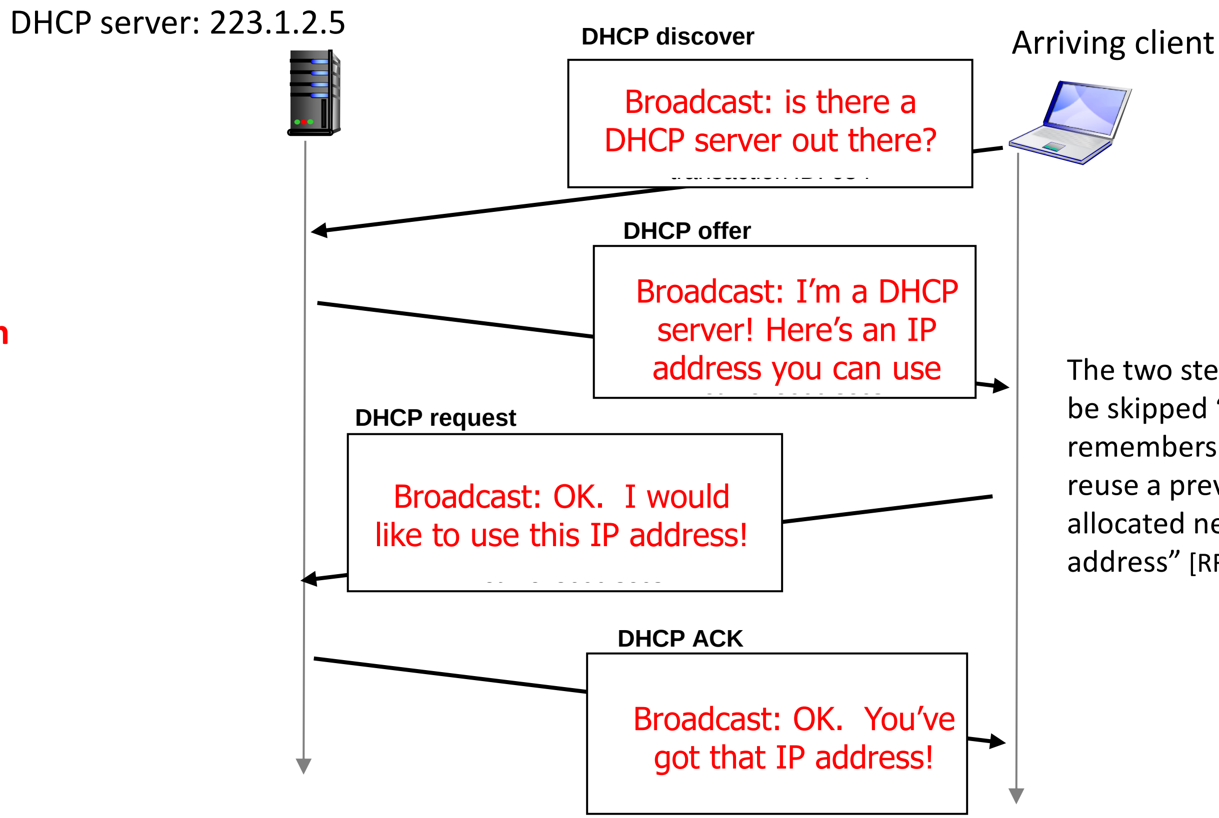
DHCP client-server scenario



Typically, DHCP server will be co-located in router, serving all subnets to which router is attached

arriving DHCP client needs address in this network

DHCP client-server scenario



- **Port 67 & 68 are standard ports in DHCP Protocol for DHCP Server & DHCP Client respectively**

