Network Security

Session 6C

IP Multicast

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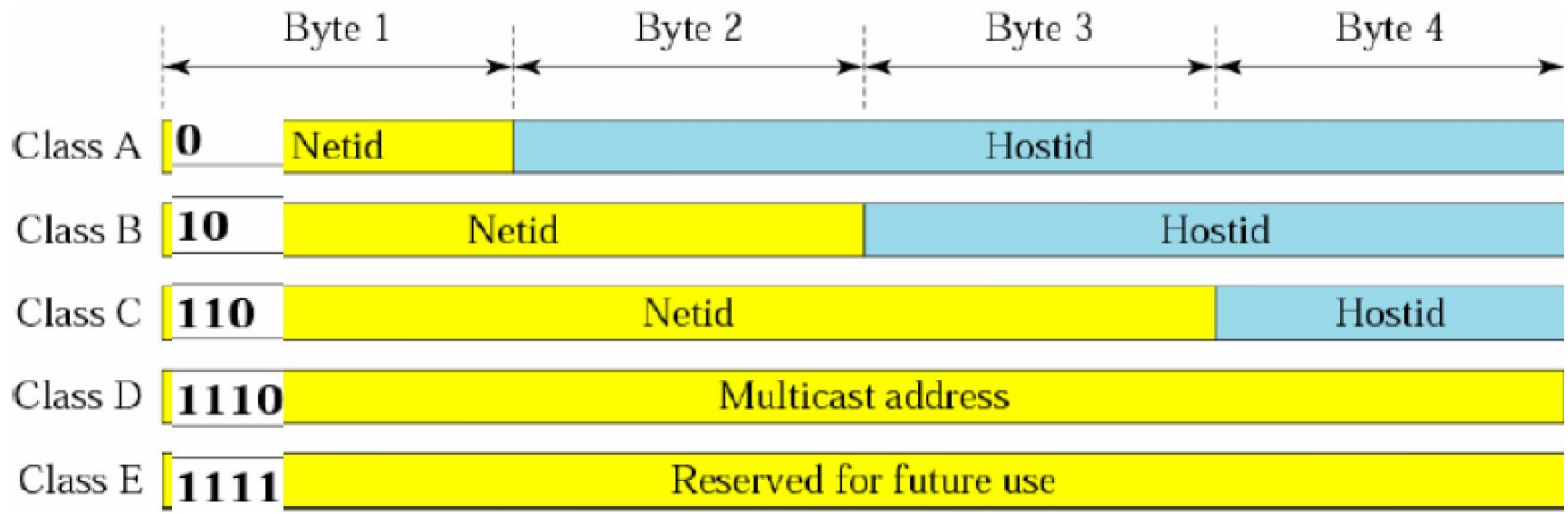
Session 6C: Focus

- Ethernet and IP Multicast addresses
- Quiz 1: Multicast on a LAN
- Levels of Conformance
- How does IP Multicast work?
  - Message Delivery and Message Flow
  - Many-to-many One-to-many
- IGMP:
  - Group Membership
  - Join and Leave operations
  - IGMP Snooping by L2 Switches
- IP Multicast Routing Protocols
  - Various Protocols Involved

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

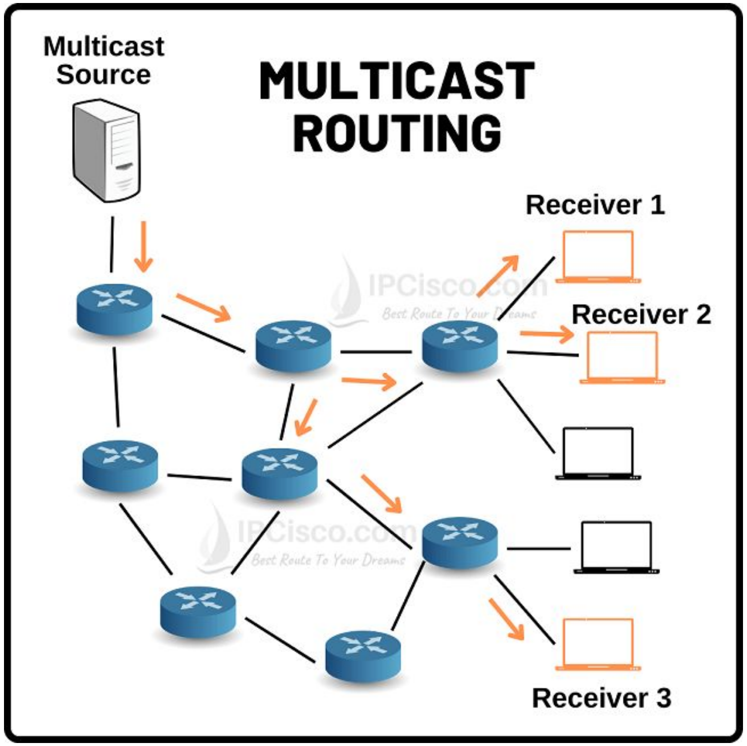
IP Multicast Addresses



- IP multicast addresses, also known as Class D addresses, fall within the range of **224.0.0.0** to **239.255.255.255** **Note: 224 □ 0xE0, 239 □ EF**
- These addresses are used for sending data to a group of recipients simultaneously, rather than individually, which is efficient for **one-to-many** communication.
- The source IP address of a multicast packet is always a unicast address, while the destination is a multicast address

Multicast Routing: Need for it

- Multicast is used wherever any media is to be shared with a large number of subscribers who have registered for it.
  - Mostly in media or live telecast, etc.
- This involves media to be streamed to many customers simultaneously
- It is highly suboptimal and waste of network bandwidth if individual customers are streamed the same media from the server.



- IP Multicast addresses are used for this purpose, network bandwidth can be preserved as much as possible based on the physical location of the customers.
- Need to have a mechanism for registration for a multicast stream and updating the routing tables in the routers accordingly. **Solution: IGMP**

Some Popular IP Multicast Addresses - Info

Multicast Address	Use Case
233.89.188.1 – 233.89.188.255	BBC Multicast Streaming
233.56.12.1 – 233.56.12.255	CNN, Fox News, Bloomberg TV
239.1.1.1 – 239.1.1.255	IPTV and media streaming
239.255.1.1 – 239.255.1.255	Content Delivery Networks (CDN)

- **The 239.x.x.x range (Administratively Scoped Multicast)** is often used for **private multicast streaming**.

