Session 4E

Routing Metrics and Costs

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Session 4E: Focus

- Default Routing
  - Quiz 1
  - Example Networks
  - Configuring Default Routes on CISCO Router
- Routing Metrics and Costs
  - Metrics of Links
  - Hop
  - Bandwidth
  - Delay
  - Reliability
  - Load
- Quiz 2: Choose the Optimal Path
- GATE 2024: Networking Questions

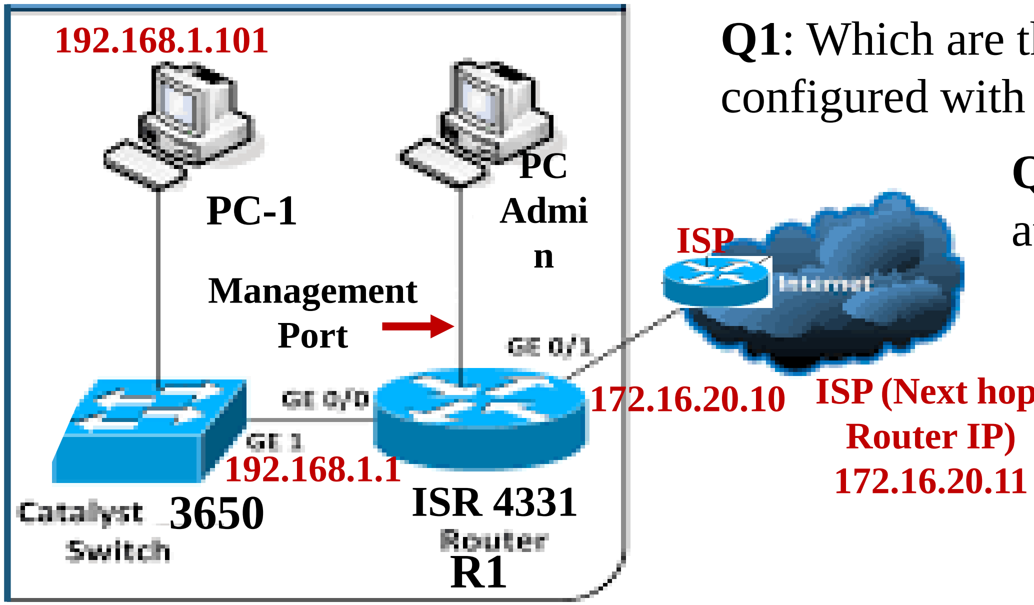
Course page where the course materials will be posted as the course progresses:

Default Routing

New Reference: **Ref5**: **IP Routing Primer Plus** By Heather Osterloh

Chapters 3 & 4: IP Routing and RIP

Quiz 1: Default Route Entries



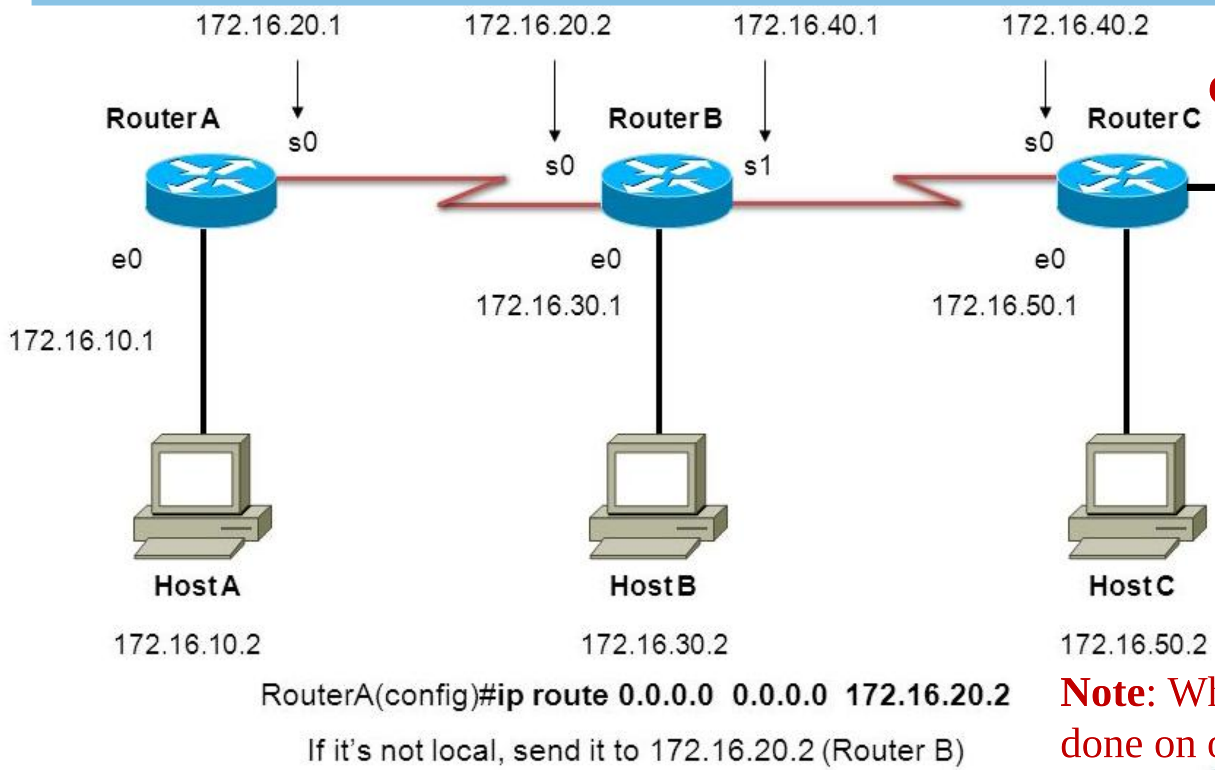
Q1: Which are the devices need to be configured with default route? **ANS1: Both the hosts and the Router**

