Module 4
(Lecture – 8)

(Network Layer: Router architecture; Internet Protocol (IP) - Forwarding and Addressing in the Internet; Routing algorithms - Link-state routing, Distance vector routing, Hierarchical routing; Routing in the Internet - RIP, OSPF, BGP; Broadcast & multicast routing; ICMP; Next Generation IP - IPv6)

Dr. Nirnay Ghosh

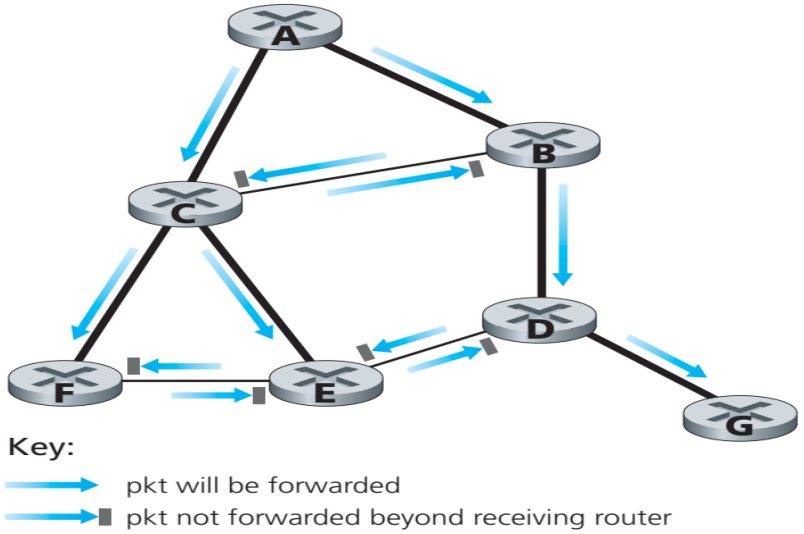
Assistant Professor

Department of Computer Science & Technology

IIEST, Shibpur

Broadcast Routing: Controlled Flooding

- Sequence-number-controlled Flooding
  - Source node puts its address as well as a broadcast sequence number into the packet
  - Forwards the packet to all of its neighbors
  - Each node maintains a list of the source address and the sequence of the broadcast packet it has received, duplicated, and forwarded
  - On receiving a broadcast packet, the node checks its list
  - If the packet is in its list, it is dropped
  - Else, it is duplicated and forwarded to all of its neighbors (except the one from which the packet has arrived)
- Gnutella (P2P application) uses a time-to-live (TTL) field to limit the number of hops over which a flooded query will be forwarded
  - TTL field is decremented at each node – limited scope flooding