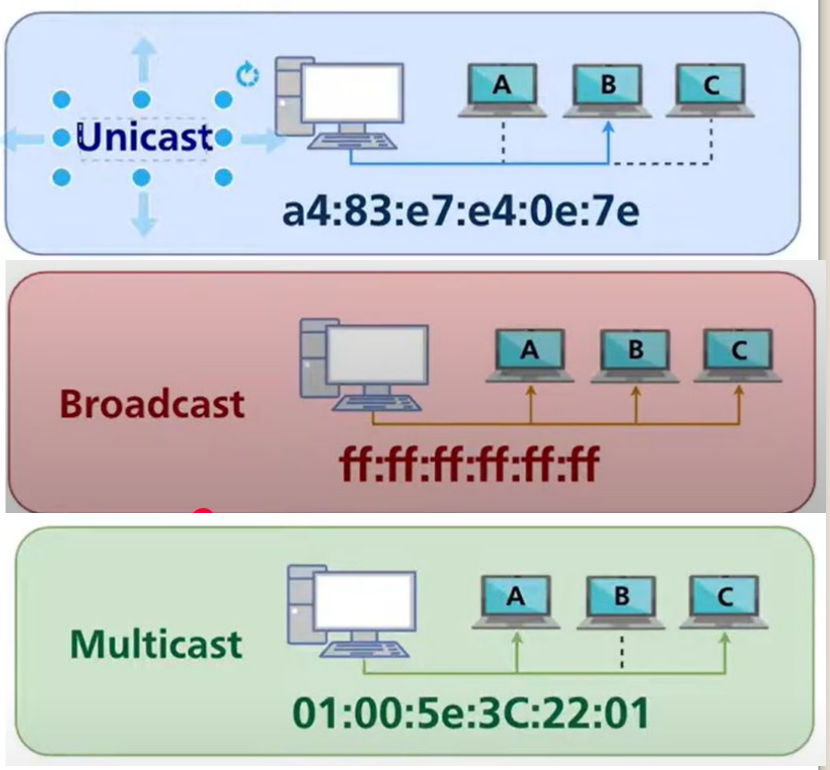
Class D	**1110**	Multicast address

Note: 233 □ 0xE9 239 □ 0xEF

Types of Ethernet MAC Addresses

- There are three types of MAC addresses

1. **Unicast**: Single device on the LAN receives it.
2. **Broadcast**: It is delivered to all the hosts in a LAN. (all 48 bits are ones)
   - **FF:FF:FF:FF:FF:FF**
3. **Multicast**: It is received by only a set of devices which have registered for a particular multicast address in a LAN.
   - The lowest bit (**Bit 0**) only is **to be set to 1**



- Multicast IP addresses are mapped to multicast MAC addresses while passing the multicast IP datagram to the Layer 2 (data link layer)
- It prevents multicast packets from being treated as broadcast by the Layer 2, thus reducing network traffic and overhead

Mapping of IP to Ethernet MAC Addresses for Multicast

[Ref: Article on Mapping]

- Multicast Ethernet MAC address has a **25-bit fixed prefix**: (**01:00:5E**).
- The remaining 23 bits out of 48 bits of MAC address is mapped to the lower 23 bits of IP multicast address, leaving out the higher **5 bits** of IP multicast address (**note**: The most significant nibble is fixed (**0b1110**))

Step 1: Take the lower 23 bits of IP multicast (**in blue**)

```
239.5.5.5 = 11101111.00000101.00000101.00000101
```

Step 2: Retain the 24 bits of fixed prefix of Ethernet MAC address (**in red**)

```
multicast MAC prefix is 00000001.00000000.01011110.0xxxxxxx.xxxxxxxx.xxxxxxxx
```

Step 3: Merge both these values to get the final Ethernet MAC address mapped to a specific multicast IP address

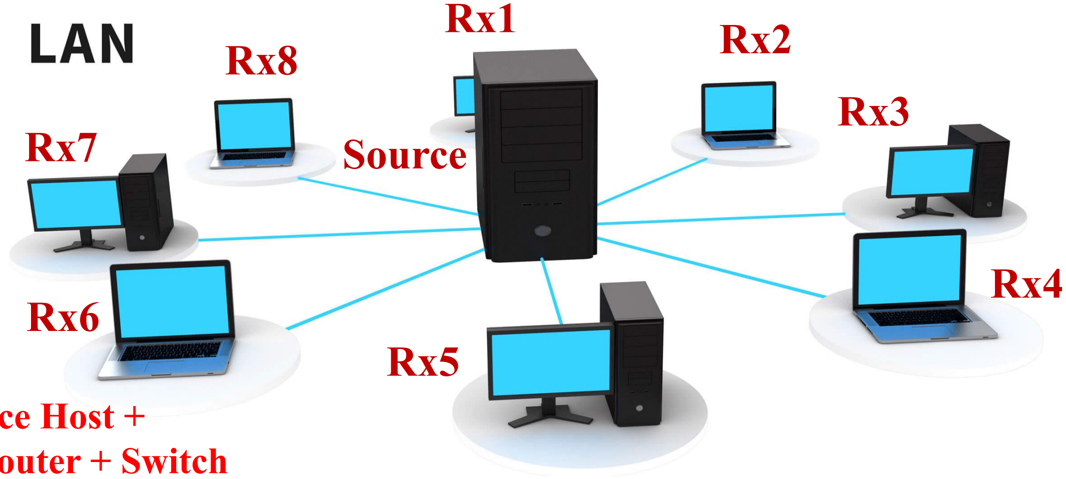
```
Map the last 23 IP bits (in blue) to the MAC prefix (in red)
The result is 00000001.00000000.01011110.00000101.00000101.00000101
```

Note: Since multiple (2^5) IP multicast addresses map to the same Ethernet MAC address, switches check if the IP address inside the packet matches with the intended multicast group, a device has registered for, before accepting a multicast frame and passing it up.

Quiz 1: Multicast within a LAN

Note: Remember IP Multicast packet is converted into a multicast MAC frame by mapping the lower 23 bits of IP Multicast address into Multicast MAC address.

Q: Does Multicast use TCP or UDP? **UDP**



- Assume the source host and all the **registered receiver hosts** of an IP multicast group are all on the same Ethernet LAN.
- How many copies of every IP packet of voice data is sent out by the sender on this Ethernet LAN so that all the eight receivers receive the IP multicast?

ANS: Only one Ethernet MAC Multicast frame per IP Multicast packet of voice data. Since all the receivers on the LAN have registered for that IP Multicast, they all receive the MAC multicast frame sent out by the sender host.

Note: On a switched Ethernet LAN the switch sends out a copy of the frame on all its ports.

