CS348: Computer Networks

Broadcast and Multicast Routing

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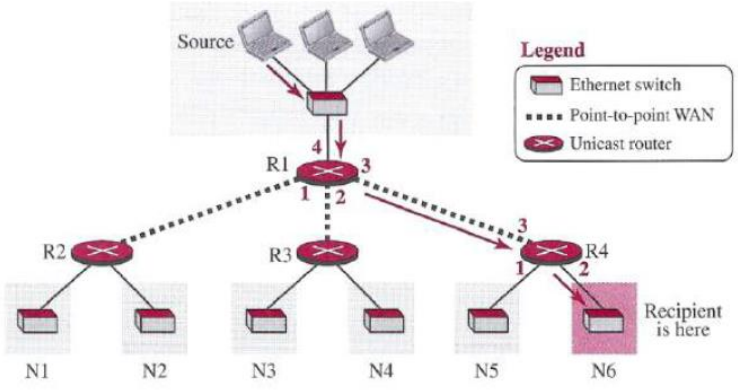
Unicasting, Broadcasting, Multicasting

- In unicast routing, there is one source and one destination node i.e. point-to-point communication
- The relationship between the source and the destination network is one to one.
- Each router in the path tries to forward the packet to one and only one of its interfaces.
- In broadcast routing, the network layer provides a service of delivering a packet sent from a source node to all other nodes in the network
- In multicast routing, a single source node can send a copy of a packet to a subset of the other network nodes.



Unicast Routing

Broadcast Routing Algo.

- Most straightforward way: **N-way-unicast**
  - no new network-layer routing protocol, packet-duplication, or forwarding functionality is needed.
  - **Drawbacks**:
    - *Inefficiency*: As it would be more efficient for the network nodes themselves (rather than just the source node) to create duplicate copies of a packet
    - *Unrealistic assumption*: An implicit assumption of N-way-unicast is that broadcast recipients, and their addresses, are known to the sender.
    - *More overhead* : it would be unwise (at best!) to rely on the unicast routing infrastructure to achieve broadcast.

Broadcast Algorithms:

1. Uncontrolled Flooding
2. Controlled Flooding
3. Spanning Tree Broadcast
4. Etc.

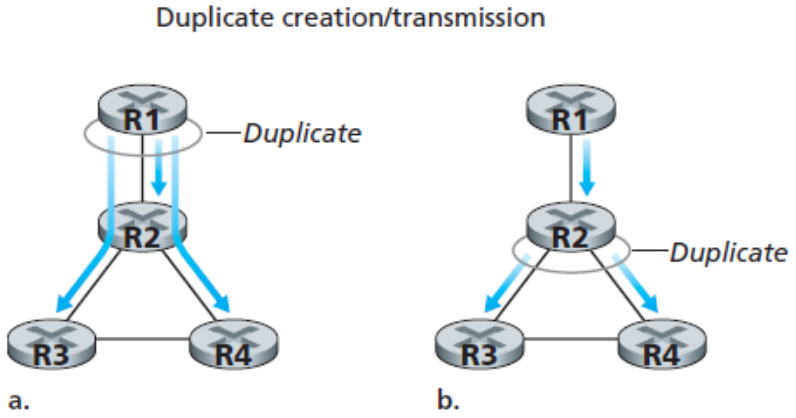


Figure 4.43 ♦ Source-duplication versus in-network duplication

Uncontrolled Flooding

- most obvious technique for achieving broadcast is a flooding
  - Source node sends a copy of the packet to all of its neighbors
  - When a node receives a broadcast packet, it duplicates the packet and forwards it to all of its neighbors (except the neighbor from which it received the packet).
  - this scheme will eventually deliver a copy of the broadcast packet to all nodes if they are connected
- Disadvantages:
  - (1) If the graph has cycles, then one or more copies of each broadcast packet will cycle indefinitely
  - (2) When a node is connected to more than two other nodes, then it could result in broadcast storm (resulting from the endless multiplication of broadcast packets)

Controlled Flooding

- key to avoiding a broadcast storm
  - for a node to judiciously choose when to flood and when not to flood a packet
  - i.e. controlled way of flooding