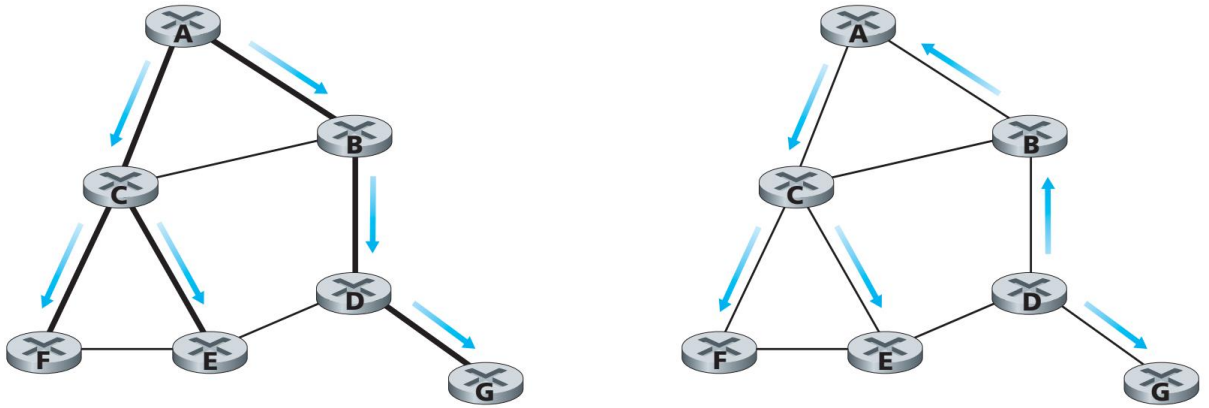


Reverse Path Forwarding

- Reverse Path Forwarding (RPF)
  - Router checks if the received broadcast packet has arrived on the link that is on its own least-cost (shortest) unicast path back to the source
  - If so, the packet is transmitted on all of its outgoing link (except the one on which it is received) – else it is simply discarded
  - Underlying assumption: router will either receive or has already received copies of packets on the link that is on its least-cost (shortest) path back to the source
  - RPF does not use unicast routing - does not require the router to know the complete least-cost (shortest) path back to the sender
  - RPF needs to know only the next neighbor on its unicast shortest path to the sender

Broadcast Routing: Spanning-Tree Broadcast

- Sequence-number-controlled Flooding & RPF: does not completely avoid the transmission of redundant broadcast packets
- Ideal scenario: every node should receive only one copy of the broadcast packet
- If broadcast packets are forwarded only along the least-cost (shortest) unicast paths, each node will receive one copy of the packet
  - The resulting tree: Spanning tree

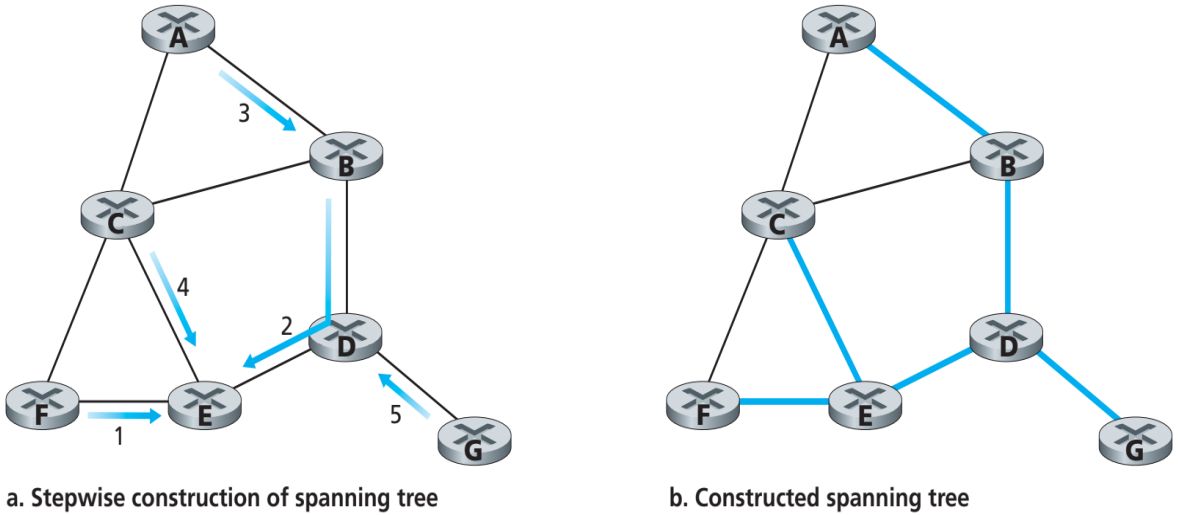


Broadcast along a Spanning Tree

- Broadcast mechanism
  - Source node sends the broadcast packet out on all of the incident links that belongs to the spanning tree
  - Receiving node forwards the packet to all its neighbors in the spanning tree (except the neighbor from which it received the packet)
  - Node need not be aware of the entire tree – need to determine which of its neighbors in the network *G* are spanning-tree neighbors