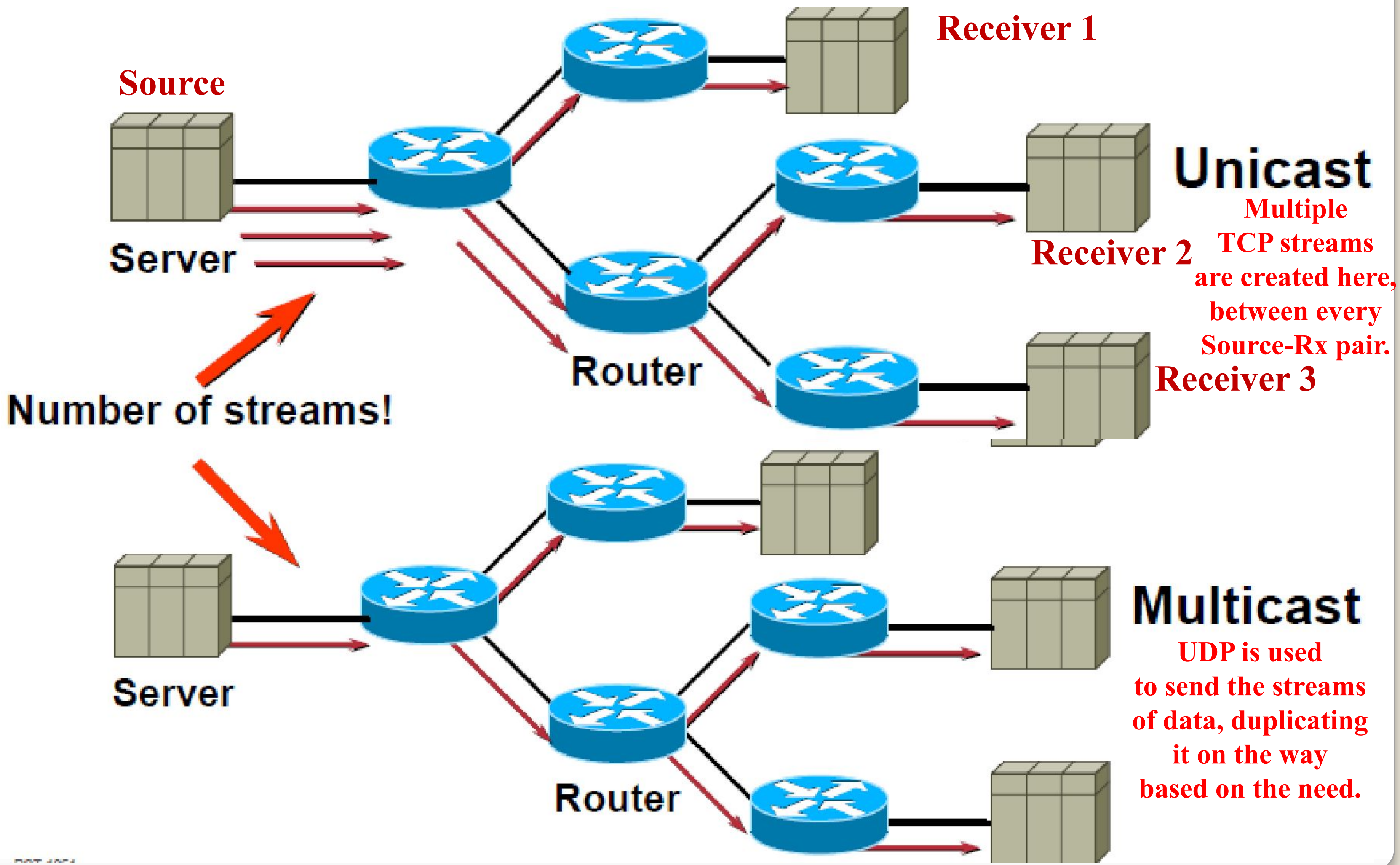
Levels of Conformance

Hosts can be in **three different levels** of conformance with the Multicast specification, according to the requirements they meet.

- **Level 0** is the "**no support for IP Multicasting**" level.
- Lots of hosts and routers in the Internet are in this state, as multicast support is not mandatory in IPv4 (it is, however, in IPv6.)
- Hosts in this level can neither send nor receive multicast packets.
- They must ignore the ones sent by other multicast capable hosts.
- **Level 1** is the "**support for sending but not receiving multicast IP datagrams**" level.
- Thus, note that it is not necessary to join a multicast group to be able to send datagrams to it.
- **Level 2** is the "**full support for IP multicasting**" level.
- Level 2 hosts must be able to both send and receive multicast traffic.
- They must know the way to join and leave multicast groups and to propagate this information to multicast routers.

How does IP Multicast work?

IP Unicast Vs Multicast



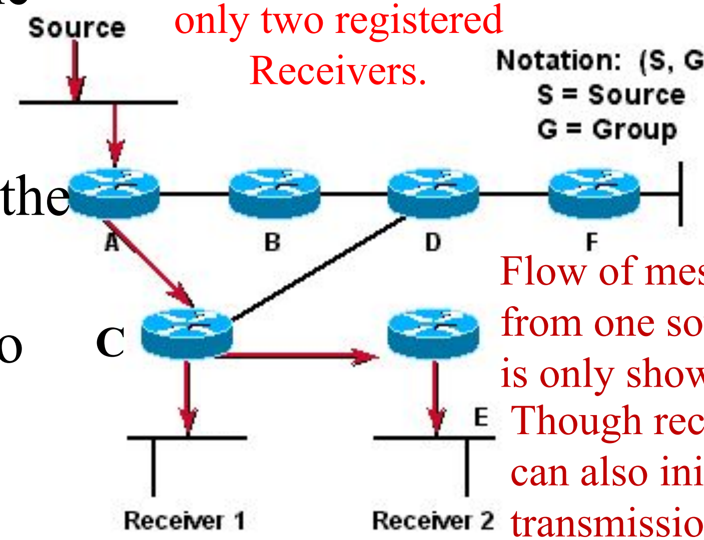
IP Multicast Message Delivery

- Normal IP communication, in which each packet must be addressed and sent to a single host, is not well suited to multicast applications.
- If an application has data to send to a group, it would have to send a separate packet with the identical data to each member of the group.
- This would consume more bandwidth than necessary.
- Furthermore, the redundant traffic (multiple copies of the same data) is not distributed evenly but rather is focused around the sending host.
- And may easily exceed the capacity of the sending host and the nearby networks and routers.
- IP provides an IP-level multicast analogous to the link-level multicast provided by multi-access networks like Ethernet.
- Using IP multicast, instead of sending identical packets to each member of the group, a host sends a single copy of the packet addressed to the group's multicast address.

IP Multicast Message Flow: An Example

- The sending host doesn't need to know the individual unicast IP address of each member of the group because, as we will see, that knowledge is distributed among the routers in the internetwork.
- Similarly, the sending host doesn't need to send multiple copies of the packet.

Assume there are only two registered Receivers.

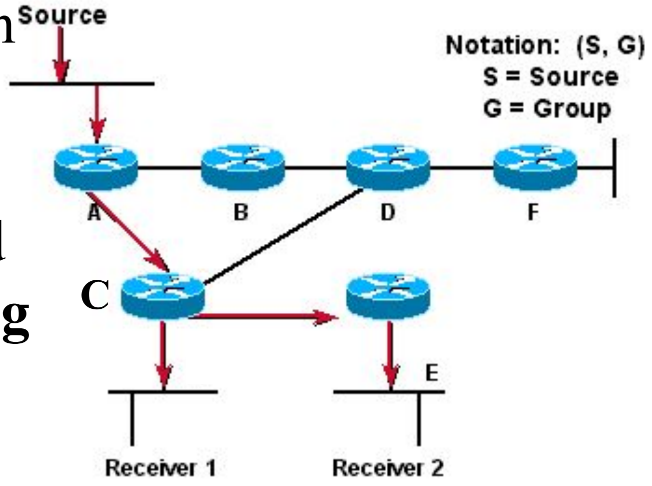


Flow of messages from one source is only shown here. Though receivers can also initiate transmission..