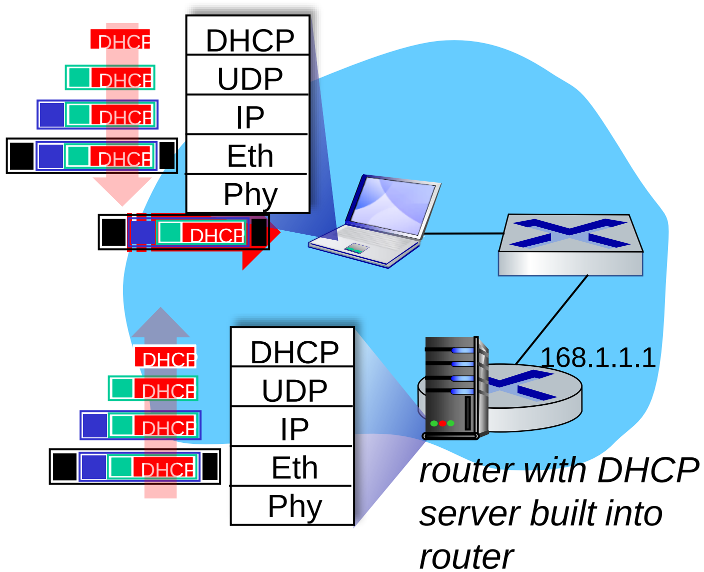
The two steps above can be skipped "if a client remembers and wishes to reuse a previously allocated network address" [RFC 2131]

DHCP: more than IP addresses

DHCP can return more than just allocated IP address on subnet:

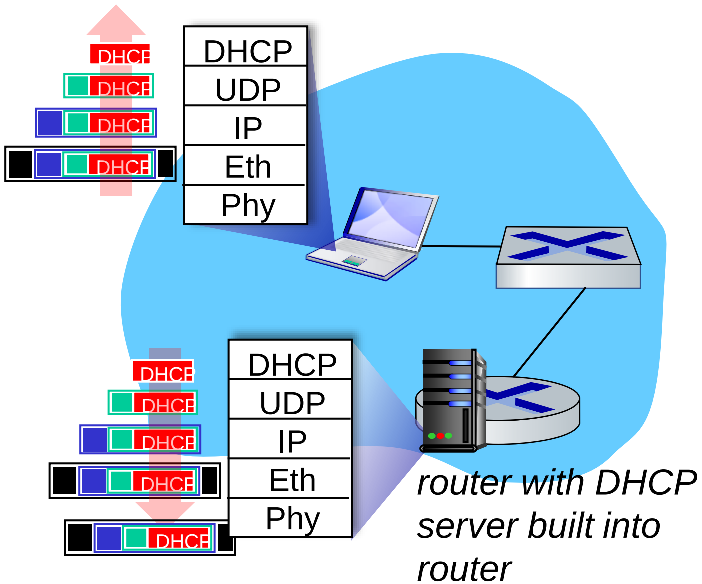
- address of first-hop router for client
- name and IP address of DNS sever
- network mask (indicating network versus host portion of address)

DHCP: example



- Connecting laptop will use DHCP to get IP address, address of first-hop router, address of DNS server.
- DHCP REQUEST message encapsulated in UDP, encapsulated in IP, encapsulated in Ethernet
- Ethernet frame broadcast (dest: FFFFFFFFFFFF) on LAN, received at router running DHCP server
- Ethernet de-mux'ed to IP de-mux'ed, UDP de-mux'ed to DHCP

DHCP: example



- DCP server formulates DHCP ACK containing client's IP address, IP address of first-hop router for client, name & IP address of DNS server
- encapsulated DHCP server reply forwarded to client, de-muxing up to DHCP at client
- client now knows its IP address, name and IP address of DNS server, IP address of its first-hop router

IP addresses: how to get one?

Q2: how does *network* get subnet part of IP address?