Broadcast Routing: Spanning-Tree Broadcast

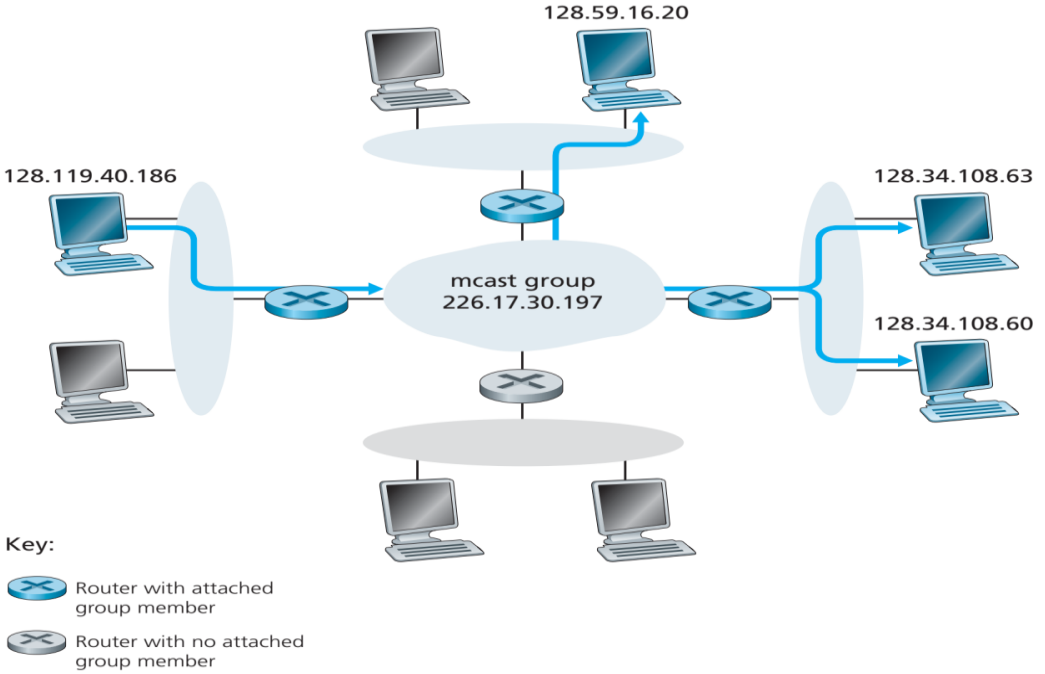
- Construction of the Spanning Tree: Center-based Approach
- A center node (rendezvous point or a core) is defined
- Nodes unicast tree-join messages to the center node
- Tree-join message: forwarded using unicast routing towards to the center
  - Arrives either at a node that already belongs to the spanning tree or arrives at the center
- Path that the tree-join message has followed defines the branch of the spanning tree between the edge node that initiated the tree-join message and the center
  - Enables grafting of a new path onto the existing spanning tree



Center-based Construction of a Spanning Tree

Multicast Routing

- A multicast packet is delivered to only a subset of network nodes
- Typical network applications requiring multicast routing are:
  - Bulk data transfer (e.g., transfer of software upgrade from a software developer), Streaming continuous media, Shared data application, data feeds, Web cache updating, and interactive gaming
- Two challenges in multicast communication
  - How to identify the receivers of a multicast packet?
  - How to address a packet sent to these receivers?
- Addressing a multicast packet: address indirection
  - Single identifier (e.g., 226.17.30.197): used for a group of receivers (e.g., 128.59.16.20, 128.119.40.186, 128.34.108.63, 128.34.108.60)
  - Copy of the packet addressed to the group using a single identifier is delivered to all of the multicast receivers associated with that group