- Because, the routers will make copies whenever they have to forward the packet over more than one link, based on the presence of receivers.
- Compared to using unicast IP to deliver the same packets to many receivers, IP multicast is more scalable.
- Because it eliminates the redundant traffic (packets) that would have been sent many times over the same links, especially those near to the sending host.

Many-to-many One-to-many

- IP's original many-to-many multicast has been supplemented with support for a form of **one-to-many multicast**.
- In this model of one-to-many multicast, called **Source-Specific Multicast (SSM)**, a **receiving host** specifies both a **multicast group** and a specific **sending host**.



- The receiving host would then receive multicasts addressed to the specified group, but only if they are from the specified sender.
- Many Internet multicast applications (e.g., radio broadcasts) fit the SSM model.
- To contrast it with SSM, IP's original many-to-many model is sometimes referred to as **Any Source Multicast (ASM)**.

Any Source Multicast (ASM): Examples

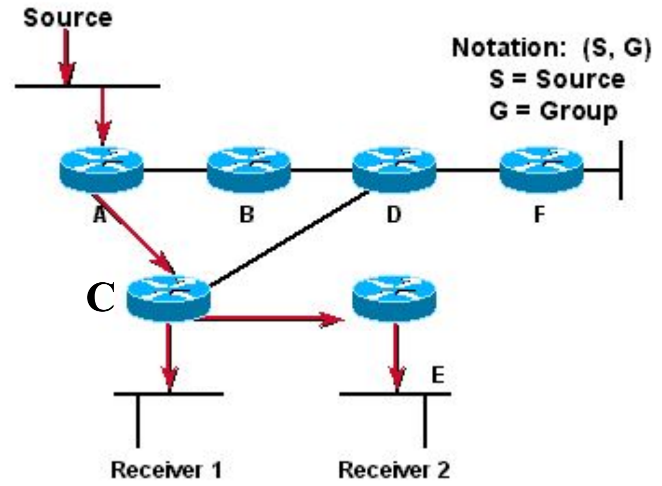
- IPTV (Internet Protocol Television) – Allows multiple sources to provide content.
- Video Conferencing – Participants can send and receive video/audio streams.
- Stock Market Data Feeds – Multiple sources broadcast market data to traders.
- Gaming & Real-Time Applications – Supports dynamic multiplayer environments.

IGMP

Internet Group Management Protocol (**IGMP**) is a network layer protocol (Layer 3) used for managing multicast group memberships in IPv4 networks

Join and Leave Operations

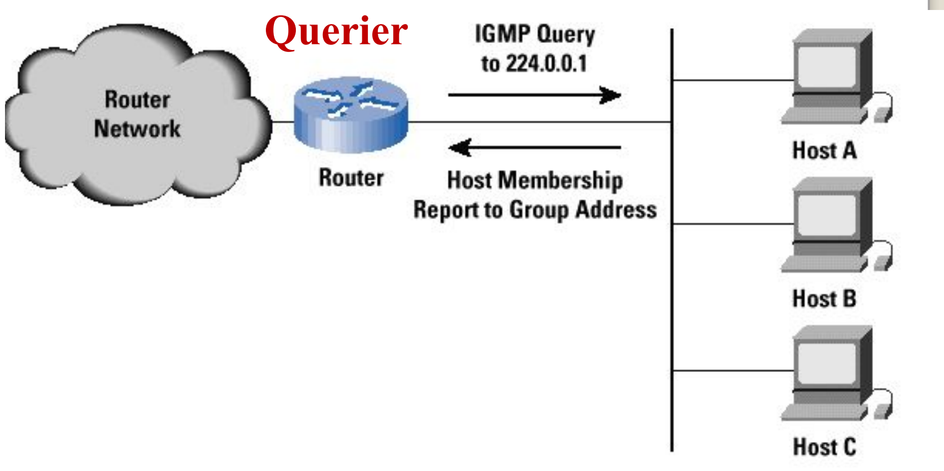
- A host signals its desire to join or leave a multicast group by communicating with its **local router** using a special protocol for just that purpose.
- In **IPv4**, that protocol is the **IGMP**



- In **IPv6**, it is **MLD** **(Multicast Listener Discovery)**
- The router (A here) then has the responsibility of making the multicast behave correctly with regard to that host, by interacting with the Routers on other ASs, designated for this purpose.
- Because a host may fail to leave a multicast group when it should (after a crash or other failure, for example), each router periodically polls its own LAN to determine which groups are still of interest to the attached hosts.