- Sequence-number-controlled flooding
  - a source node puts its address as well as a broadcast sequence number into a broadcast packet
  - Each node maintains a list of the source address and sequence number of each broadcast packet it has already received, duplicated, and forwarded
  - When a node receives a broadcast packet, it first checks in this list.
    - If found, then dropped the packet
    - If not found, then the packet is duplicated and forwarded to all the node's neighbors (except the node from which the packet has just been received)

Cont…

- Reverse path forwarding (RPF) / reverse path broadcast (RPB).
  - When a router receives a broadcast packet with a given source address,
    - it transmits the packet on all of its outgoing links (except the one on which it was received)
      - » only if the packet arrived on the link that is on its own shortest unicast path back to the source.
  - Otherwise, the router simply discards the incoming packet
  - RPF does not use unicast routing to actually deliver a packet to a destination, nor does it require that a router know the complete shortest path from itself to the source.
  - RPF need only know the next neighbour on its unicast shortest path to the sender

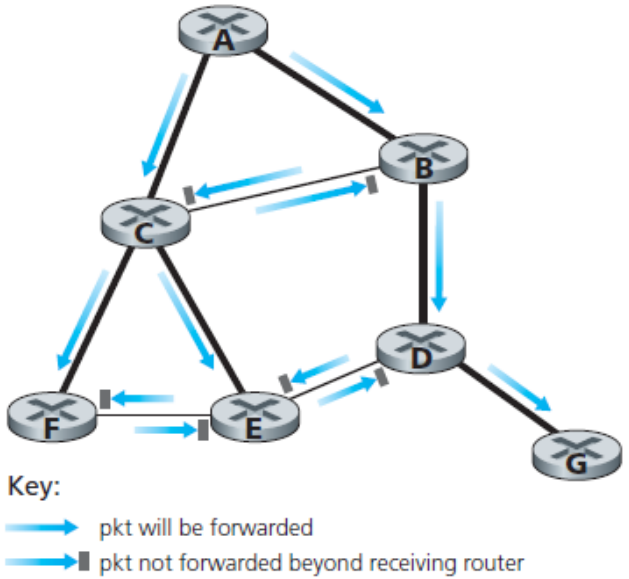


Figure 4.44 ♦ Reverse path forwarding

Spanning-Tree Broadcast

- While sequence-number-controlled flooding and RPF avoid broadcast storms,
  - they do not completely avoid the transmission of redundant broadcast packets

- In this figure, nodes B, C, D, E, and F receive either one or two redundant packets.

- Solution: **spanning tree** — a tree that contains each and every node in a graph

- So, first construct a spanning tree.
- When a source node wants to send a broadcast packet,
  - it sends the packet out on all of the incident links that belong to the spanning tree.