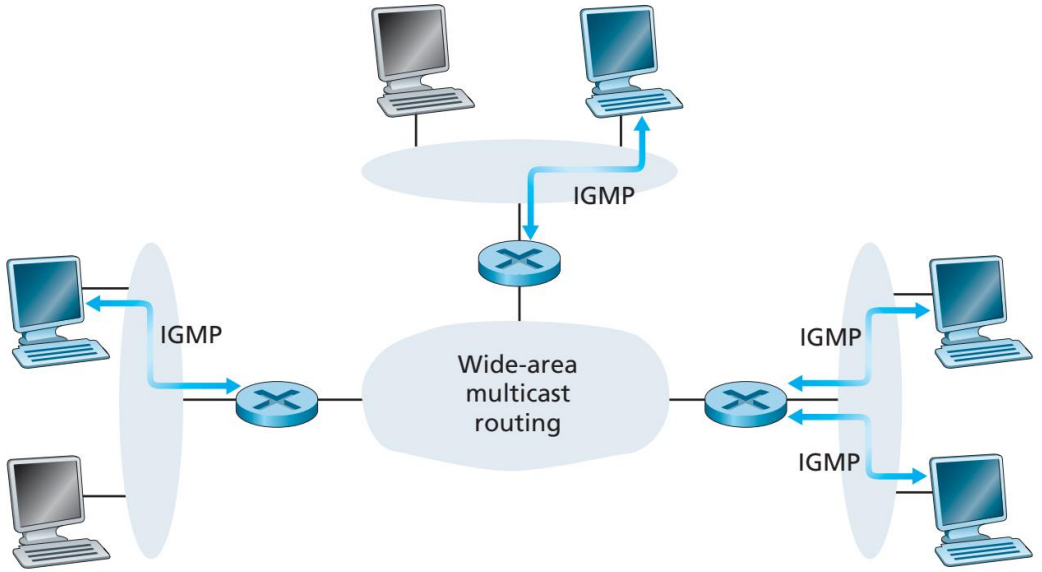
A Multicast Group

Class D Multicast IP Address

- Class D multicast IP address (multicast group)
  - Represents group of receivers in the Internet
  - Network portion: not applicable
  - Range of the first byte (8-bits): 224 to 239

Multicast Routing: Internet Group Management Protocol (IGMP)

- Operates between a host and its direct attached router
- Provides the means for a host to join a specific multicast group
- Three messages used in IGMP: encapsulated within an IP datagram (IP protocol number = 2)
  - *membership_query*: message sent by the router to all hosts on an attached interface – determines the set of all multicast groups that they have joined
  - *membership_report*: response from the hosts – can also be generated by a host when an application first joins a multicast group
  - *leave_group*: optional message sent by the hosts on leaving any multicast group
    - If message is not sent, the router infers that the host has left the multicast group if it no longer responds to a membership query message within the given group address

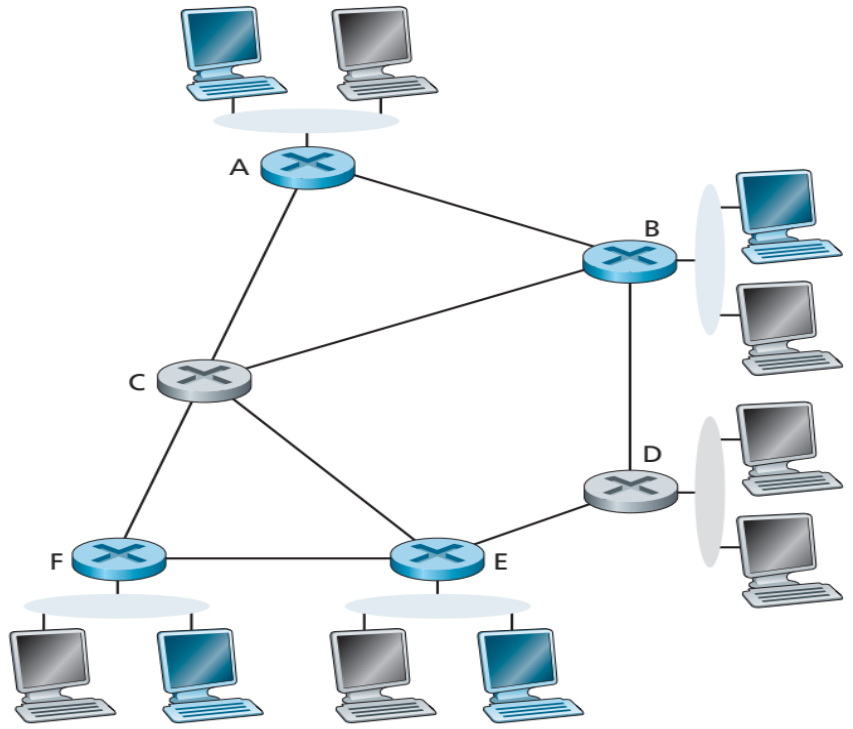


IGMP & Multicast Routing Protocols

- IGMP: *Soft state protocol*
  - Protocol "state": status of the host joined to a multicast group
  - The state is removed via a timeout event (e.g., periodic membership query message from the router) if it is not explicitly refreshed (e.g., by *membership_report* or *leave_group* messages from the host)