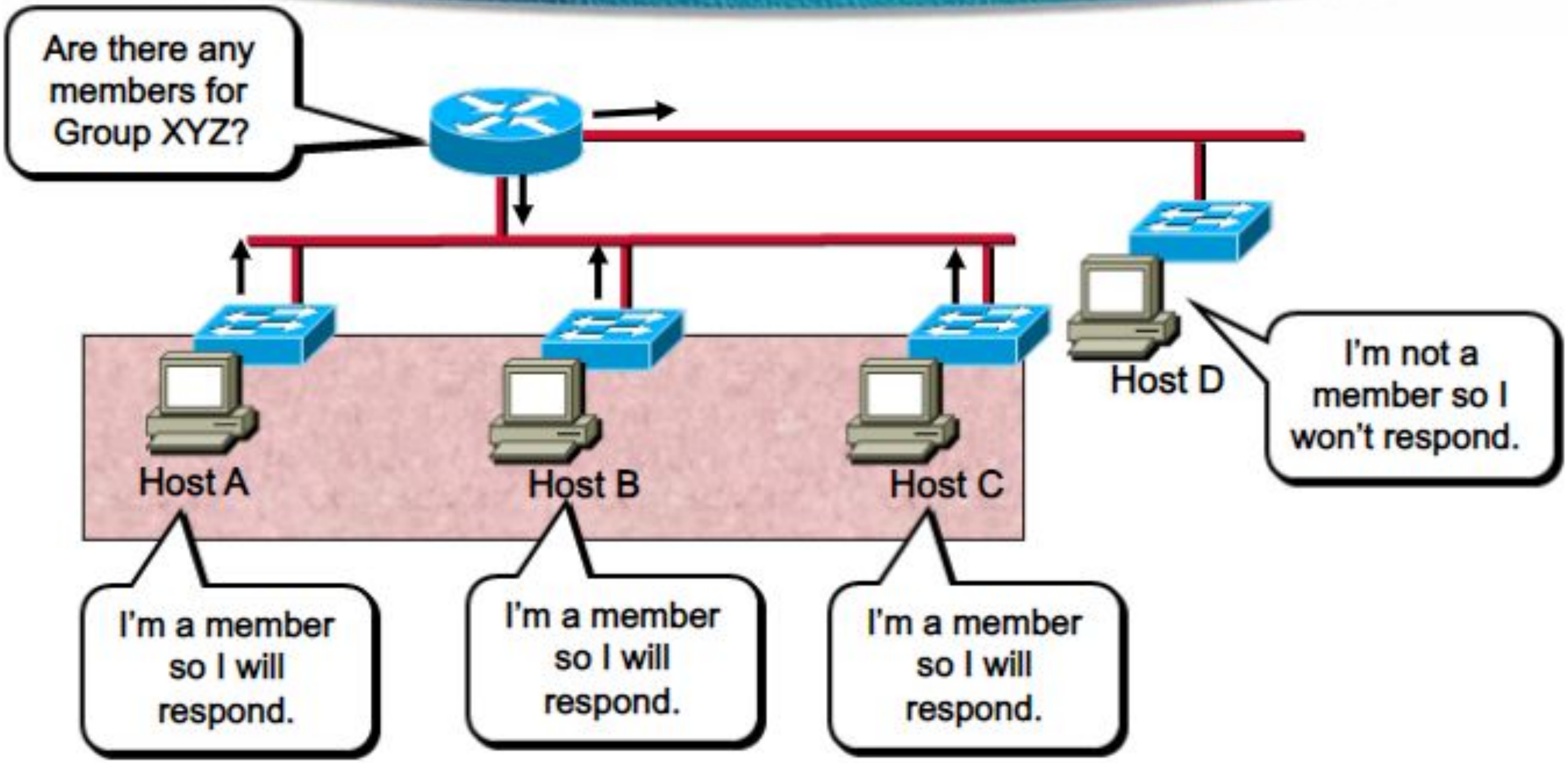
IGMP: Explained

- To participate in IP multicasting, multicast hosts, routers, and multilayer switches must have the **IGMP** operating.
- This protocol defines the **querier** and **host** roles:



- A **querier** is a network device that sends query messages to discover which network devices are members of a given multicast group.
- A **host** is a receiver that sends report messages (in response to query messages) to inform a querier of a host membership.
- A set of queriers and hosts that receive multicast data streams from the same source is called a multicast group.
- Queriers and hosts use IGMP messages to join and leave multicast groups.

IGMP in Action: Example

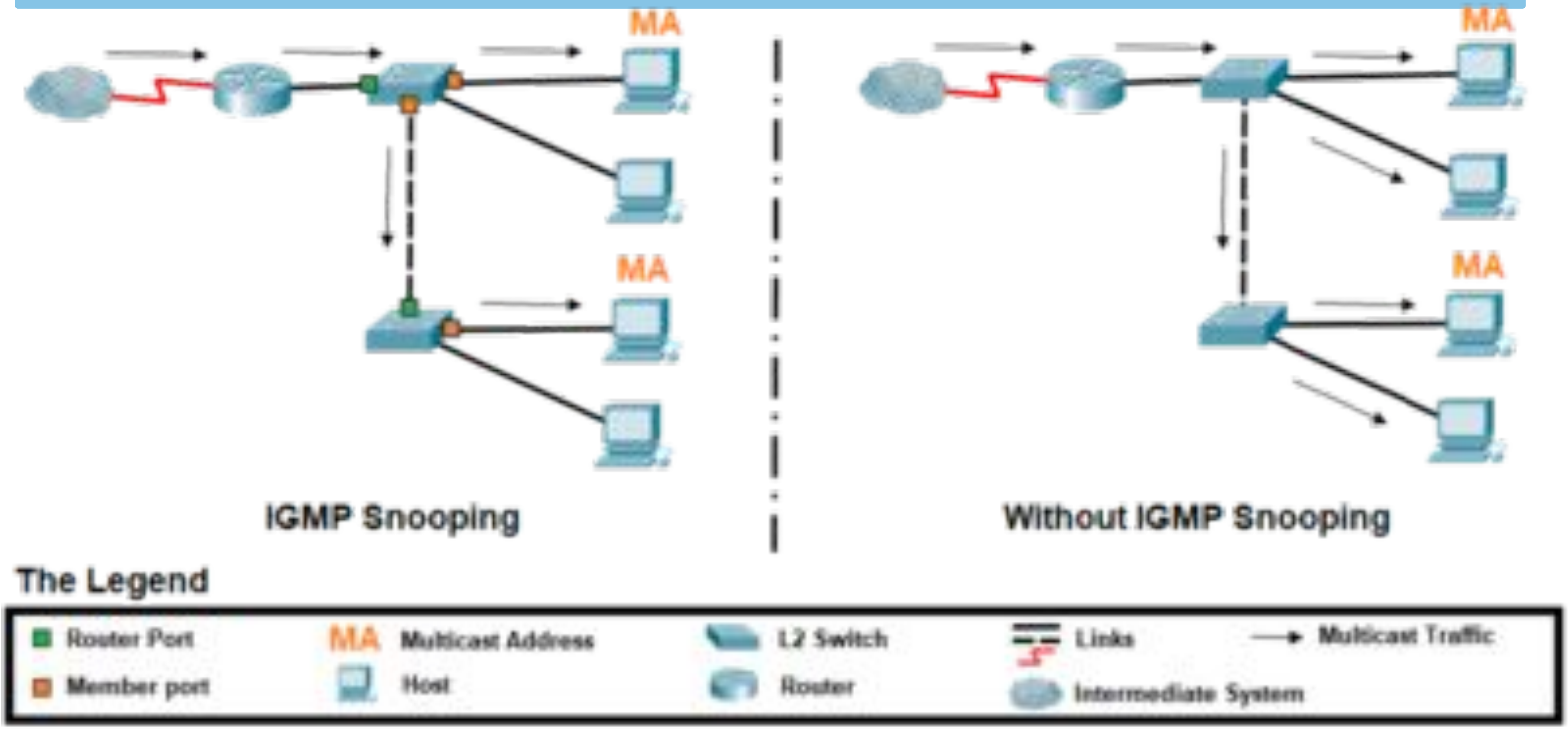


- Multicast uses query and report messages to establish and maintain group membership

IGMP: More Details

- Any host, regardless of whether it is a member of a group, can send to a group.
- However, only the members of a group receive the message.
- Membership in a multicast group is dynamic; hosts can join and leave at any time.
- There is no restriction on the location or number of members in a multicast group.
- A host can be a member of more than one multicast group at a time.
- How active a multicast group is and what members it has can vary from group to group and from time to time.
- A multicast group can be active for a long time, or it can be very short-lived.
- Membership in a group can constantly change.
- A group that has members can have no activity too.