Q2: What is the default route to be set at the host (**PC-1**)? **ANS2: 192.168.1.1**

Q3: What is the default route to be set at the router (**R1**)? **ANS3: 172.16.20.11**

- Every IP host needs to have a default route either manually configured or dynamically learned through DHCP.
  - Default routes provide end hosts a way out of their local subnet.
- When Routers are configured with a default route it is the route of last resort.
  - If no other route (specifically relating to the destination) exists in the routers route table, default route is taken.

Default Route: Another Example



Connected To ISP

Subnet mask being all zeros (**0.0.0.0**) means that there is **no network ID bits** of the **given IP** address is to be **compared** against, to **send** a packet **out**, though the **default route**.

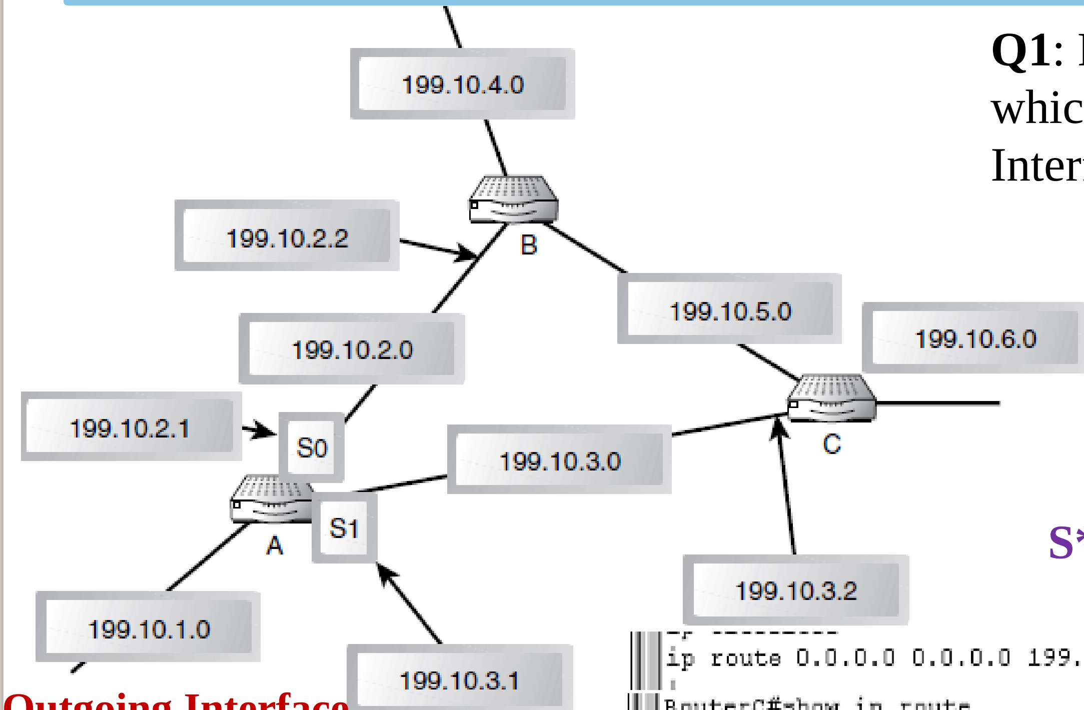
Note: When all the **longest prefix match** done on other entries in Routing table fails, **Default route** is taken (which is **catch-all**)

Command Syntax: **ip route "**destination IP address" "Subnet mask of destination network" "next hop router's IP address"

The **default route** in Internet Protocol Version 4 (**IPv4**) is **designated** as the zero-address **0.0.0.0/0** in **CIDR** notation, often called the **quad-zero route.**

The **subnet mask** is given as **/0**, which effectively **specifies all networks and it is the shortest match** available after **all other matches** have **failed**.

Default Route: Configuration on CISCO Router



Q1: From the configuration shown below which link is considered to be outgoing Interface connected to Internet here? **ANS1:**

Since RC is considering 199.10.3.1 as the default route's next hop router IP the outgoing interface from the RA is the one considered to be connected to Internet through the Network 199.10.1.0

S*: The * signifies that this route is a candidate for default routing

Outgoing Interface to Internet

Note: Static routing method is being used here to configure the default route on all the Routers.

```
ip route 0.0.0.0 0.0.0.0 199.10.3.1
!
RouterC#show ip route
Codes: C - connected, S - static, I - IGRP, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2, E - EGP
       i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, * - candidate default
       U - per-user static route, o - ODR

Gateway of last resort is 199.10.3.1 to network 0.0.0.0

C    199.10.5.0/24 is directly connected, Serial0
C    199.10.6.0/24 is directly connected, Ethernet0
C    199.10.3.0/24 is directly connected, Serial1
S*   0.0.0.0/0 [1/0] via 199.10.3.1
RouterC#
RouterC#
RouterC#
```

Homework: Configure **default routes** on RA and RB

Routing Metrics and Costs

Metrics of Links

- **Metrics** are **cost values** used by routers to determine the **best path** to a **destination network.**
- Several factors help dynamic routing protocols decide which is the preferred or shortest path to a particular destination.
- These factors are known as **metrics** and **algorithms.**
- **Metrics** are the **network variables** used in deciding what path is preferred in terms of these metrics.
- For some routing protocols these metrics are static and may not be changed.
- For other routing protocols these values may be assigned by a network administrator.
- The most common metric values are hop, bandwidth, delay, reliability, load, and cost.

