Session 6B

ASN and Border Gateway Protocol

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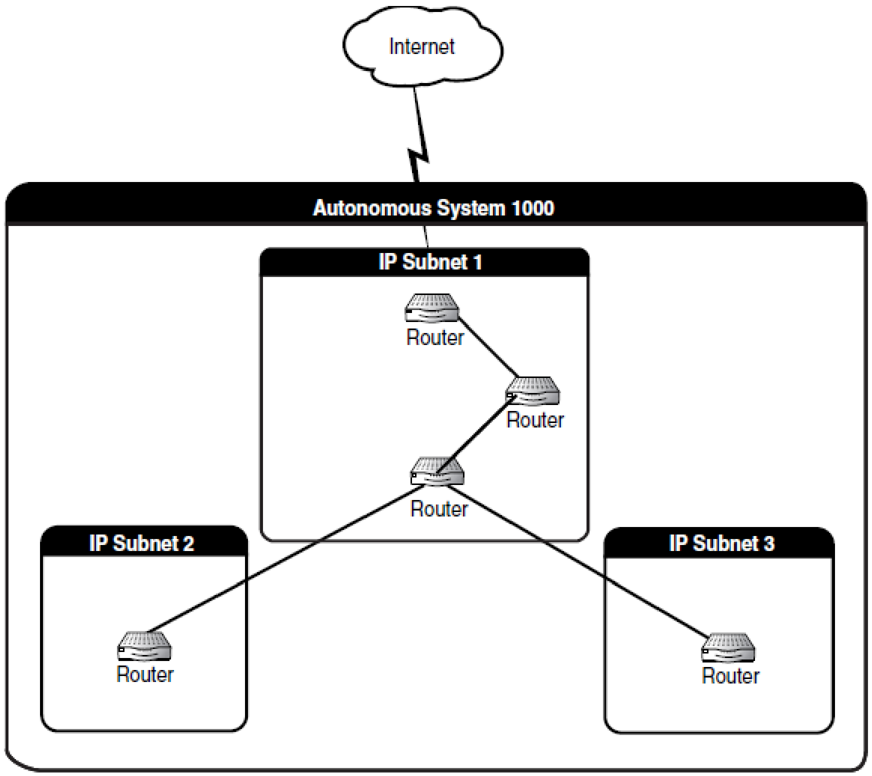
Session 6B: Focus

- Autonomous System Numbers (ASN)
  - Private and Public ASNs
  - ASNs and IP Addresses
- Border Gateway Protocol (BGP)
  - iBGP and eBGP
  - BGP Speakers
  - TCP Session
  - How does BGP work?
  - AS_PATH attribute
  - Loop Avoidance

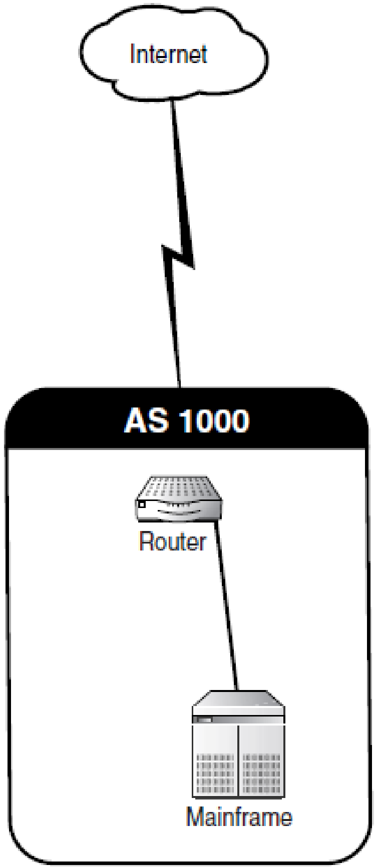
Course page where the course materials will be posted as the course progresses:

Autonomous System Numbers (ASN)

Autonomous Systems: Examples



An Autonomous System is a collection of subnets, routers and routing protocols



A single Autonomous System with one router.

Autonomous System Numbers (ASN)

- An Autonomous System Number, like an IP address, must be assigned by a governing body and it is a 32-bit integer.
- In most cases the ISPs assign ASN as a subset of its own.
- In the United States, the governing body in charge of registering and releasing Autonomous System numbers is **ARIN** (the American Registry for Internet Numbers).
- There are two main categories of ASNs, **public** and **private**.
- Public numbers are assigned to entities requiring their network be advertised to the Internet.
- Most often ISPs and other large, global companies are assigned public ASNs.

Public ASN Example:

Internet Service Providers (ISPs): AT&T, Verizon, Tata Communications
Cloud Providers: AWS, Google Cloud, Azure
Large Enterprises that operate their own global networks: Facebook, Netflix

Private ASNs

- Like their IP address counterparts these numbers cannot be advertised to the Internet and are not routable.
- Rather these numbers are used for iBGP (Internal BGP) routing within a larger BGP network.
- The numbers in the private ASN range can be used freely by anyone.
- To qualify for a public Autonomous System number, a network needs to supply a proof of **multi-homing**.
- Typically, multi-homed connections are used to load balance traffic and provide fault tolerance.

BGP: Border Gateway Protocol

Summary of ASN Allocation - Info

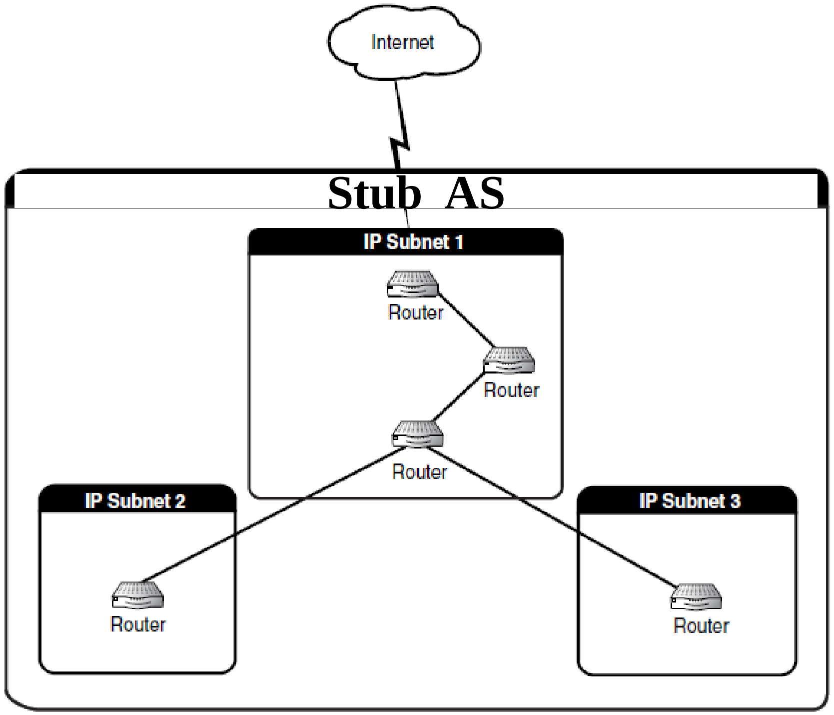
ASN Table [edit]