IGMP Snooping by L2 Switches



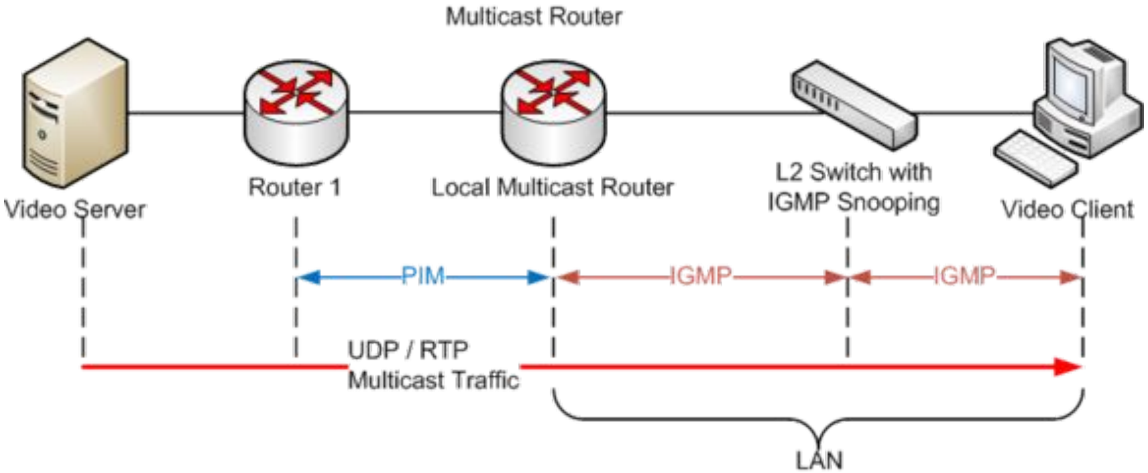
- While the hosts are participating in the IGMP interactions with the routers, switches snoop into the message exchanges and learn and configure their ports based on the mapping between MA and ports.

Snoop: Investigate or look around furtively in an attempt to find out something.

Multicast Routing
DVMRP

Distance Vector Multicast Routing Protocol (**DVMRP**)
is a multicast routing protocol that enables
efficient multicast data distribution in an IPv4 network

IP Multicast: Various Protocols Involved



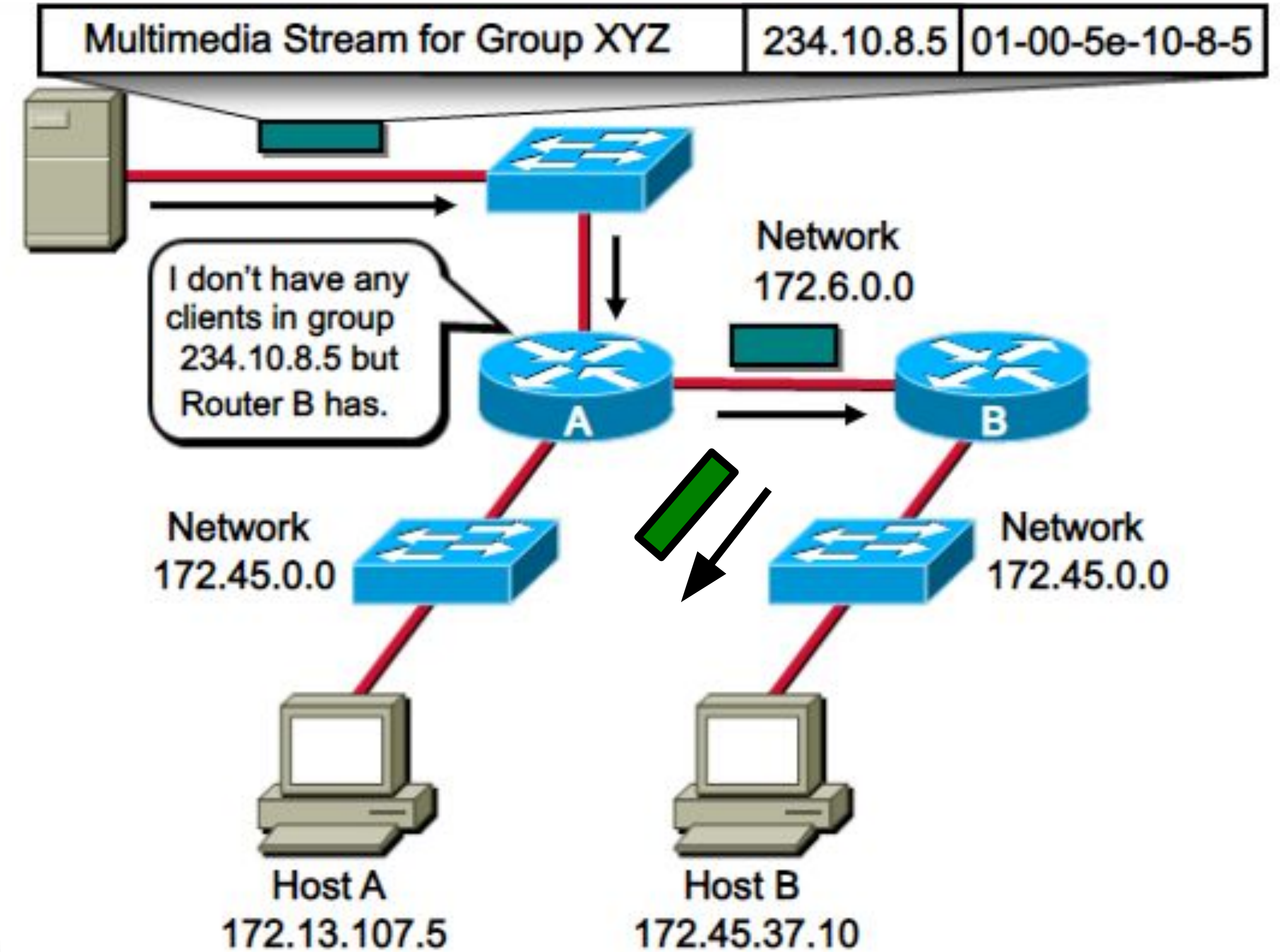
1. The actual video data are sent as **UDP** packets.

2. RTP (Real-time Protocol) is used to enable prioritized delivery of UDP packets by the routers enroute from the sender to the receivers.

- IGMP operates between a host and a local multicast router.
- IGMP operates on the network layer, just the same as other network management protocols like ICMP.
- Switches featuring IGMP snooping derive useful information by observing these IGMP transactions.
- Protocol Independent Multicast (**PIM**) routing protocol is then used between the local and remote multicast routers, to direct multicast traffic from hosts sending multicasts to hosts that have registered through IGMP to receive them.

DVMGRP: Distance vector based IP multicast routing Protocol also used apart from PIM.