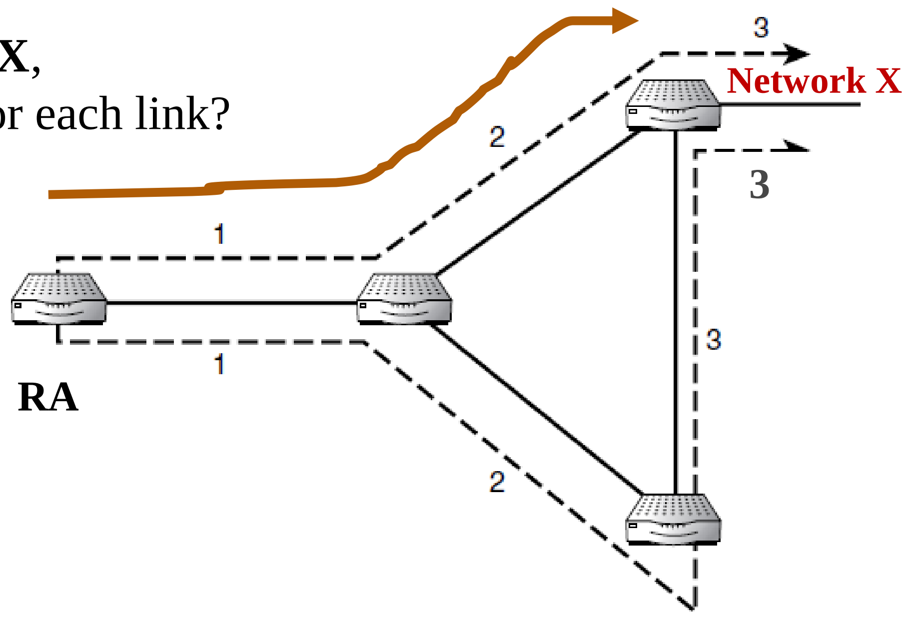
Metric: Hop

- A **hop** is a metric value used to measure **distance** based on the **number of networks** a **datagram** traverses.
- Each time a router forwards a datagram onto a segment this counts as a single hop.
- Routing protocols that observe hops as their primary metric value consider the best or preferred path (when multiple paths exist) to a destination to be the one with the least number of network hops.

Q1: Which is the **preferred path to Network X**, from RA, if the costs are given over the path for each link?

ANS1: Preferred path is the one with least amount of total costs. The Upper path to Network is preferred.

Total cost of the **chosen path** is: **1 + 2 = 3**

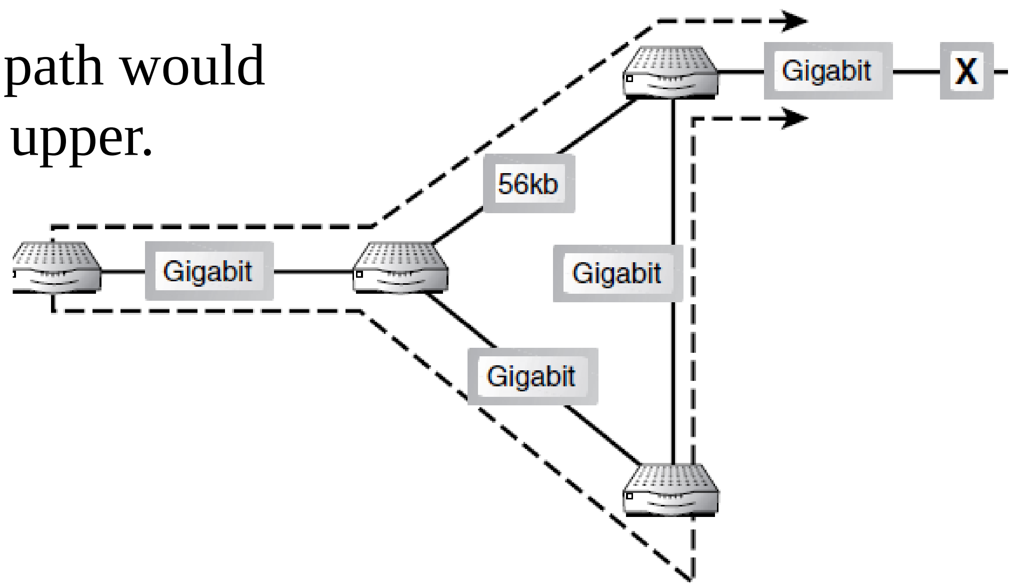


Metric: Bandwidth
(Data transfer rate of the link)

- Routing protocols that only reference hops as their metric do not always select the best path through a network.
- Just because a path to a destination contains fewer network hops than another does not make it the best.
- The upper path may contain a slower link, such as 56kb dial-up link along the second hop, whereas the lower path may consist of more hops but faster links, such as gigabit Ethernet.