A: gets allocated portion of its provider ISP's address space

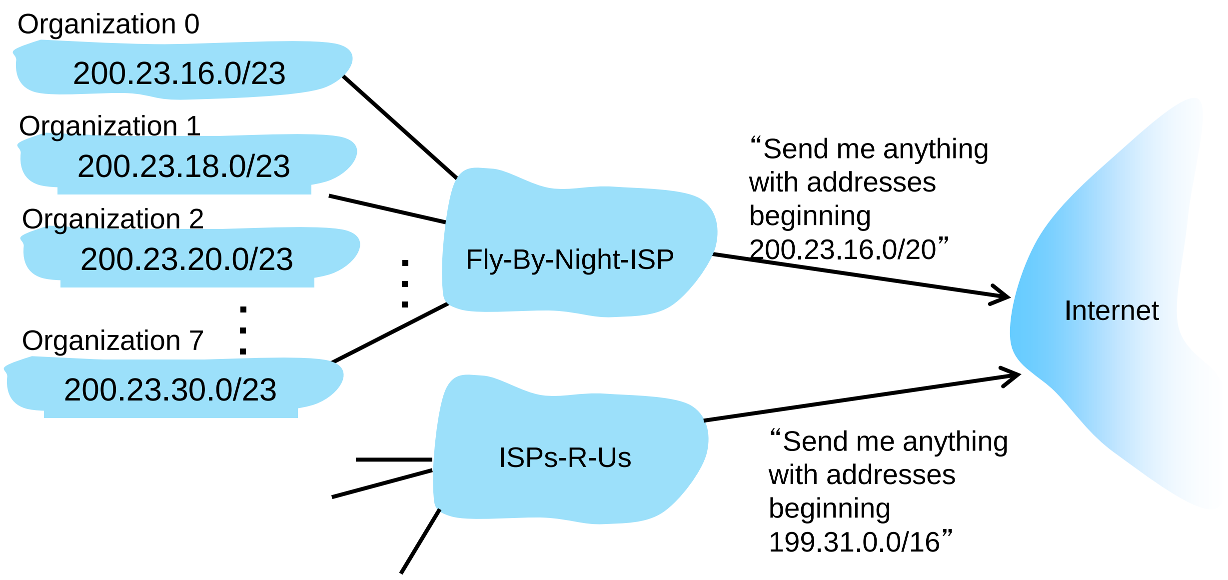
ISP's block	11001000 00010111 00010000	00000000	200.23.16.0/20

ISP can then allocate out its address space in 8 blocks:

Organization 0	11001000 00010111 00010000	00000000	200.23.16.0/23
Organization 1	11001000 00010111 00010010	00000000	200.23.18.0/23
Organization 2	11001000 00010111 00010100	00000000	200.23.20.0/23
...	…..	….	….
Organization 7	11001000 00010111 00011110	00000000	200.23.30.0/23

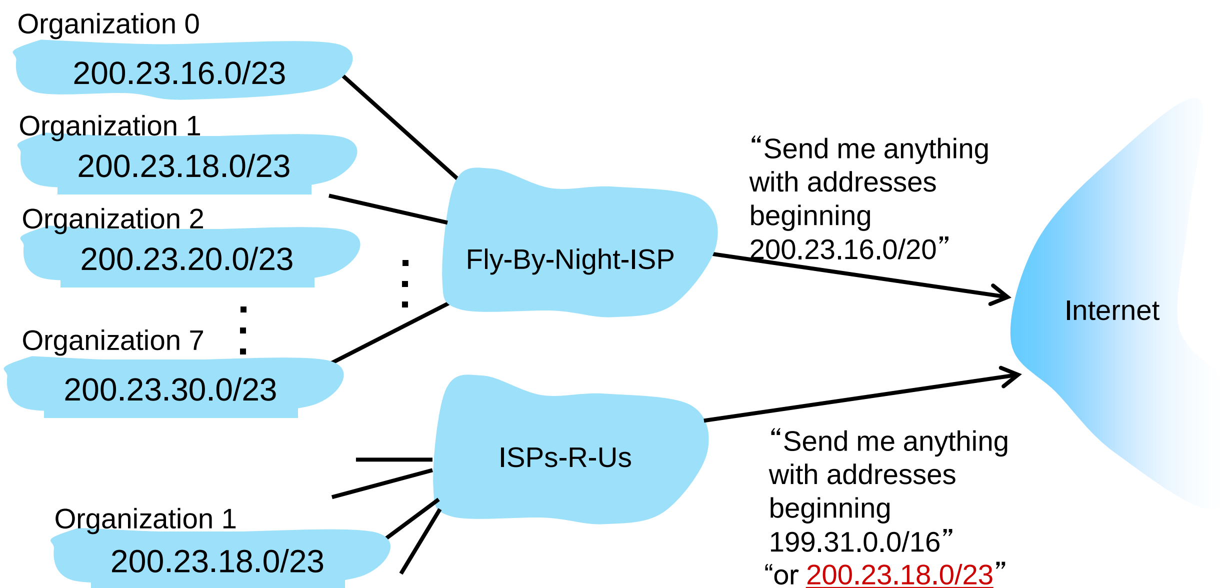
Hierarchical addressing: route aggregation
(Route Summarization / Address Aggregation)

hierarchical addressing allows efficient advertisement of routing information:



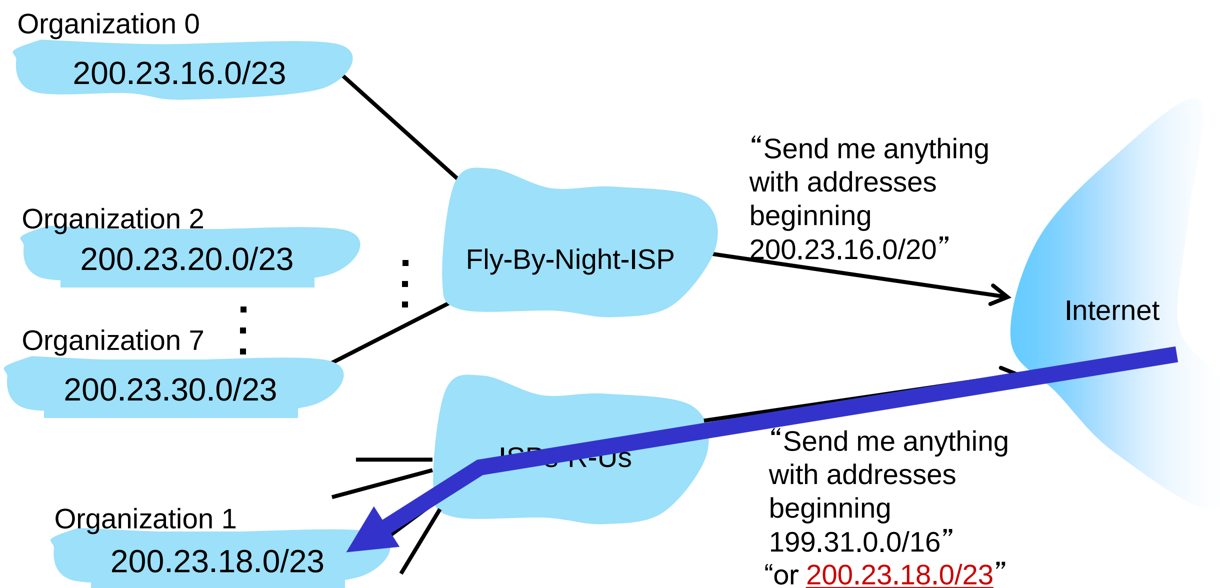
Hierarchical addressing: more specific routes

- Organization 1 moves from Fly-By-Night-ISP to ISPs-R-Us
- ISPs-R-Us now advertises a more specific route to Organization 1



Hierarchical addressing: more specific routes

- Organization 1 moves from Fly-By-Night-ISP to ISPs-R-Us
- ISPs-R-Us now advertises a more specific route to Organization 1



Hierarchical addressing: route aggregation (Route Summarization / Address Aggregation)

- As was shown in the previous Figure, the ISP Fly-By-Night advertises to the outside world that it should be sent any datagrams whose first 20 address bits match 200.23.16.0/20.

- The rest of the world need not know that within the address block 200.23.16.0/20 there are in fact eight other organizations, each with their own subnets.

- This ability to use a single prefix to advertise multiple networks is often referred to as address aggregation (also route aggregation or route summarization or loosely can be called supernetting).

- This works extremely well when addresses are allocated in blocks to ISPs and then from ISPs to client organizations.

Hierarchical addressing: route aggregation (Route Summarization / Address Aggregation)

What if the addresses are not allocated in such a hierarchical manner?

- For example , what would happen if ISP Fly-By-Night acquires ISPs-R-Us and then has Organization 1 connect to the Internet through its subsidiary ISPs-R-Us?
- As was shown in the Figure, ISPs-R-Us owns the address block 199.31.0.0/16 but Organization 1's IP addresses are unfortunately outside of this address block.
- What should be done here?