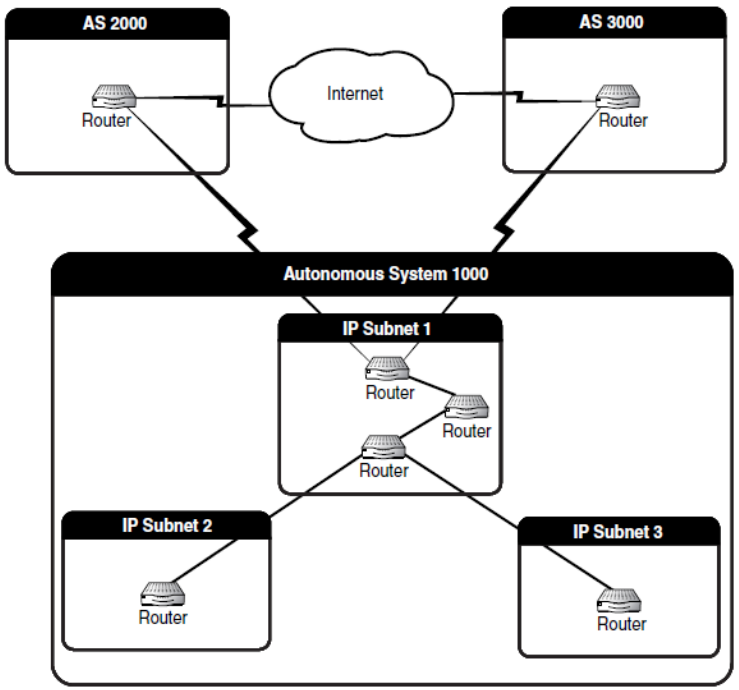
A complete table of 16-bits and 32-bits ASN available:[8]

Number	Bits	Description	Reference
0	16	Reserved	RFC1930
1 - 23455	16	Public ASN's	
23456	16	Reserved for AS Pool Transition	RFC6793
23457 - 64534	16	Public ASN's	
64000 - 64495	16	Reserved by IANA	
64496 - 64511	16	Reserved for use in documentation/sample code	RFC5398
64512 - 65534	16	Reserved for private use	
65535	16	Reserved	
65536 - 65551	32	Reserved for use in documentation and sample code	RFC4893, RFC5398
65552 - 131071	32	Reserved	
131072 - 4199999999	32	Public 32-bit ASN's	
4200000000 - 4294967294	32	Reserved for private use	RFC6996
4294967295	32	Reserved	

Note: Prior to the current 32-bit ASNs, 16-bit ASN was in use.

Three Classes of ASs





A stub AS has a single link connecting it to another AS, with only one way in and out.

The above AS cannot be a public ASN.

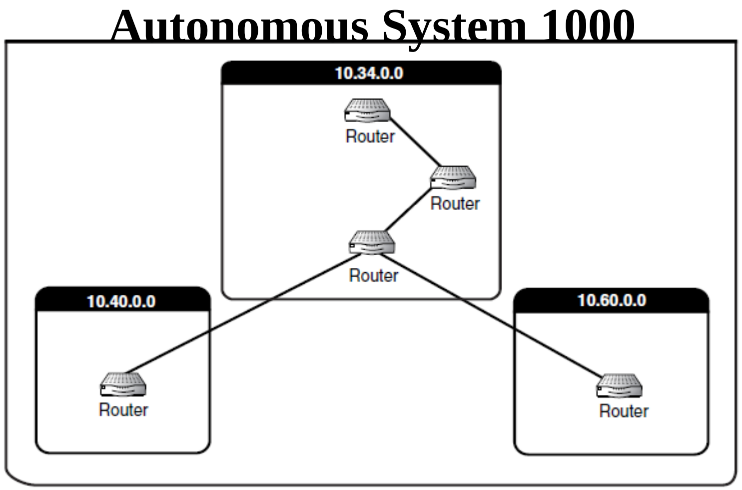
Multihomed AS 1000 has connections to two other AS', 2000 and 3000.

The above AS can be assigned a Public ASN

Third type of **AS** is **Transit AS**

ASNs and IP Addresses

- IP addresses play a big part in the operation of BGP and the formation of Autonomous Systems.
- An ASN needs to be associated with the IP address segments of the network to which it is attached.



- This ensures the traffic destined to a particular AS gets routed to it properly
- BGP uses ASNs to route packets to different ASes.
- Having a proper IP addresses configured for the ASNs ensure that any external AS, route the correct packets to the relevant **border gateways**.
- If a subnet is left out or IP addressing scheme is changed without modifying the ASN, the network will not correctly receive data bound for it.

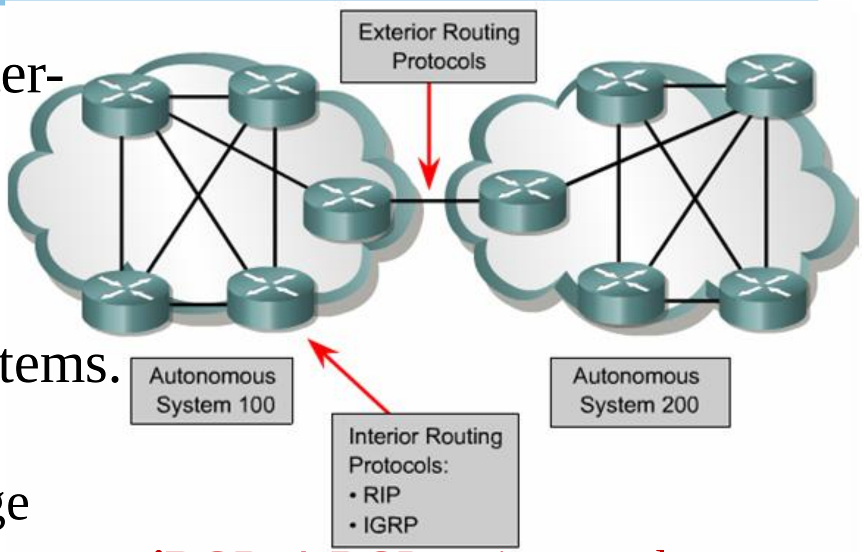
Border Gateway Protocol (BGP)

The Border Gateway Protocol (**BGP**) is the inter-domain routing protocol of the Internet. It is the protocol that connects tens of thousands of networks in the Internet to form one big interconnected network. It is the only widely used inter-domain routing protocol in the Internet and is therefore very important for the correct functioning of the Internet.