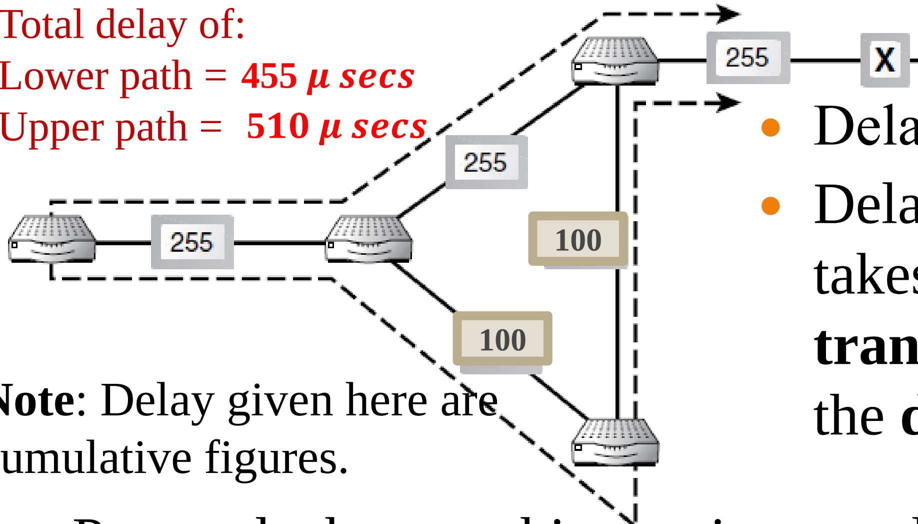
- If this were the case, the lower path would undoubtedly be faster than the upper.

- However, routing protocols that use hops do not consider other metric values in their routing decisions.



Metric: Delay

Total delay of:
Lower path = **455 μ *secs***
Upper path = **510 μ *secs***



Note: Delay given here are cumulative figures.

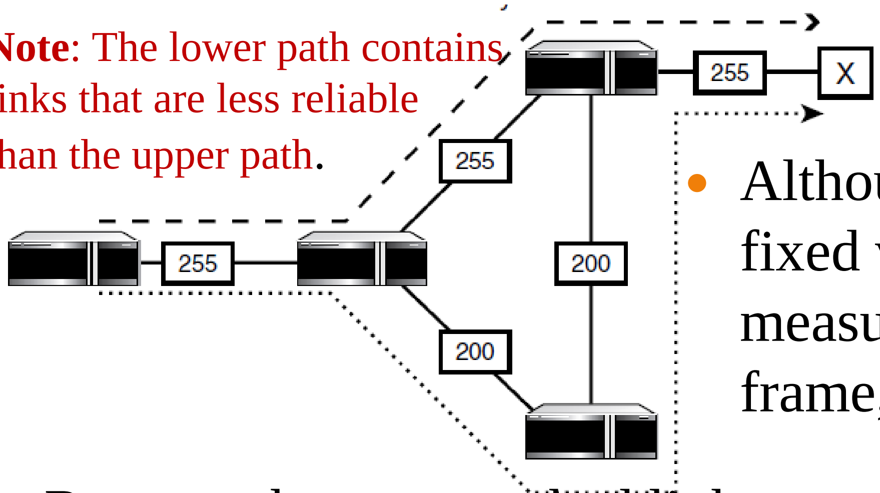
- Delay is measured in tens of µ seconds.
- Delay represents the amount of time it takes for a **router to process**, **queue**, and **transmit** a datagram **out** an **interface plus** the **delay introduced** by the **link**.

- Protocols that use this metric must determine the delay values for all links along the path end to end, considering the path with the lowest (cumulative) delay to be a better route.
- Although the lower path in the above figure is obviously longer in terms of hops, it is faster in terms of delay.
- The lower path has an overall delay time of 455 microseconds end to end, while the upper path has a delay of 510 microseconds.
- The lower the delay time the better the path.

Note: Delays introduced by the routers are not considered here.

Metric: Reliability

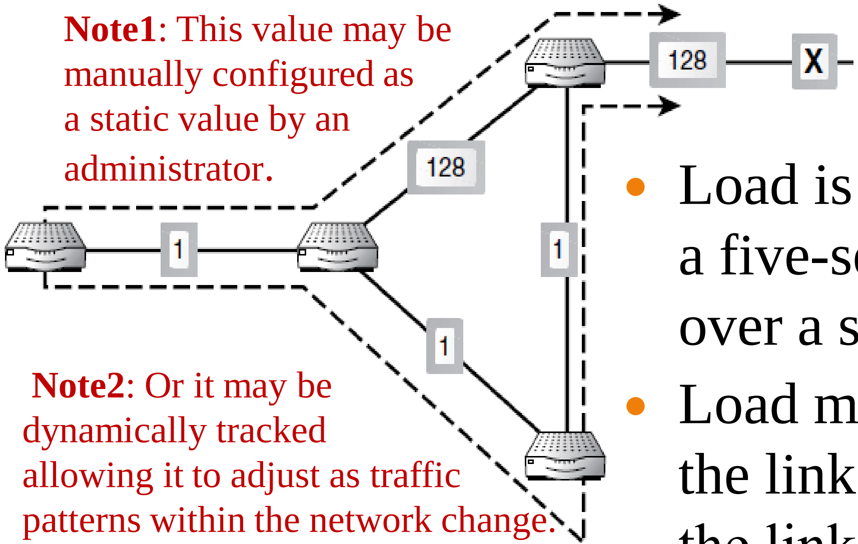
Note: The lower path contains links that are less reliable than the upper path.