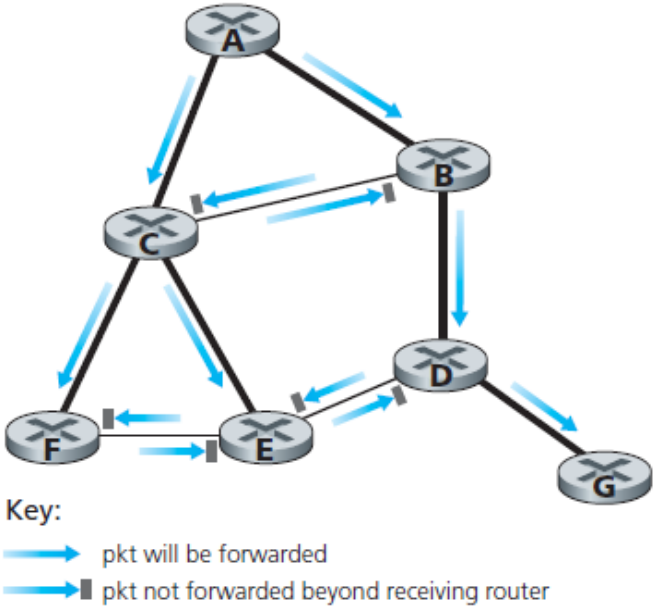


Figure 4.44 ♦ Reverse path forwarding

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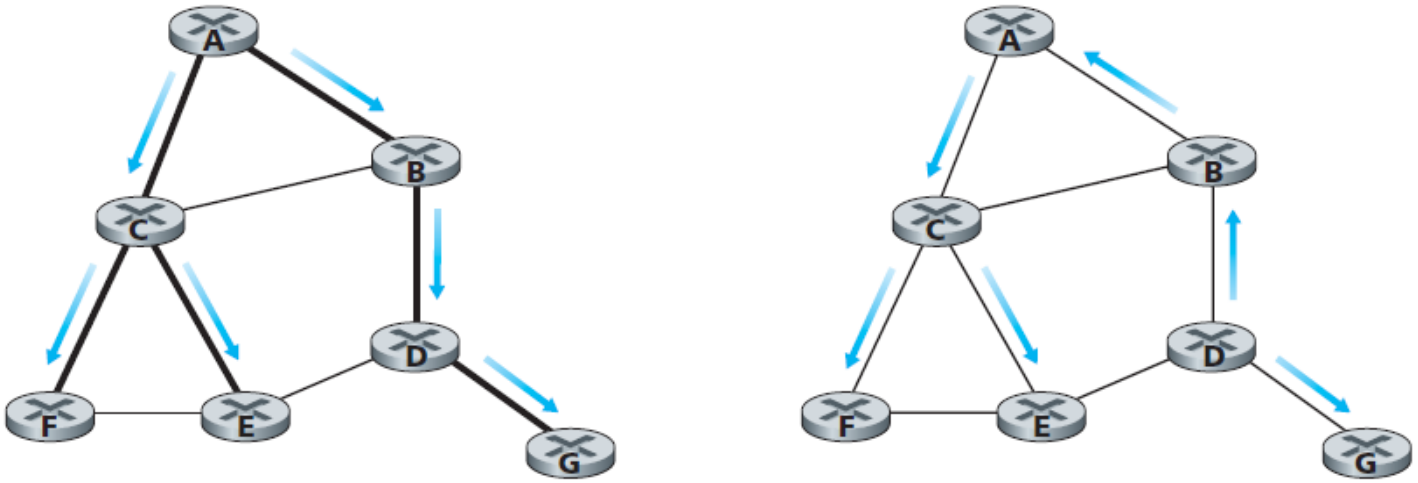


a. Broadcast initiated at A

b. Broadcast initiated at D

Figure 4.45 ♦ Broadcast along a spanning tree

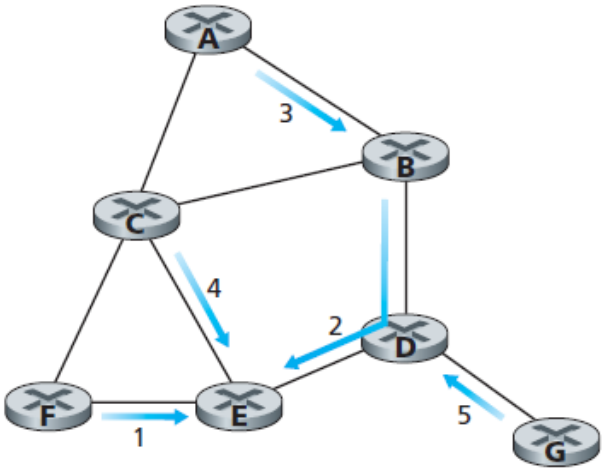
- Not only does spanning tree eliminate redundant broadcast packets, but once in place, the spanning tree can be used by any node to begin a broadcast
- In this algo, a node need not be aware of the entire tree; it simply needs to know which of its neighbors in *G* are spanning-tree neighbors.

Spanning-Tree Creation

- The main complexity associated with the spanning-tree based broadcast approach is the creation and maintenance of the spanning tree.

- One simple algorithm is center-based approach
  - At first a center node or a core is defined
  - Each nodes then unicast tree-join messages addressed to the center node
  - A tree-join message is forwarded using unicast routing toward the center
    - until it either arrives at a node that already belongs to the spanning tree or arrives at the center.