Multicast Routing: Algorithms

- Challenge with multicast routing: only a subset of routers actually needs to receive the multicast traffic
- Objective: find a tree of links that connects all the routers that have attached hosts belonging to the multicast group
  - Multicast tree: routes multicast packets from the sender to all of hosts belonging to the tree
  - Multicast packet – to be routed along this tree from the sender to all hosts belonging to the multicast tree
  - The tree may or may not contain the routers that do not have attached hosts belonging to the multicast group
- Two approaches adopted for determining multicast routing tree
- *Multicast routing using a group-shared tree*
  - Based on building a tree that includes all edge routers with attached hosts belonging to the multicast group

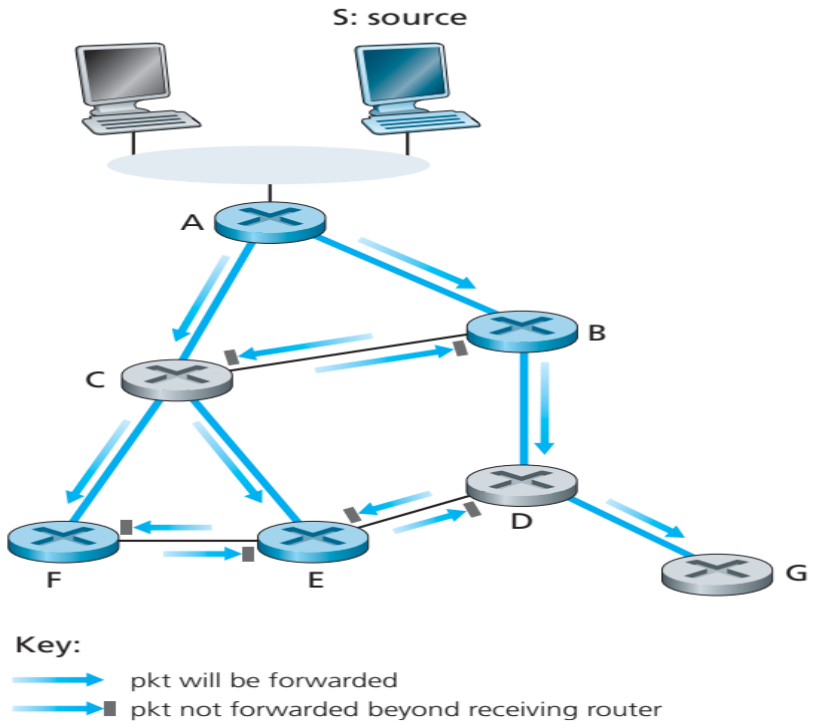


Multicast Hosts, Attached Routers, and other Routers

- Center-based approach used to construct the multicast routing tree
- Edge routers with attached hosts belonging to the multicast group send join messages (via unicast) addressed to the center node
  - Join messages: either arrives at a router that is already included in the multicast tree or arrives at the center
- All routers along the path that the join message follows will then forward the received multicast packets to the edge router that initiated the multicast join
- Major challenge: choice of the center node

Multicast Routing: Algorithms

- *Multicast routing using a source-based tree*
  - Construct a multicast routing tree for each source in the multicast group
  - RPF algorithm is used to construct a multicast forwarding tree for multicast datagrams originating at a given source
  - Drawback: delivery of unnecessary multicast packets to hundreds of routers which have no host joined to the group
  - Pruning: a technique used to prevent receipt of unwanted multicast packets under RPF
  - Prune message: sent by a multicast router that received multicast packets and has no attached hosts joined to that group to its upstream router
  - If a router receives prune message from each of its downstream routers, it forwards it upstream
- Multicast routing in the Internet
  - Distance-Vector Multicast Routing Protocol (DVMRP)
    - Implements source-based tree with reverse path forwarding and pruning



Reverse Path Forwarding (Multicast Routing)

- Protocol Independent Multicast Routing Protocol (PIM): explicitly recognizes two multicast distribution scenarios
  - Dense mode: most of the routers in the area need to be involved in routing multicast datagrams – uses flood-and-prune reverse path forwarding technique
  - Sparse mode: group members are widely dispersed – uses center points to set up the multicast distribution tree
- Multicast Source Discovery Protocol (MSBP)
  - Used for inter-domain multicast routing
  - Connects center points in different PIM sparse-mode domains