- Although this metric may be configured as a fixed value by an administrator, it is generally measured dynamically over a specific time frame, such as five seconds
- Routers observe attached links, reporting problems, such as link failures, interface errors, lost datagrams and so on.
- Links experiencing more problems would be considered less reliable than others making them less desirable paths—the higher the reliability the better the path.
- Because network conditions are constantly changing, link reliability will change.
- This value is generally measured as a percentage of 255, with 255 being the most reliable and 1 being least reliable.

Metric: Load

Note1: This value may be manually configured as a static value by an administrator.



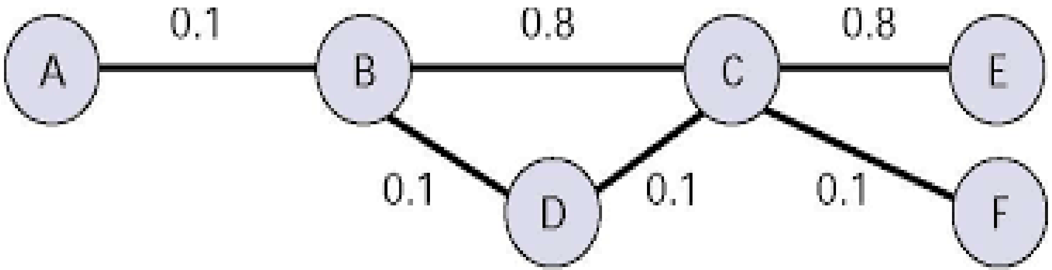
Note2: Or it may be dynamically tracked allowing it to adjust as traffic patterns within the network change.

Note3: It is important to remember that as traffic increases load across a link will increase. This Load metric value changes as traffic patterns change.

- Load is a variable value, generally measured over a five-second window indicating the traffic load over a specific link.
- Load measures the amount of traffic occupying the link over this time frame as a percentage of the link's total capacity

- The value 255 is equivalent to 100% utilization or load—the higher the value the higher the traffic load (bandwidth utilization) across this link.
- As traffic increases, this value increases.
- Values approaching 255 indicate congestion, while lower values indicate moderate traffic loads—the lower the value, the less congested the path, the more preferred.

Quiz 2: Choose the Optimal Path



The numbers given over the links are the delay experienced by the Data packets over those links.

- Assume the Routing algorithm operates on the delay metric and hop count find the Optimal path for the traffic going between the nodes:

	Metric: Delay	**Metric: Hop Count**
A to F:	**A→B→D→C→F**	**A→B→C→F**
B to E:	**B→D→C→E**	**B→C→E**
F to D:	**F→C→D**	**F→C→D**

Note: Network administrators can affect the way routers make path decisions by setting **arbitrary metric values** on links along the path end to end. These arbitrary values are typically single integers with lower values indicating better paths, which are called as **costs of the links**.

GATE Questions on Networking

CS2: GATE 2024 : Q28

1 mark

- Which of the following statements about IPv4 fragmentation is/are TRUE?

A. The fragmentation of an IP datagram is performed only at the source of the datagram

B. The fragmentation of an IP datagram is performed at any IP router which finds that the size of the datagram to be transmitted exceeds the MTU

C. The reassembly of fragments is performed only at the destination of the datagram

D. The reassembly of fragments is performed at all intermediate routers along the path from the source to the destination

ANS: **B and C**

Multiple Correct Options

CS2: GATE 2024 : Q32

1 mark

- Which of the following fields of an IP header is/are always modified by any router before it forwards the IP packet?

A. Source IP Address
B. Protocol
C. Time to Live (TTL)
D. Header Checksum

ANS: C and D

Multiple Correct Options

CS2: GATE 2024 : Q38

1 mark

- Which one of the following CIDR prefixes exactly represents the range of IP addresses **10.12.2.0** to **10.12.3.255**?

A. 10.12.2.0/23

B. 10.12.2.0/24

C. 10.12.0.0/22

D. 10.12.2.0/22

Multiple Correct Options

ANS: A

CS2: GATE 2024 : Q55

2 marks

- Consider an Ethernet segment with a **transmission speed** of **10^8 bits/sec** and a maximum segment length of **500 meters**. If the **speed of propagation** of the signal in the medium is **2×10^8 meters/sec**, then the **minimum frame size** (in bits) required for collision detection is __________?