Considering node E as core

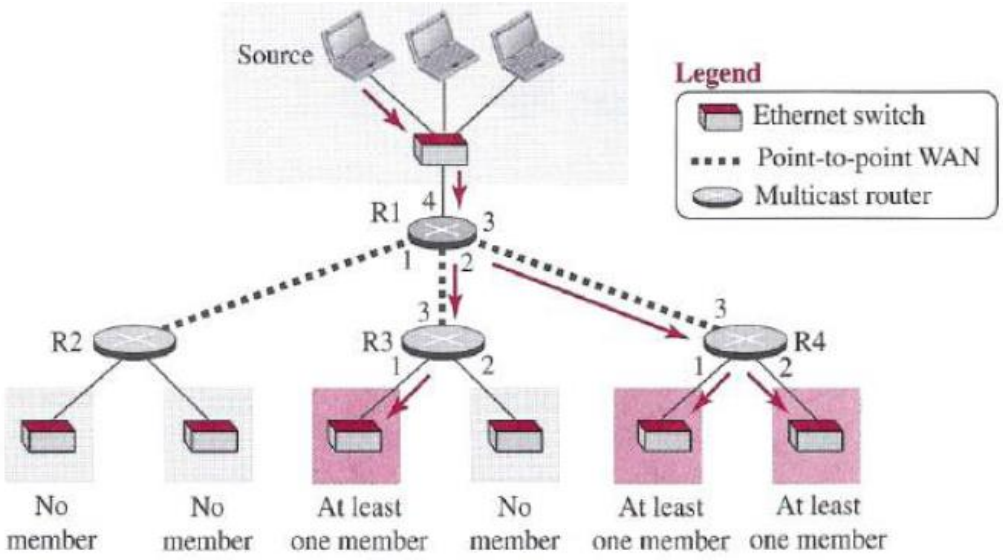


a. Stepwise construction of spanning tree

Practical Use in Practice:
A form of sequence-number-controlled flooding is also used to broadcast link-state advertisements (LSAs) in the OSPF routing algorithm

Multicasting

- There is one source and a **group** of destinations, but not all.
- The relationship is one to **many**.
- The source address is a unicast address,
- but the destination address is a group address,
  - in which there is at least one member of the group that is interested in receiving the multicast datagram.



Few Applications:

- bulk data transfer to a group
- streaming continuous media
- shared data applications (e.g. teleconferencing)
- Web cache updating
- interactive gaming