Hierarchical addressing: route aggregation (Route Summarization / Address Aggregation)

Proposed Solutions

- **Organization 1 could renumber all of its routers and hosts to have addresses within the ISPs-R-Us address block.**

  - It's a costly solution.
  - Organization 1 might well be reassigned to another subsidiary in the future.

- **Organization 1 keeps its IP addresses in 200.23.18.0/23 and ISPs-R-Us advertises the block of addresses for Organization 1 (in addition to its own block of addresses.)**

  - When routers in the Internet see the address block 200.23.16.0/20 (from Fly-By-Night) and 200.23.18.0/23 (from ISPs-R-Us), and want to route to an address in the block 200.23.18.0/23, they will use longest prefix matching and route towards ISPs-R-Us as it advertises the longest (most specific) address prefix that matches the destination address.

Longest prefix matching

longest prefix match

when looking for forwarding table entry for given destination address, use *longest* address prefix that matches destination address.

Destination Address Range				Link interface
11001000	00010111	00010***	********	0
11001000	00010111	00011000	********	1
11001000	00010111	00011***	********	2
otherwise				3

examples:

11001000 00010111 00010110 10100001 which interface?

11001000 00010111 00011000 10101010 which interface?

Longest prefix matching

longest prefix match

when looking for forwarding table entry for given destination address, use *longest* address prefix that matches destination address.

Destination Address Range	Link interface
11001000 00010111 00010*** ********	0
11001000 00010111 00011000 ********	1
11001000 00010111 00011*** ********	2
otherwise	3

match!

examples:

11001000 00010111 00010110 10100001 which interface?

11001000 00010111 00011000 10101010 which interface?

Longest prefix matching

longest prefix match

when looking for forwarding table entry for given destination address, use *longest* address prefix that matches destination address.

Destination Address Range	Link interface
11001000 00010111 00010*** ********	0
11001000 00010111 00011000 ********	1
11001000 00010111 00011*** ********	2
otherwise	3

match!

examples:

11001000 00010111 00010110 10100001 which interface?

11001000 00010111 00011000 10101010 which interface?

Longest prefix matching

longest prefix match

when looking for forwarding table entry for given destination address, use *longest* address prefix that matches destination address.

Destination Address Range				Link interface
11001000	00010111	00010***	********	0
11001000	00010111	00011000	********	1
11001000	00010111	00011***	********	2
otherwise				3

match!

examples:

11001000	00010111	00010110	10100001	which interface?
11001000	00010111	00011000	10101010	which interface?

Route Summarization / Address Aggregation

- For revision of Route Summarization / Address Aggregation (Supernetting) discussed in the Class, please watch and review my video shared via Google Classroom. (Please watch the complete video, where I explain & solve an example for this in detail.)

Important topic of Computer Networks !!!!!!!

IP addressing: last words ...

Q: how does an ISP get block of addresses?

A: ICANN: Internet Corporation for Assigned Names and Numbers http://www.icann.org/

- allocates IP addresses, through 5 regional registries (RRs) (who may then allocate to local registries)
- manages DNS root zone, including delegation of individual TLD (.com, .edu , …) management

Q: are there enough 32-bit IP addresses?

- ICANN allocated last chunk of IPv4 addresses to RRs in 2011
- NAT (next) helps IPv4 address space exhaustion
- IPv6 has 128-bit address space

"Who the hell knew how much address space we needed?" Vint Cerf (reflecting on decision to make IPv4 address 32 bits long)

Assignment # 4 (Chapter – 4)

- *4th Assignment will be uploaded on Google Classroom on Thursday, 27th March, 2025, in the Stream - Announcement Section*

- *Due Date: Tuesday, 8th April, 2025 (Handwritten solutions to be submitted during the lecture)*

- *Please read all the instructions carefully in the uploaded Assignment document, follow & submit accordingly*

Quiz # 4 (Chapter – 4)

- *On: Tuesday, 8th April, 2025(During the lecture)*

- *Quiz to be taken during <u>own section class only</u>*

Quiz 3 – Chapter 3