For **collision detection** to be effective, the transmitting station must continue sending the frame for at least 2×Propagation Delay so that if a collision occurs, the signal reflecting the collision can reach the sender before it finishes sending the frame

Minimum Transmission Time ≥ 2×Propagation Delay

CS2: GATE 2024 : Q55 (solution)

- **Propagation Speed** = 2×10^8 meters/sec
- **Maximum Segment Length** = **500 meters** (one-way distance)

Propagation delay (T_{prop}):

$$T_{\text{prop}} = \frac{\text{Distance}}{\text{Speed}} = \frac{500}{2 \times 10^8}$$

$$T_{\text{prop}} = 2.5 \times 10^{-6} \text{ sec (2.5 microseconds)}$$

Since the signal must propagate to the other end and back **(collision round-trip time)**, the total time required for collision detection is:

$$T_{\text{detect}} = 2 \times T_{\text{prop}} = 2 \times 2.5 \times 10^{-6}$$

$$T_{\text{detect}} = 5 \times 10^{-6} \text{ sec (5 microseconds)}$$

- **Transmission Speed** = 10^8 bits/sec
- **Minimum Transmission Time** = 5×10^{-6} sec

Using:

$$\text{Frame Size} = \text{Transmission Rate} \times \text{Transmission Time}$$

$$\text{Frame Size} = 10^8 \times 5 \times 10^{-6}$$

$$\text{Frame Size} = 500 \text{ bits}$$

ANS: 500 bits

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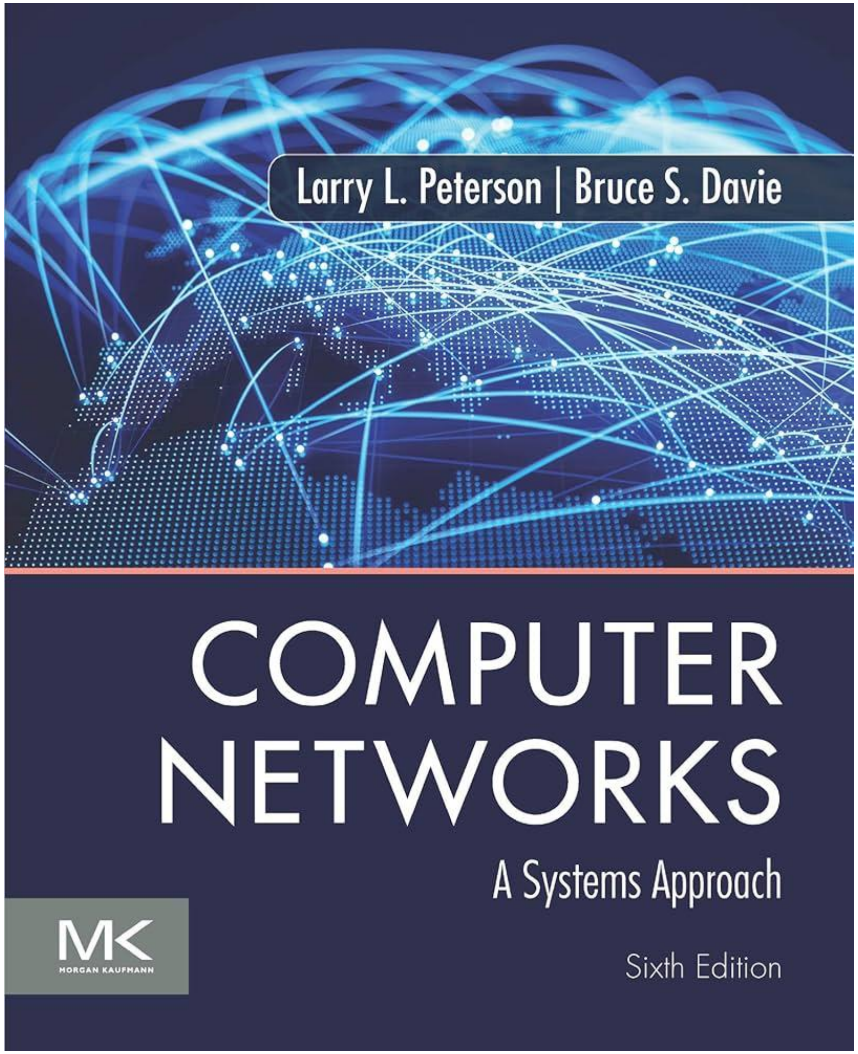
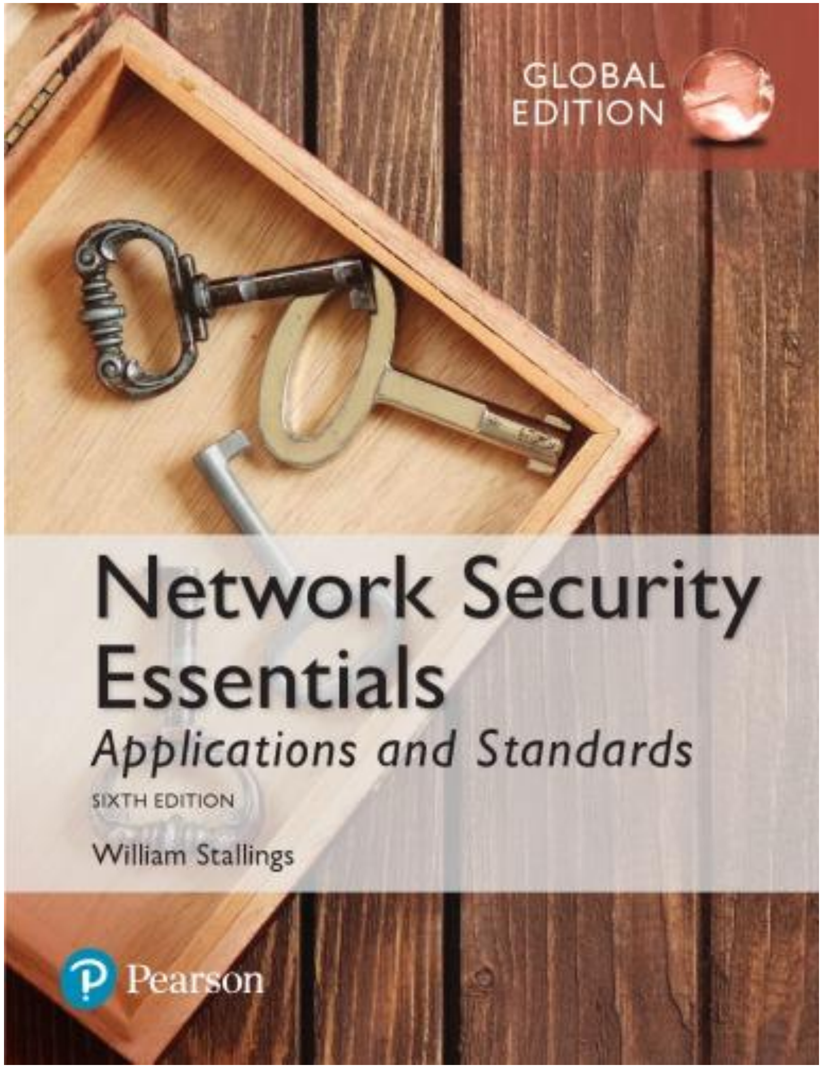
Textbooks