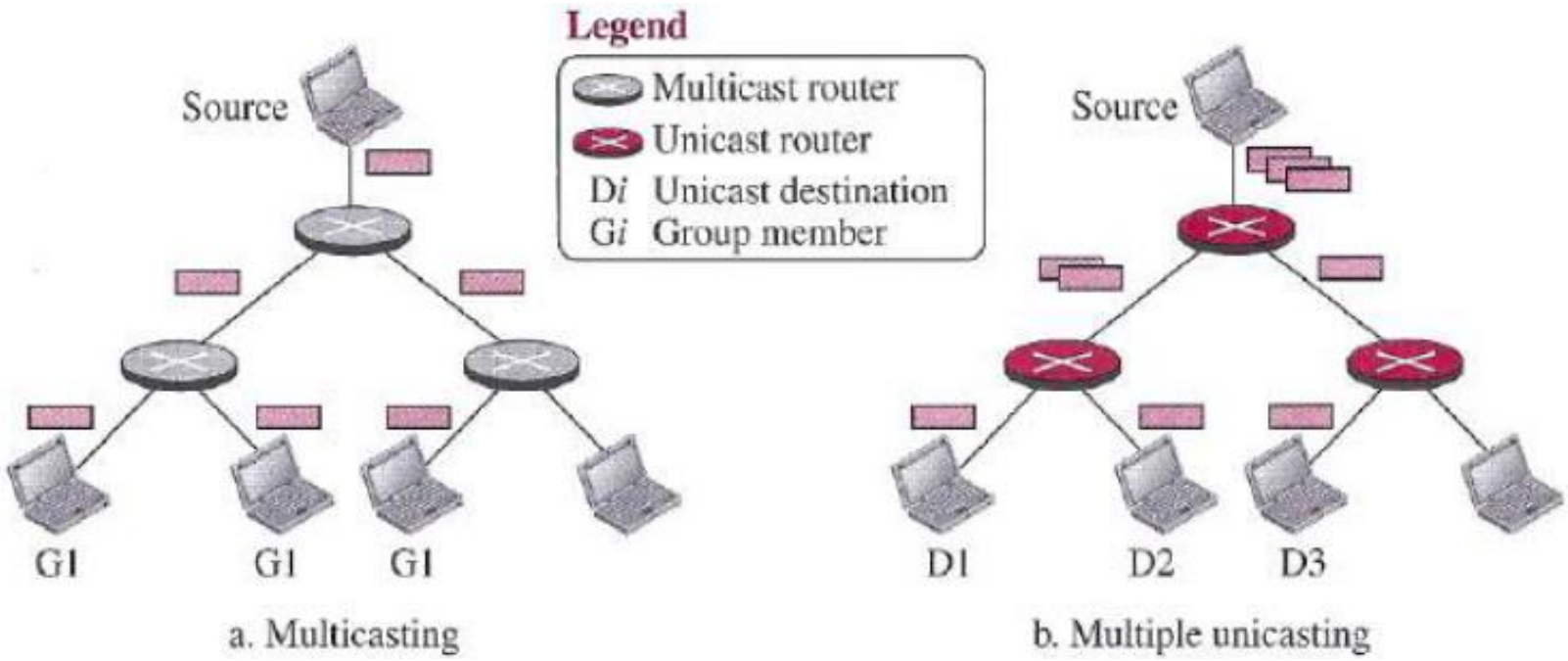
Multicast vs Multiple Unicast

- **Multicasting**
  - starts with a single packet from source that is duplicated by the routers.
  - The destination address in each packet is the same for all duplicates.
  - Only a single copy of the packet travels between any two routers.
  - IP Multicast uses UDP for communication, therefore it is unreliable.

- **Multiple Unicasting**
  - several packets start from the source.
  - If there are three destinations, the source sends three packets, each with a different unicast destination address.
  - Note that there may be multiple copies traveling between two routers.

Cont…

- Example:
  - Group Email: When a person sends an e-mail message to a group of people, this is multiple unicasting.
  - Teleconferencing: A group of workstations form a multicast group such that a transmission from any member is received by all other group members.



Why Multicasting?

- Two main reasons:
  - Multicasting requires less bandwidth than multiple unicasting.
  - In multiple unicasting, the packets are created by the source with a relative delay between packets.
  - In multicasting, there is no delay because only one packet is created by the source.

- Why group e-mail is multiple unicast?
  - Multicast involves a subscription from the receiver's side,
  - But, multiple unicast is a decision from the sender's side.
  - Usually, sender manage the group of multiple unicast,
  - But, a receiver is associated with a multicast group.

Multicasting Challenges

- two important problems
  - how to identify the receivers of a multicast packet
  - how to address a packet sent to these receivers

- Solution:
  - a multicast packet is addressed using address indirection
    - i.e., a single identifier is used for the group of receivers
  - The group of receivers associated with such address is referred to as a multicast group.
    - IGMP is used to create and maintain multicast groups

Multicast Address

- In IP datagram, we can only write one destination address.
- So, we need **multicast address** for sending the datagram to many destinations.
- a multicast address is an **identifier** for a group.
- If a new group is formed with some active members, an authority can assign an unused multicast address to this group to uniquely define it
- A router / a destination host needs to **distinguish** between a unicast and a multicast datagram.
- IPv4 assigns a block of addresses for this purpose
  - In classful addressing, all of class D was composed of these addresses;
  - In classless addressing, it is referred to as the block 224.0.0.0/4 (i.e., 224.0.0.0 - 239.255.255.255).