BGP: Introduction

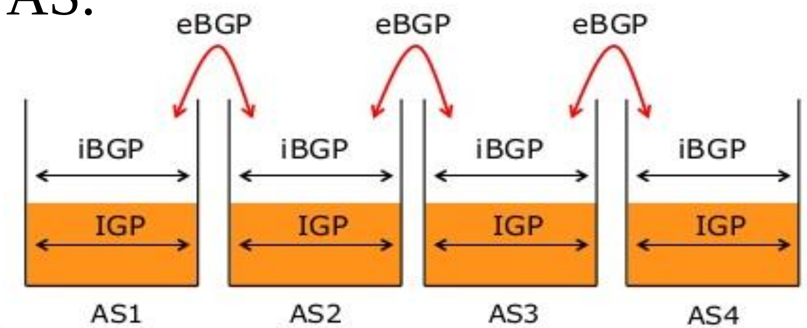
iBGP: Internal BGP
eBGP: External BGP

- BGP allows you to create loop-free inter-domain routing between autonomous systems (ASs).
- BGP exchanges network reachability information between Autonomous Systems.
  - **IGP** handles internal routing within a network, while **iBGP** and **eBGP** manage routing between different networks across autonomous systems.

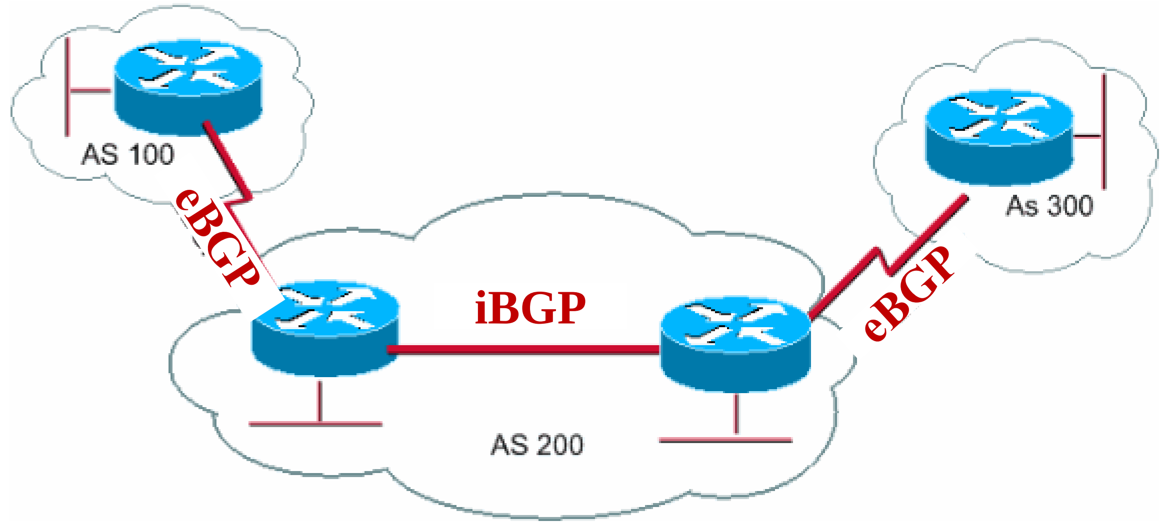


iBGP: A BGP variant used within an AS. Has full mesh of connections within an AS.

- Routers in an AS use multiple Interior Gateway Protocols (IGPs) to exchange routing information within the AS.
  - Example: RIP, OSPF, IGRP, etc.
- The routers use an exterior gateway protocol to route packets outside the AS.
  - Example: **BGP**



iBGP and eBGP

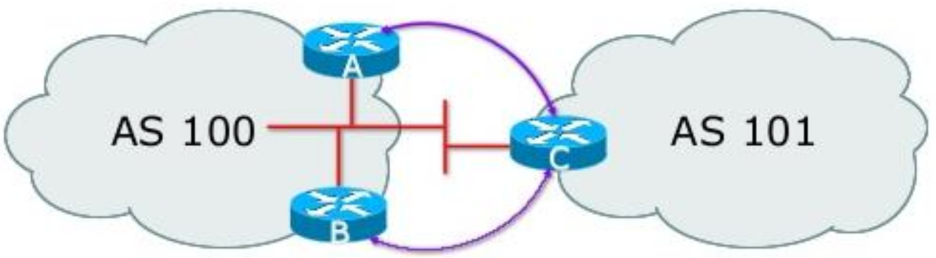


- Internal BGP (**iBGP**) is for **peering** between routers inside an AS.
- When BGP runs between routers that belong to two different ASs, it is called as exterior BGP (**eBGP**).
- eBGP takes care of exchanging the routing information across different ASs.
- Whereas, iBGP's responsibility is to disseminate the route information learnt from other ASs with the other **BGP routers** inside an AS.

BGP Routers: The routers within an AS that runs BGP and connected to other BGSP routers.

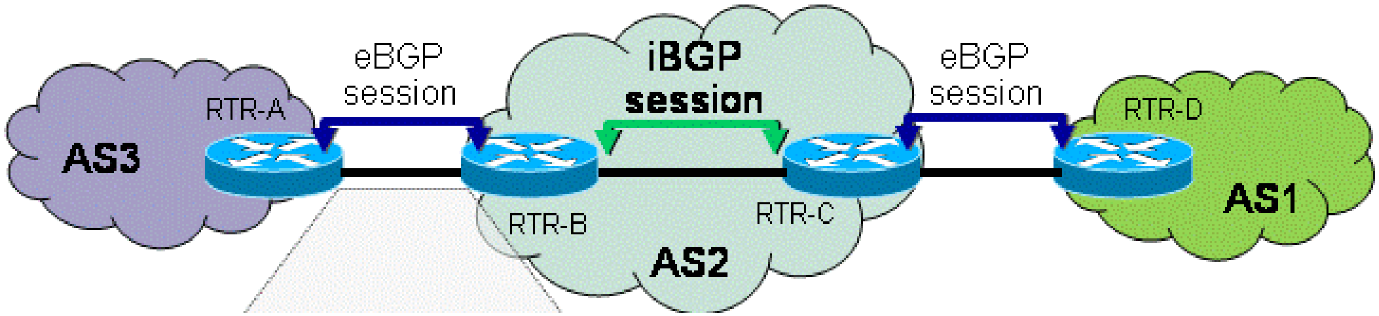
BGP Speakers

- All the routers within an AS (that are configured for BGP) are known as BGP speakers.
  - They speak BGP language which means they run BGP protocol.