Textbook 1

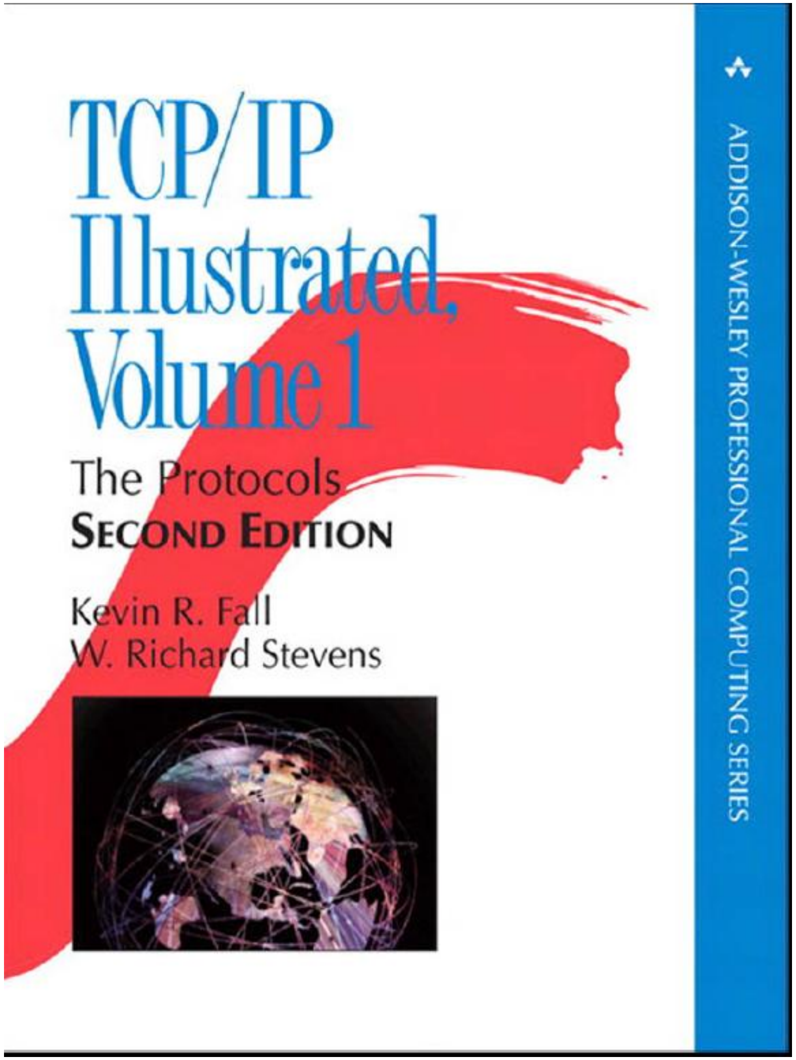


Textbook 2



References

Ref 1



Ref 2

[TCP Congestion Control: A Systems Approach]