Delivery at Datalink Layer

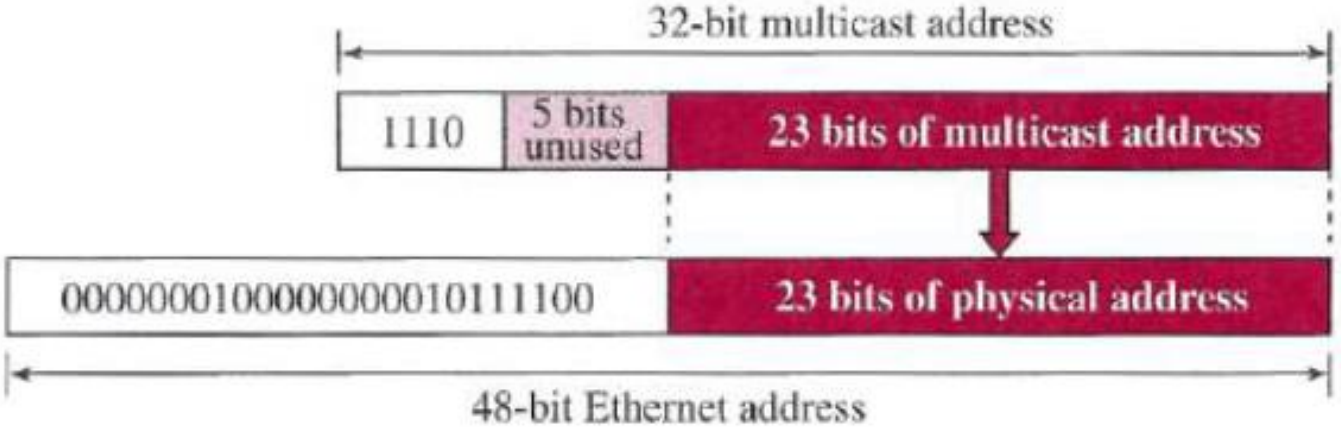
- In multicasting, the delivery at the Internet level is done using multicast IP addresses
- But, data-link layer multicast addresses are also needed to deliver a multicast packet encapsulated in a frame.
- Address Resolution Protocol (ARP) cannot help in finding multicast MAC address
- Solution for two scenario:
  - Network with Multicast Support
  - Network with No Multicast Support

Cont…

Case 1: Network with Multicast Support

Most LANs (e.g. Ethernet) support physical multicast addressing.

If the first 25 bits in an Ethernet address are
0000 0001 0000 0000 0101 1110 0
this identifies a physical multicast address for the TCP/IP protocol.



- An Ethernet multicast physical address is in the range
  01:00:5E:00:00:00 - 01:00:5E:7F:FF:FF

Cont…

- ***Example***:

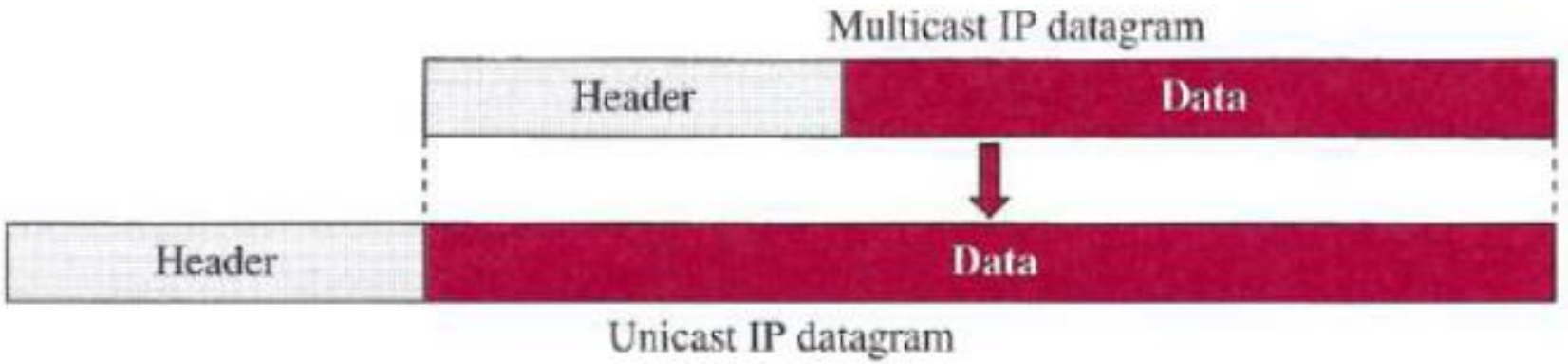
Change the multicast IP address 232.43.14.7 to an Ethernet multicast physical address.