IP Multicast Routing: Example



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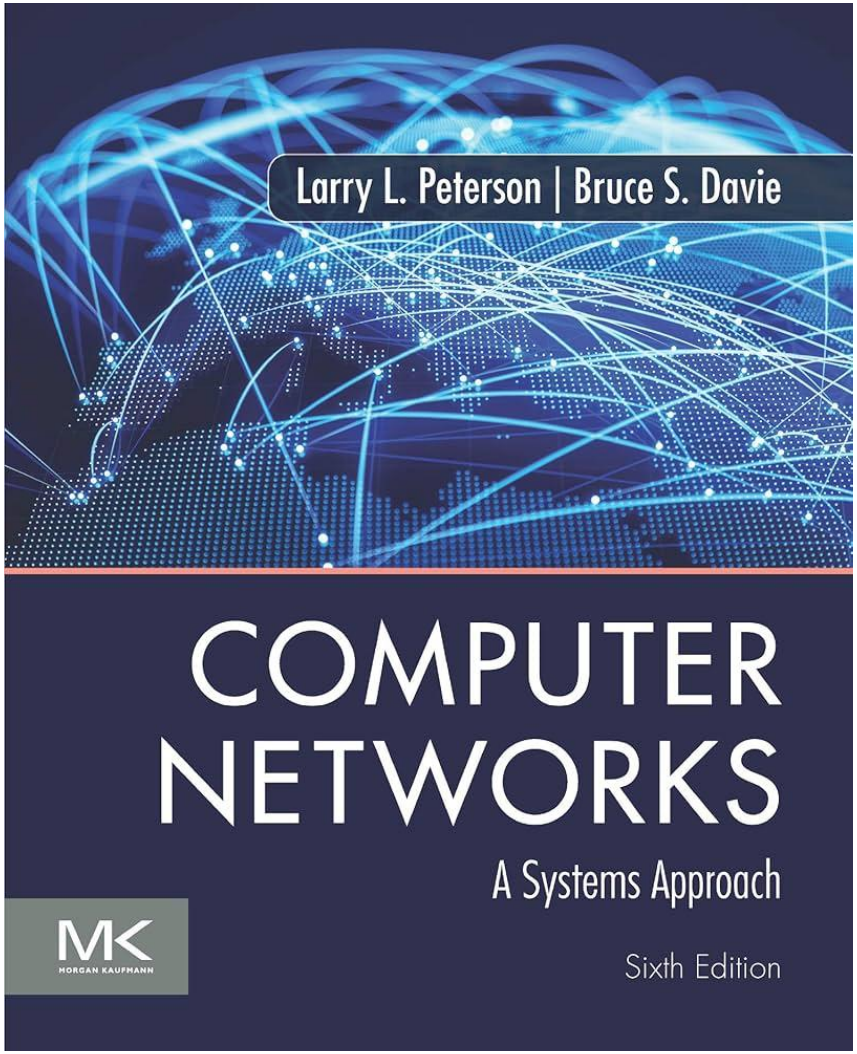
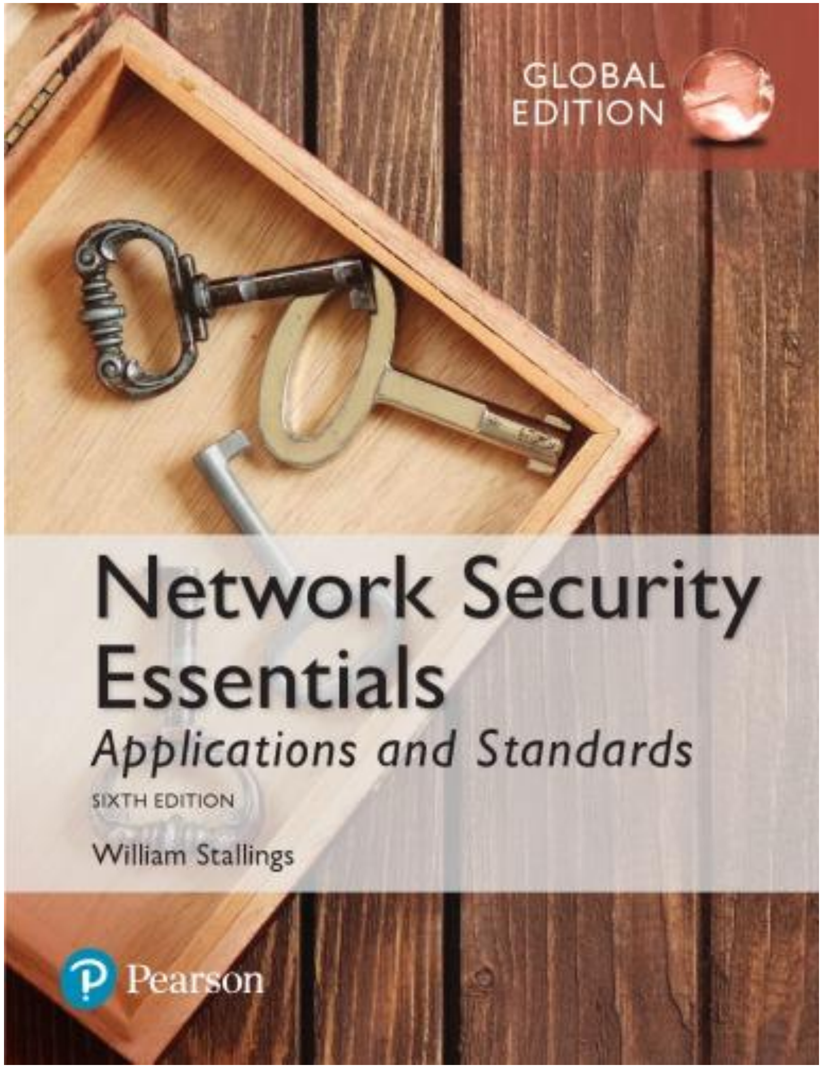
Textbooks