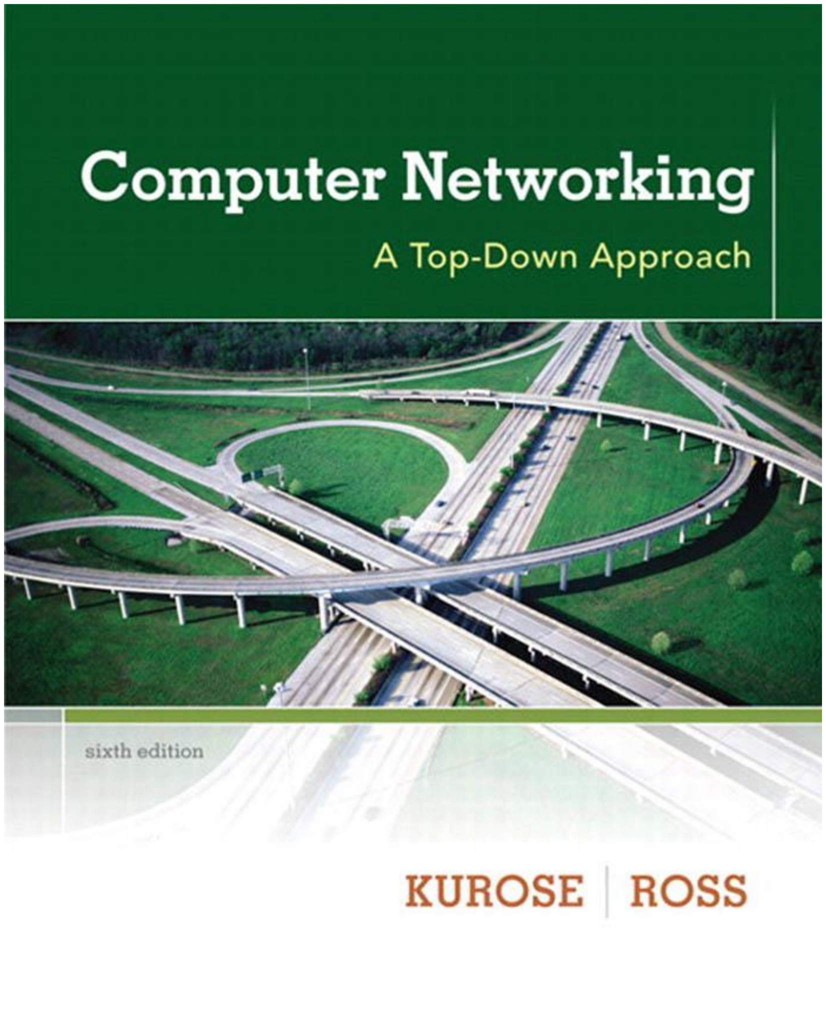
HTTPS://SYSTEMSAPPROACH.ORG

TCP Congestion Control: A Systems Approach

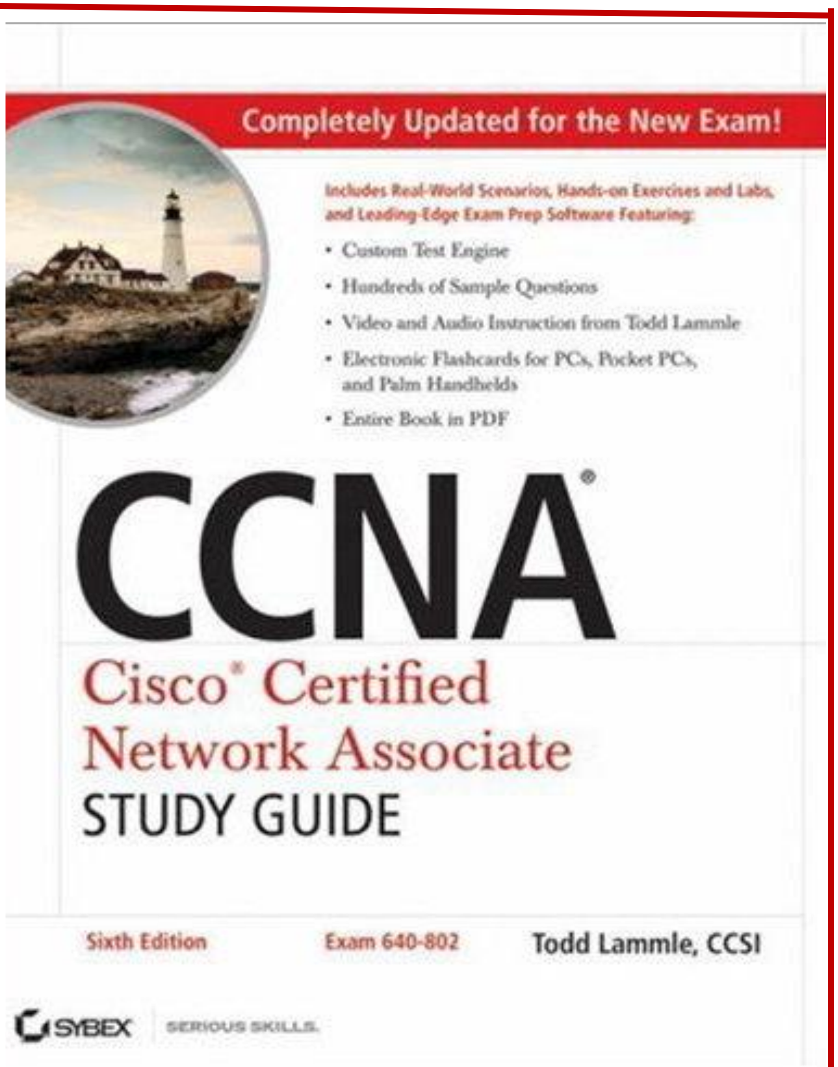
Peterson, Brakmo, and Davie

References

Ref 3



Ref 4



References

Ref 5