- We can do this in two steps:
  - We write the rightmost 23 bits of the IP address in hexadecimal.
  - Then subtracting 8 from the leftmost digit if it is greater than or equal to 8.
  - In our example, the result is 2B:OE:07
  - We add the result of part a to the starting Ethernet multicast address, which is 01:00:5E:00:00:00.The result is 01:00:5E:2B:OE:07

Cont…

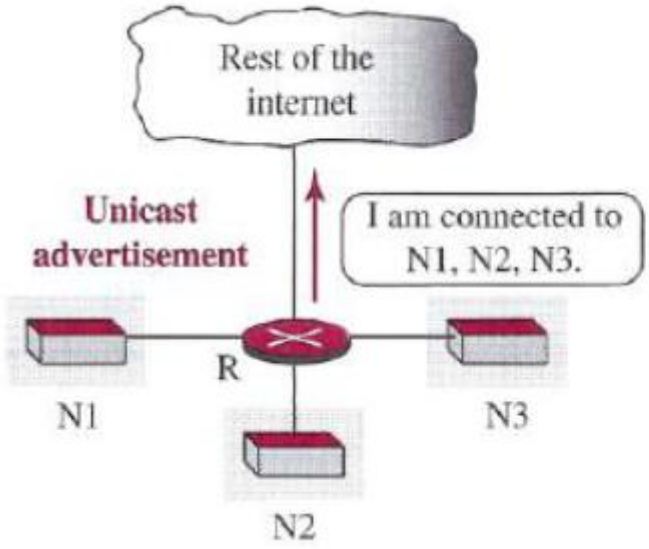
Case 2. Network with No Multicast Support

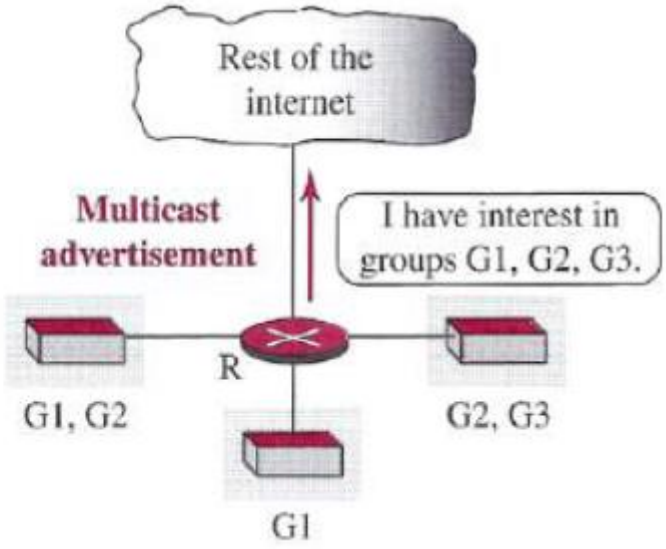
- Most WANs do not support physical multicast addressing
- To send a multicast packet through these networks, a *tunneling* is used
- In tunneling, the multicast packet is encapsulated in a unicast packet and sent



Collecting Information about Groups

- Creation of forwarding tables in both unicast and multicast routing involves two steps:
  - A router needs to know to which destinations it is connected.
  - Each router needs to propagate information obtained in the first step to all other routers so that each router knows to which destination each other router is connected