- These BGP speakers need to be configured by an administrator with the ASN of the Autonomous System they belong to.
- If the AS is comprised of more than one IP subnet, all of the IP networks need to be associated with the ASN.
- If a BGP speaker in an AS has an IP address that is not associated with the ASN, then the speaker will not be able to participate in the AS.
- The BGP speakers on different ASs should be directly connected.
- But IGP is not run between the eBGP peers.

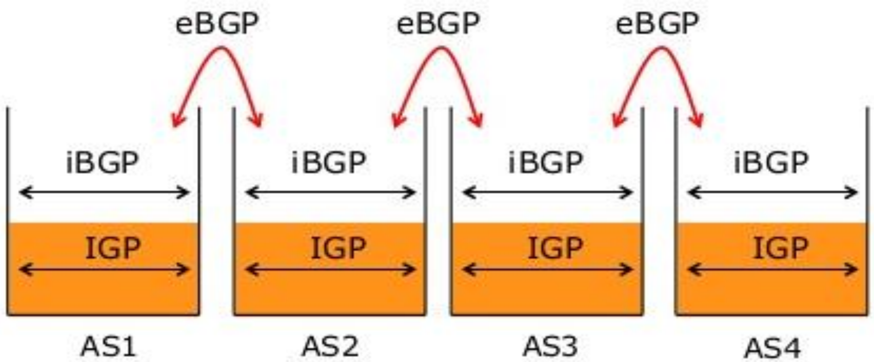
BGP: TCP Session

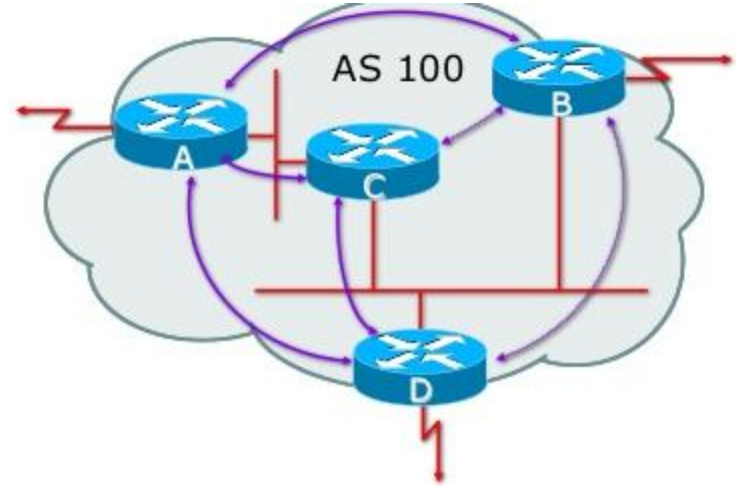


Note: Which router initiates TCP connection does not matter once a TCP session is established.

- BGP uses TCP as the transport protocol, on port 179.
- Two BGP routers form a TCP connection between one another.
- These **peer routers** or called as **BGP Speakers**.
- The peer routers exchange messages to open and confirm the TCP connection parameters, that include:
  - The **version** of BGP supported by the router
  - **Autonomous System Numbers** each **Router** belongs to
  - **Hold timer (**time it will wait for **"keep alive"** messages**) – 60 secs**
  - The router's **BGP identifier**
  - The **optional parameters** the router supports

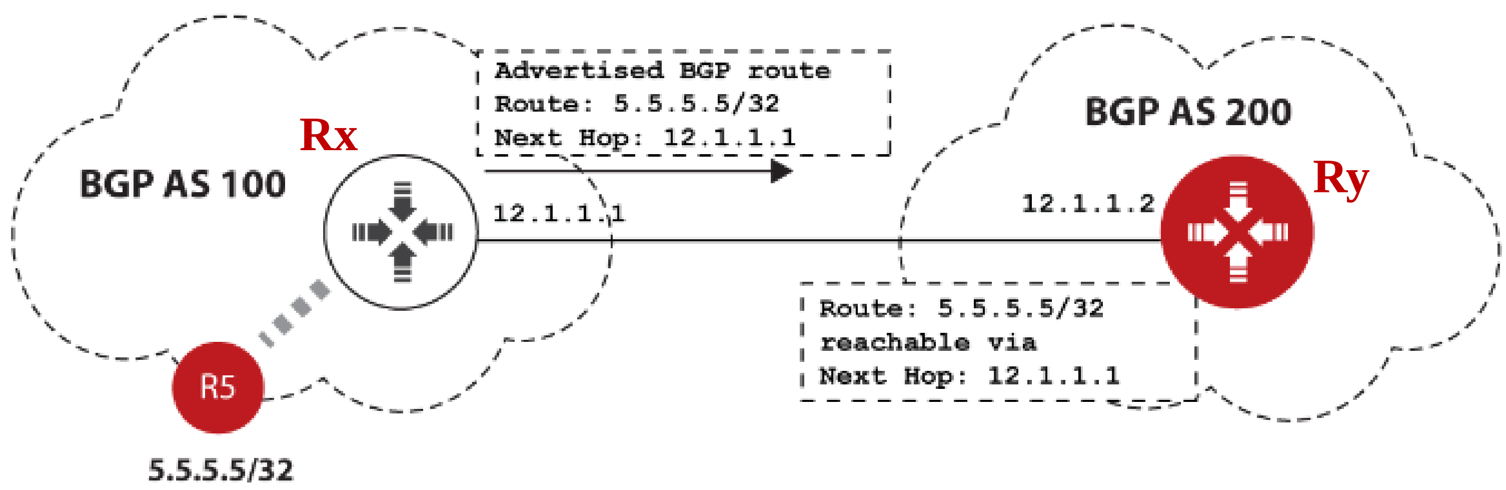
iBGP: Internal BGP





- iBGP runs between the peer routers within the same AS
- They are not required to be directly connected, but indirectly connected.
- IGP takes care of inter-BGP speaker connectivity
- iBGP speakers within an AS must be fully connected or meshed.
  - i.e., each iBGP speaker must peer with every other iBGP speaker in the AS
- They pass on IP prefixes (network IDs) learned from outside ASs
- They do not pass on prefixes learned from other iBGP speakers

Quiz 1: BGP Explained with an Example



Rx and **Ry** are called as BGP neighbours

R5 is another BGP Speaker getting added to AS100

- What is the protocol run between Rx and Ry? (iBGP or eBGP) **eBGP**
- How is Rx able to route packets to R5? **Through IGP (running within the AS)**
- How does R5 learn about the routes that Rx has learnt from Ry? **iBGP**
- What is being shared by Rx with Ry using eBGP? **An RT entry to be added into Ry for R5**

How does BGP work?