Textbook 1

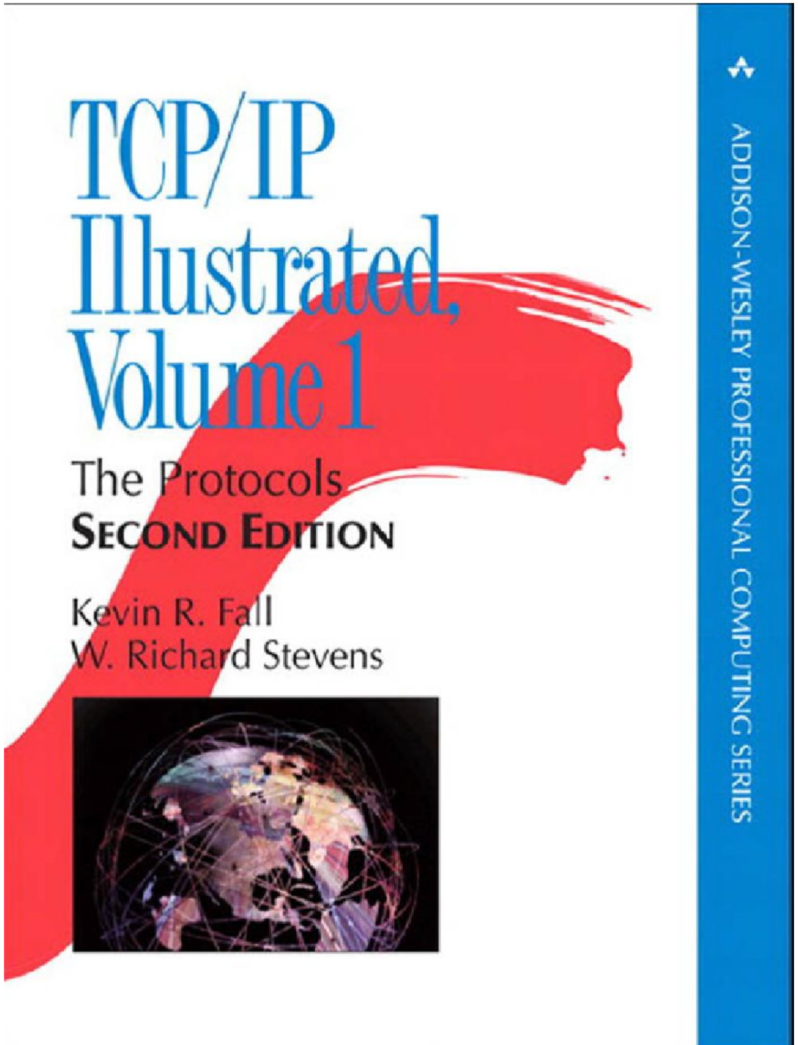


Textbook 2



References

Ref 1



Ref 2

[TCP Congestion Control: A Systems Approach]

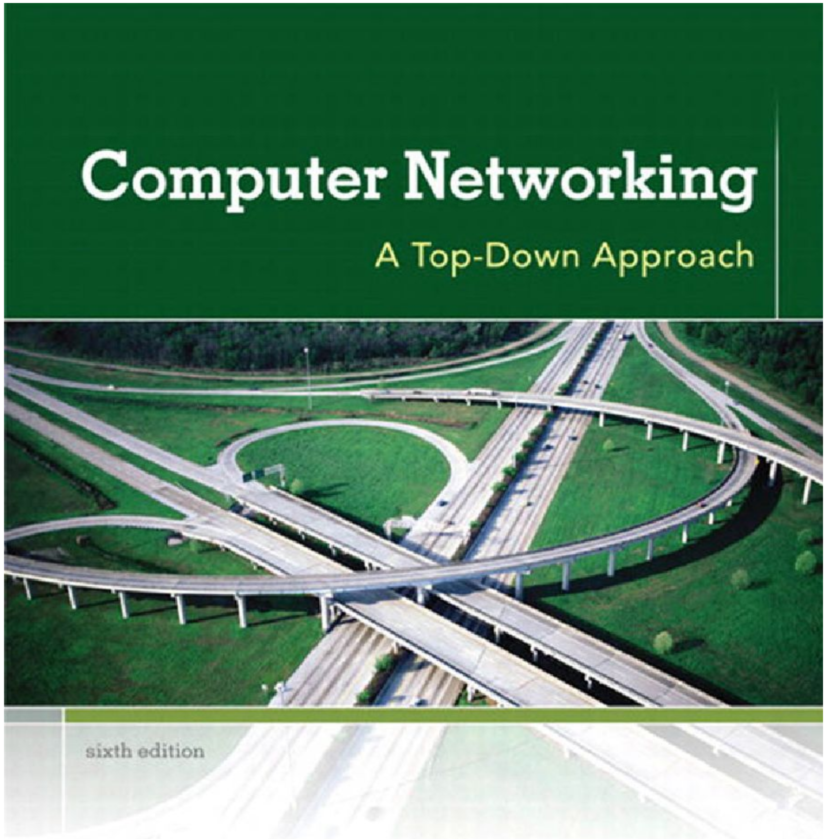
HTTPS://SYSTEMSAPPROACH.ORG

TCP Congestion Control: A Systems Approach

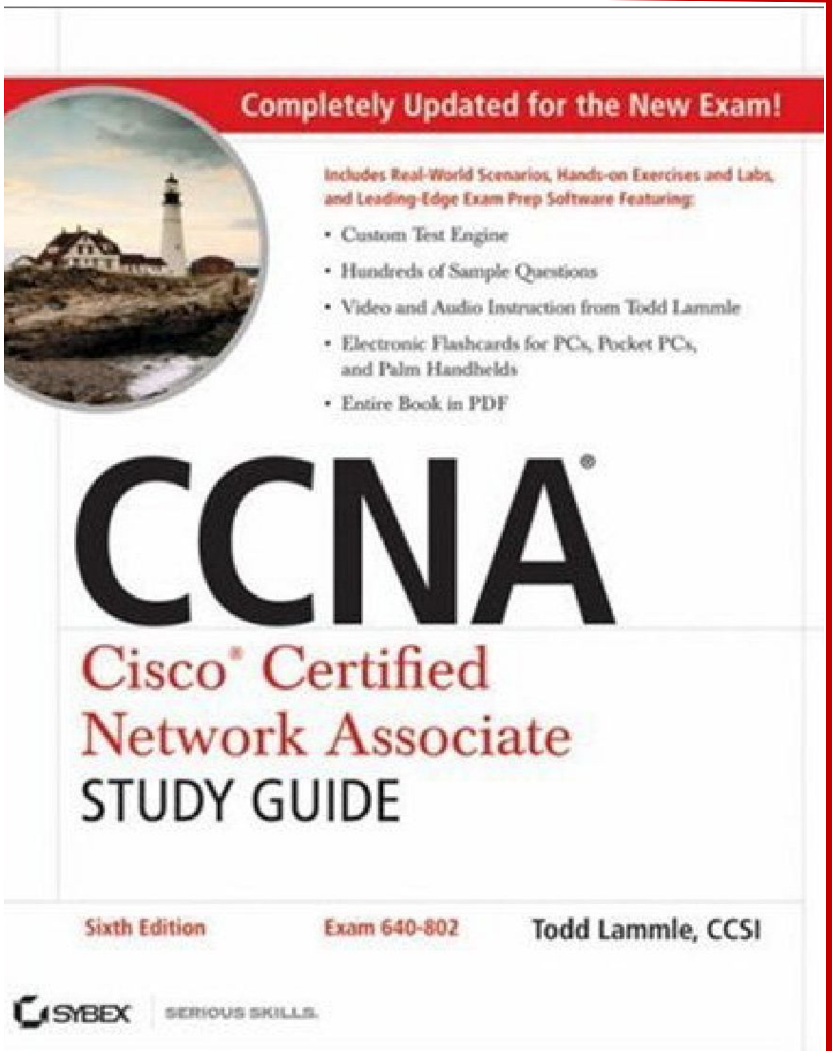
Peterson, Brakmo, and Davie

References

Ref 3



Ref 4



References

Ref 5