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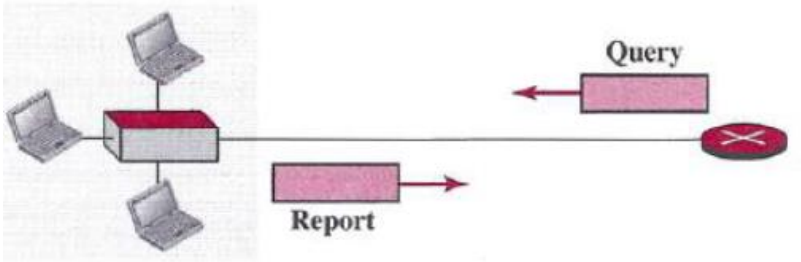
- In **unicast routing**, the collection of the information in the first step is automatic
- Each router knows to which network it is connected, and the prefix of the network (in CIDR) is what a router needs.
- In **multicast routing**, the collection of information in the first step is not automatic.
- Because,
  - a router does not know which host in the attached network is a member of a particular group;
  - membership in the group does not have any relation to the prefix associated with the network.
  - the membership is not a fixed attribute of a host;
  - a host may join some new groups and leave some others even in a short period of time.
- For unicasting, the router needs no help to collect;
- but for multicasting, it needs the help of another protocol namely Internet Group Management Protocol (IGMP)

IGMP

- IGMP: Internet Group Management Protocol
- IGMP messages, like ICMP messages, are carried (encapsulated) within an IP datagram.
- IGMP uses three messages: Query, Report, Leave
- A **query** message is periodically sent by a router to all hosts attached to it to ask them to report their interests about membership in groups.
- A **report** message is sent by a host as a response to a query message.
- After a router has collected membership information from the hosts and other routers at its own level in the tree, it can propagate the information to the router located in a higher level of the tree.
- **Leave** group message is used to inform its leaving. This message is optional.



Multicast Forwarding

- a router needs to make a decision to forward a multicast packet

a. Destination in unicasting is one

b. Destination in mulicasting is more than one

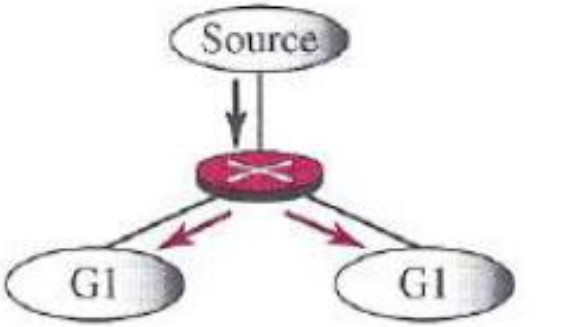
- In unicast communication, the destination address of the packet defines one single destination.
- So, forwarded through **one interface**.

- In multicast communication, the destination of the packet defines one group, but that group may have more than one member in the internet.
- So, forwarded through **many interfaces**.

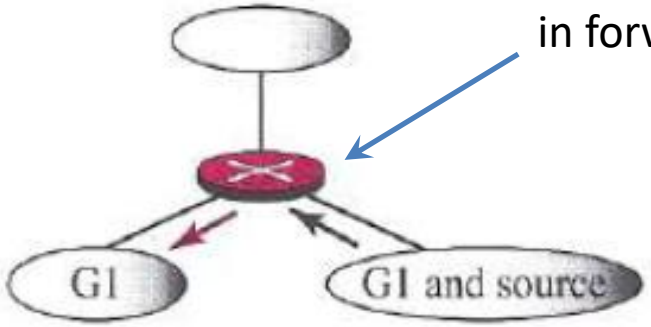
Cont…

- Forwarding decisions in unicast communication depend only on the destination address of the packet.

- Forwarding decisions in multicast communication **depend on both** the destination and the source address of the packet.



a. Packet sent out of two interfaces



b. Packet sent out of one interface

Multicast Routing Algorithms

- **Goal of multicast routing**: need to create routing trees to optimally route the packets from a source to the destinations belonging to the multicast group

  - Source-Based Tree Approach
    - each router needs to create a separate tree for each source-group combination.
    - In each tree, the corresponding source is the root, the members of the group are the leaves, and the router itself is somewhere on the tree.

  - Group-Shared Tree Approach
    - we designate a router to act as the dummy source for each group.
    - The designated router (called as *core* router) acts as the representative for the group.
    - Any source that has a packet to send to a member of that group
      - First, sends it to the core router (unicast communication) and
      - Then the core router is responsible for multicasting.

Thanks!