- BGP routers exchange network reachability information.
- This information is mainly an indication of the **full paths** that a route must take in order to reach the destination network.
- The **paths** are **AS numbers** given as a **list**.

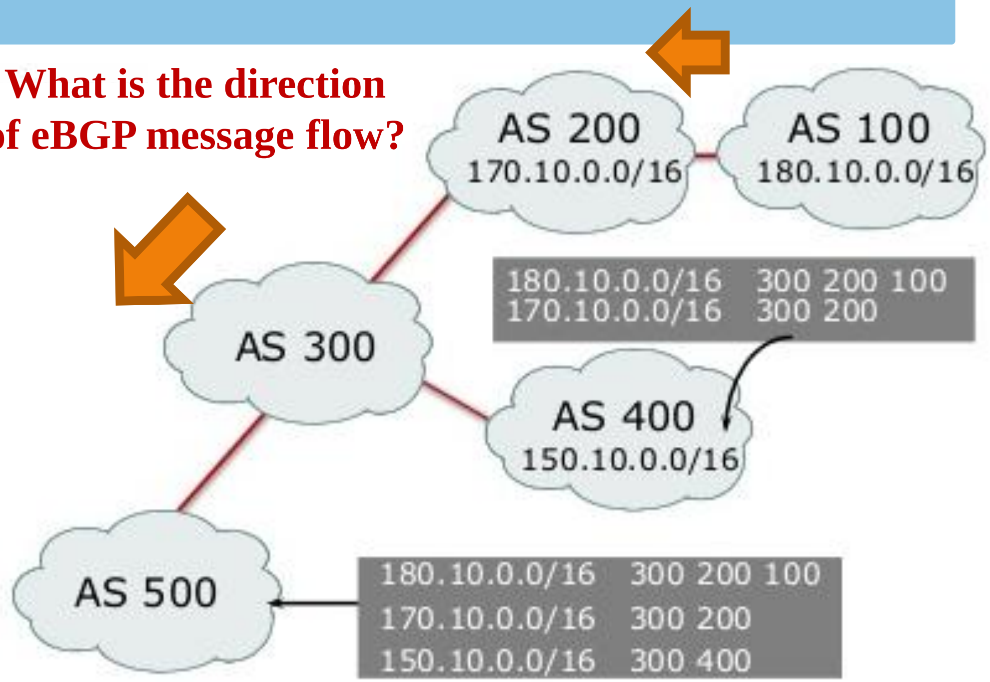
Thus, **BGP** is called a **path-vector protocol**

- This information helps in the construction of a graph of ASs that are loop-free.
- BGP peers initially exchange the full BGP routing tables (for ASes).
- After this exchange, the peers send incremental updates as the routing table changes.
- BGP keeps a version number of BGP tables and they need to be the same on all the participating routers, to have a consistent view of the network.
- The version number changes whenever BGP updates the table with routing information changes.

AS_PATH: An Attribute of eBGP

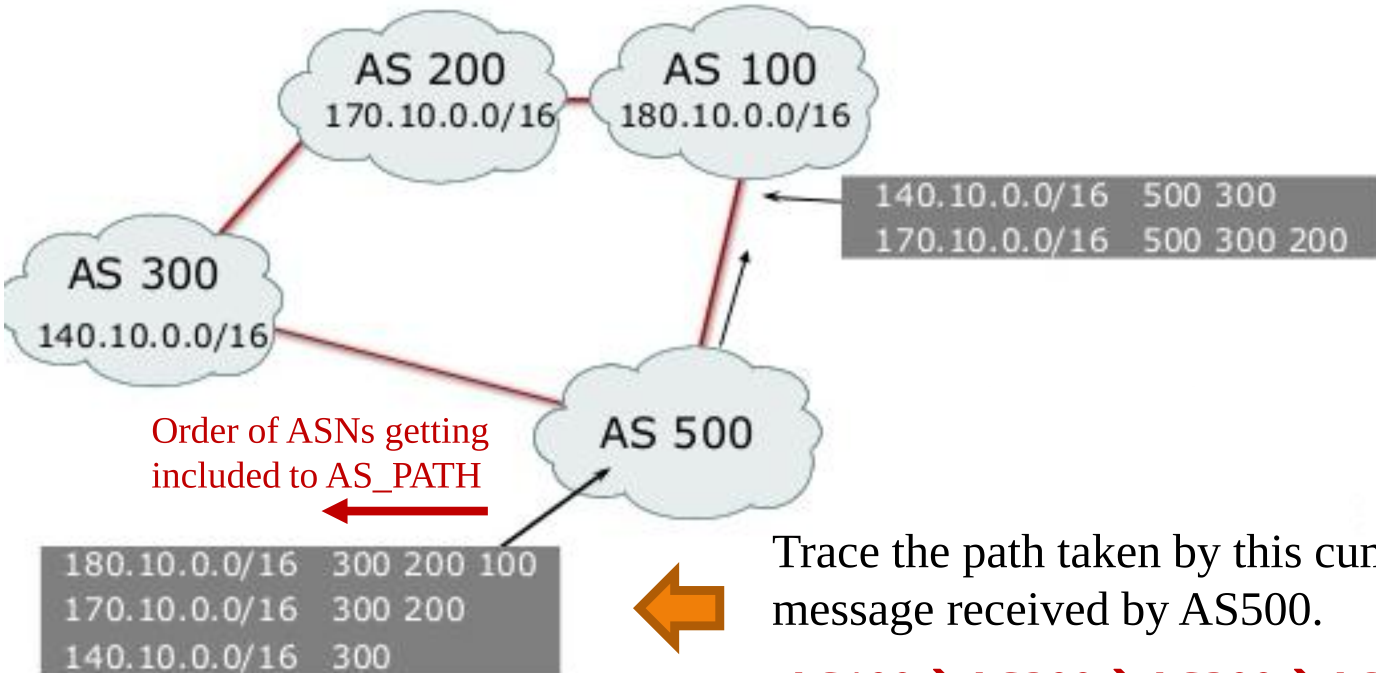
- It is a sequence of ASes a route has traversed.
- It has a mandatory **transitive** attribute.
- It is also useful for finding a loop and also to apply specific routing policies.

What is the direction of eBGP message flow?



- When AS100 sends eBGP message the AS_PATH has an entry
  - 180.10.0.0/16 100 (that this network can be reached through AS100)
- When AS200 receives it appends it's own reachability info to it
  - 180.10.0.0/16 200 100 and 170.10.0.0/16 200
- When the message goes to AS300 and then when it finally reaches AS400 and AS500, the respective contents are show above.

AS_PATH Loop Detection

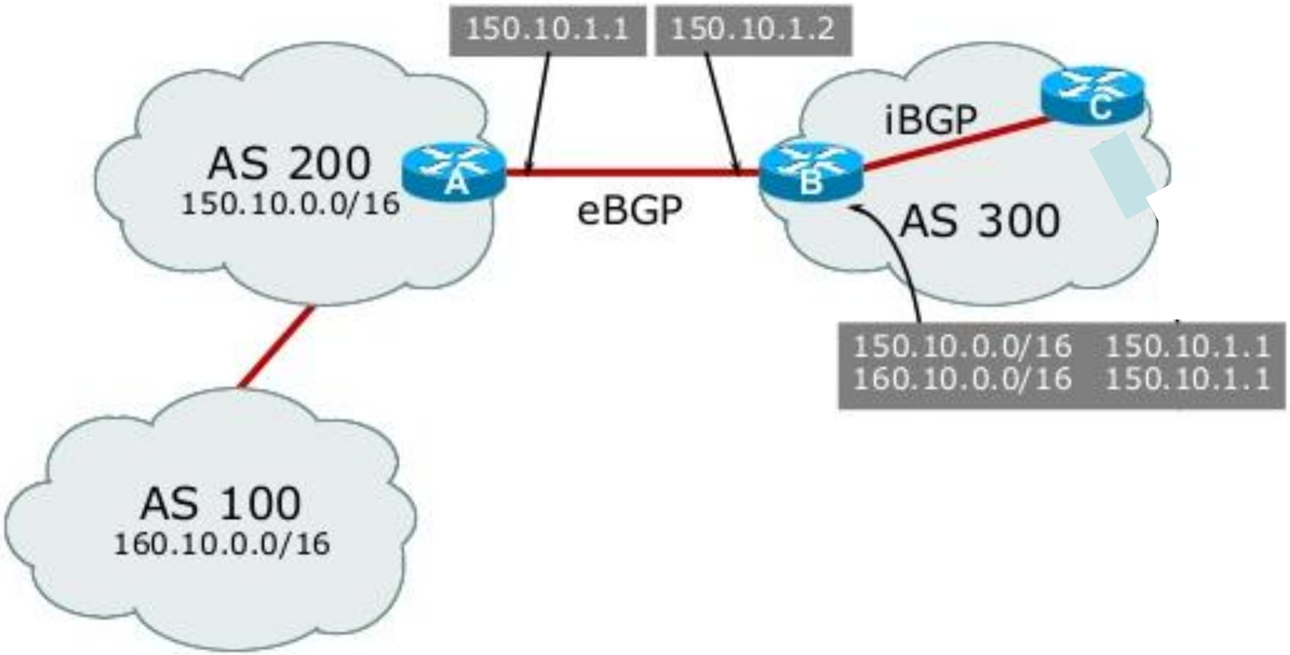


Trace the path taken by this cumulative eBGP message received by AS500.

AS100→AS200→AS300→AS500

- 180.10.0.0/16 entry coming from AS 500 is not accepted by AS100 because it will cause a loop since it has AS100 already in it.
- What is the direction a datagram to a host in AS100 from a host on AS500 would travel? **AS500→AS300→AS200→AS100** **Note: i.e., AS_PATH is always transitive.**

Next Hop Entry



- The Router B's RT entries show that the next hop for the hosts on AS200 and AS100 are set to the directly connected interface of Router A (150.10.1.1)
- Router A takes care of forwarding the packet to AS100 by learning the route from other eBGP routers within AS200

Routing and Loop Avoidance: Explained

- When a router advertises a destination within its own AS to a neighbor in another AS, it puts its local ASN in the AS_PATH.
  - AS_PATH is one of the attributes in eBGP
- As the route is advertised to subsequent autonomous systems, each AS border router adds its own ASN to the attribute.
- The AS_PATH, then, becomes a list of ASNs that describes the path back to the destination.
- A router can choose a shortest path by choosing the route with the fewest ASNs listed in its AS_PATH.
- How can a router find if there is a loop within the AS_PATH?
- If a router sees its own ASN listed in the AS_PATH of a route advertised to it by a neighbor, it drops the route.
  - Because if the router accepts the route and adds itself to it, it's ASN will be twice in the path causing a loop.

Session 6B: Summary

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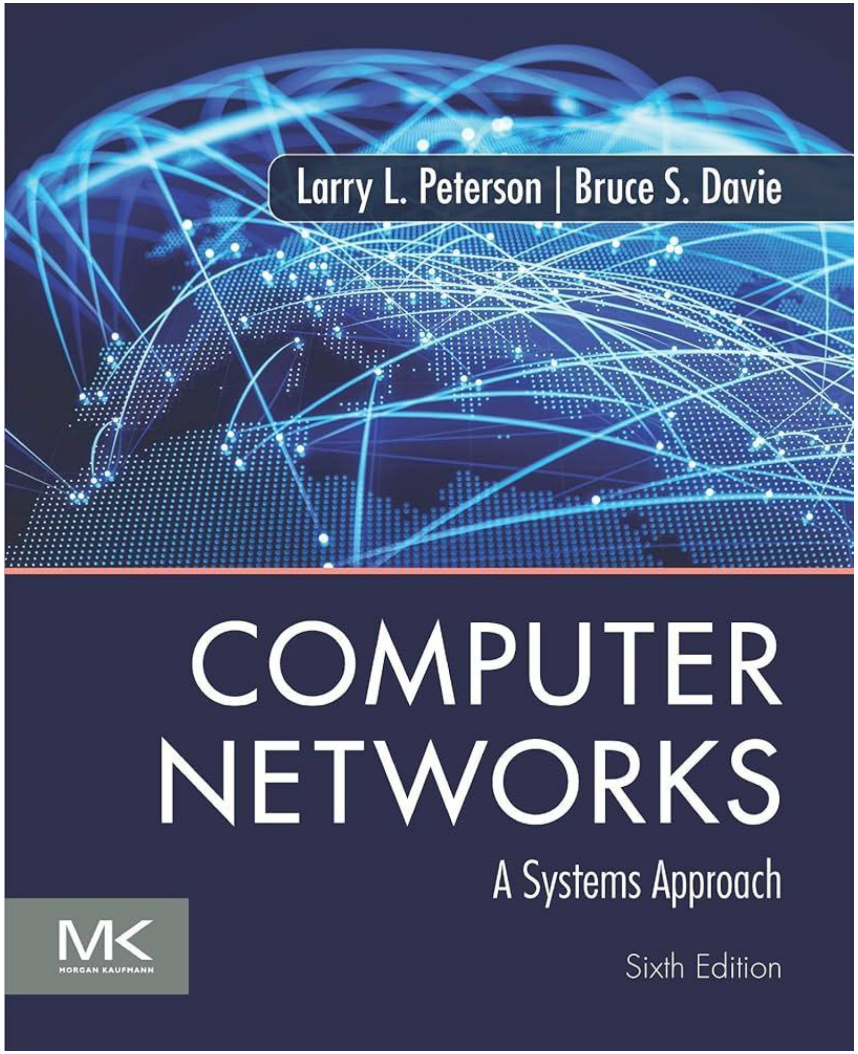
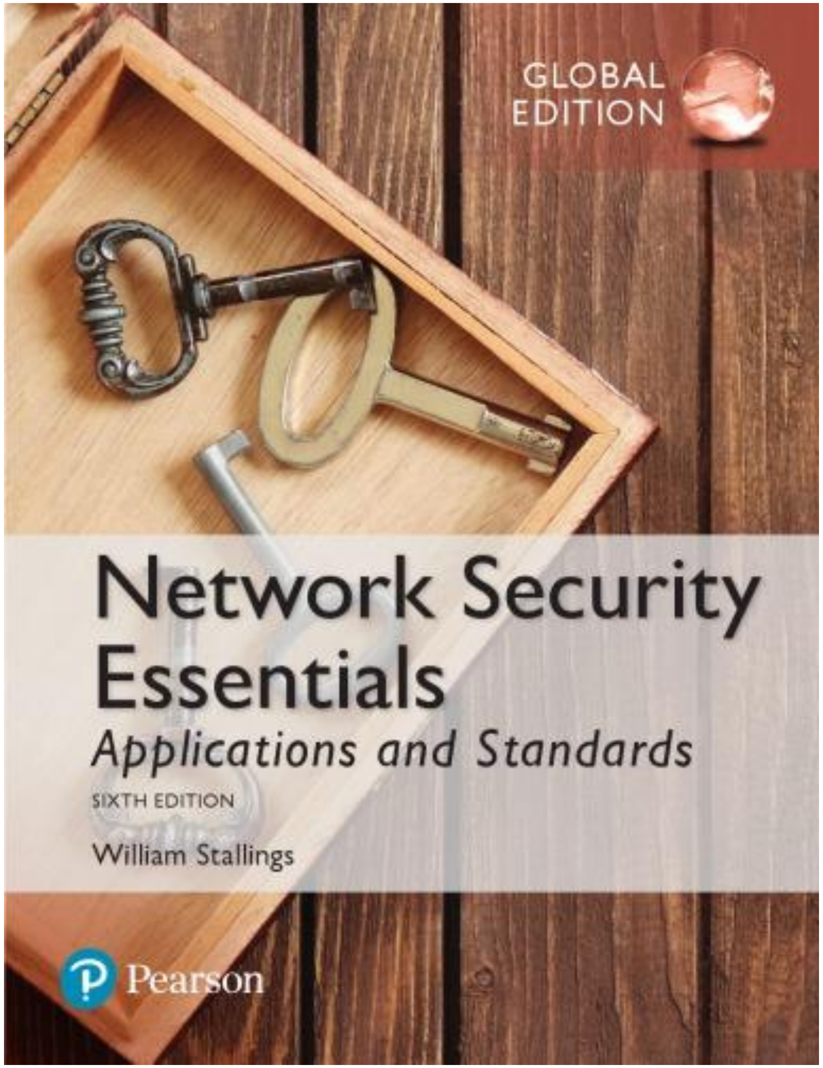
- Border Gateway Protocol (BGP)
  - iBGP and eBGP
  - BGP Speakers
  - TCP Session
  - How does BGP work?
  - AS_PATH attribute
  - Loop Avoidance

Textbooks

Textbook 1

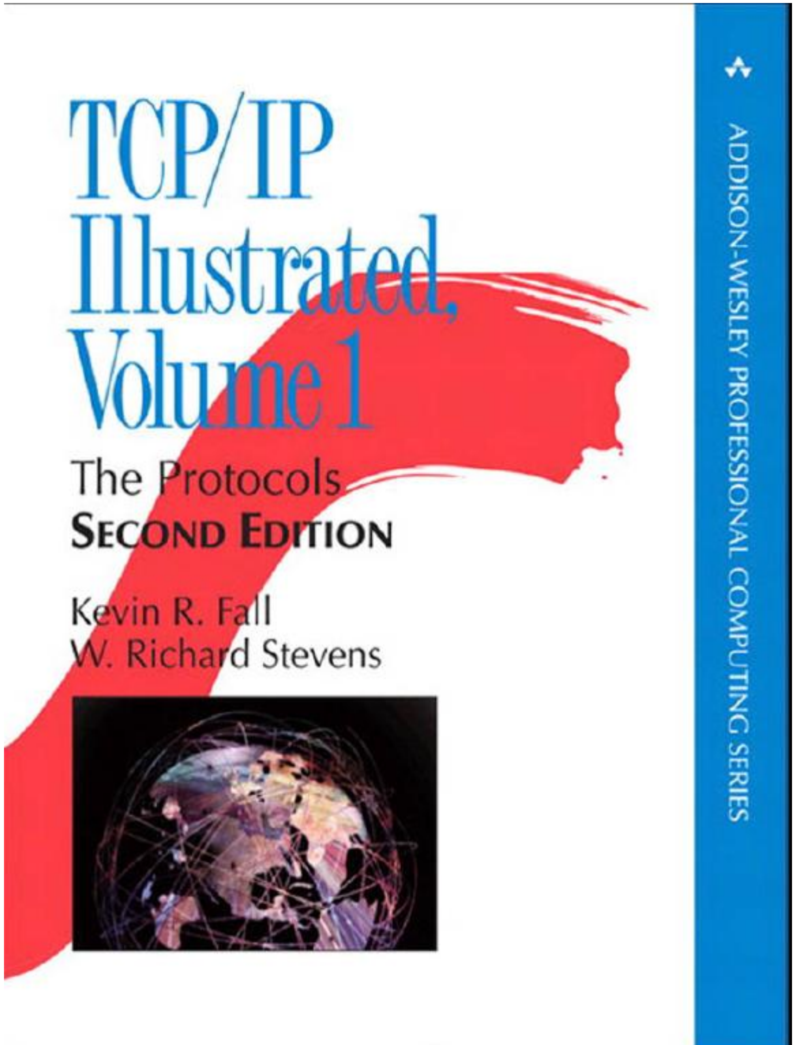


Textbook 2



References

Ref 1



Ref 2

[TCP Congestion Control: A Systems Approach]

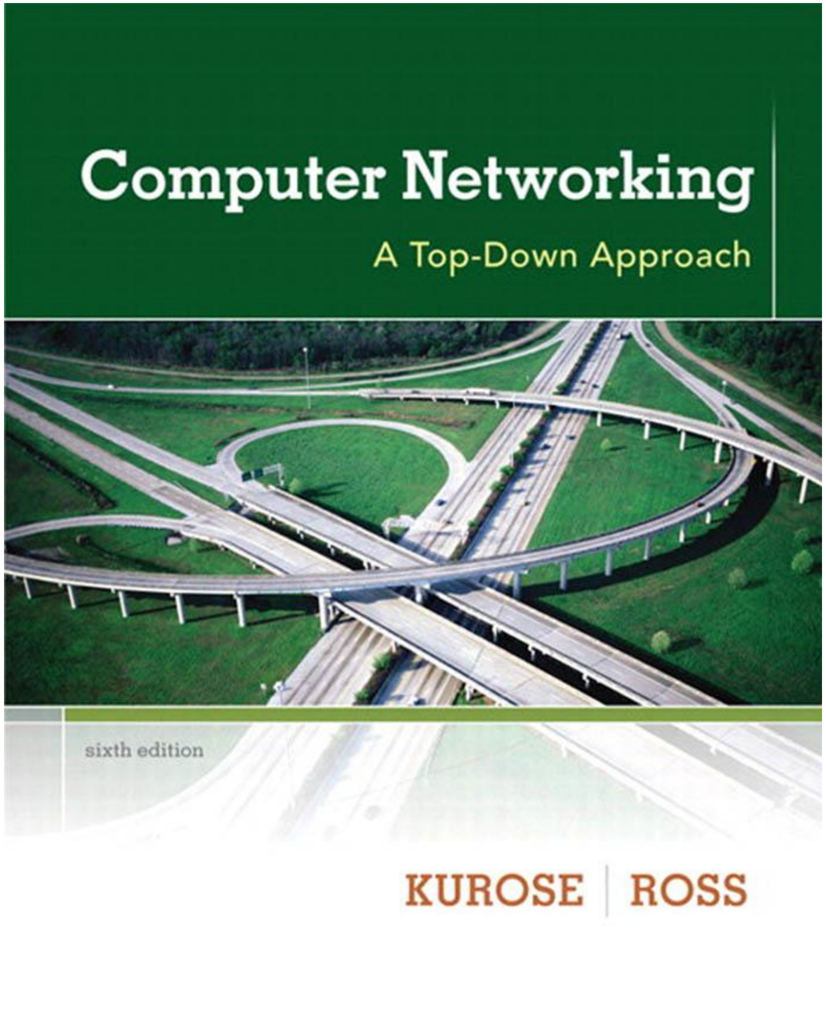
HTTPS://SYSTEMSAPPROACH.ORG

TCP Congestion Control: A Systems Approach

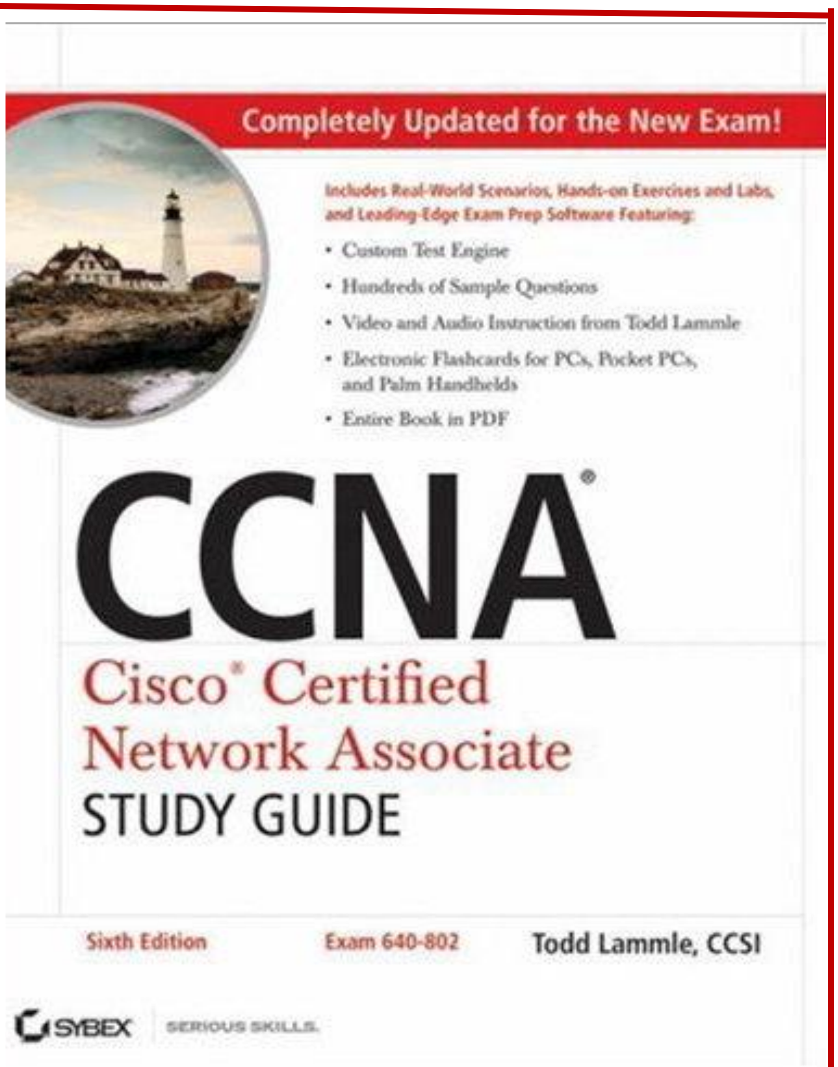
Peterson, Brakmo, and Davie

References

Ref 3



Ref 4



References

Ref 5