ΟΙΚΟΝΟΜΙΚΟ ΠΑΝΕΠΙΣΤΗΜΙΟ ΑΘΗΝΩΝ
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Multimedia Technology

Section # 16: Multicasting

Instructor: George Xylomenos

Department: Informatics

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Why multicasting?

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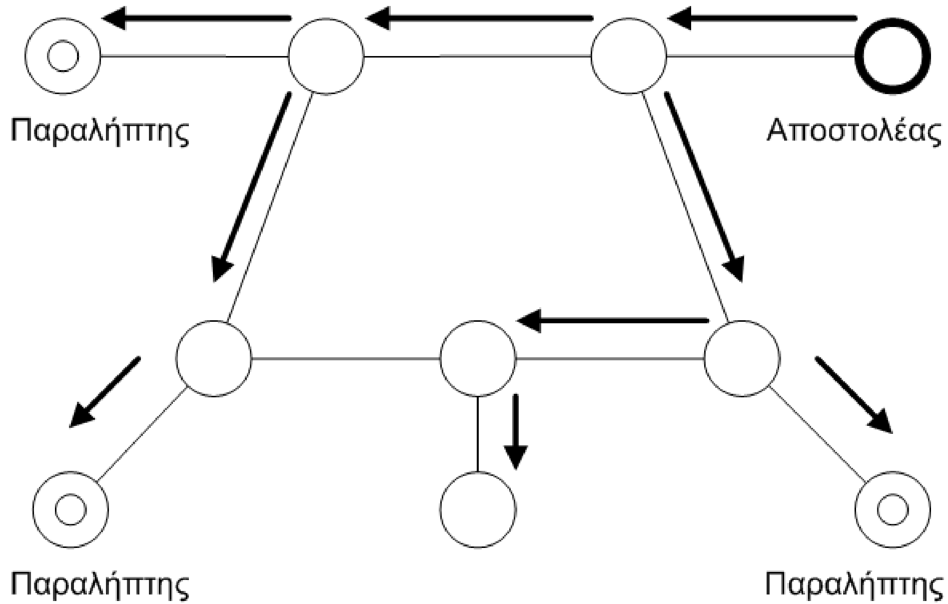
Communication models (1 of 5)

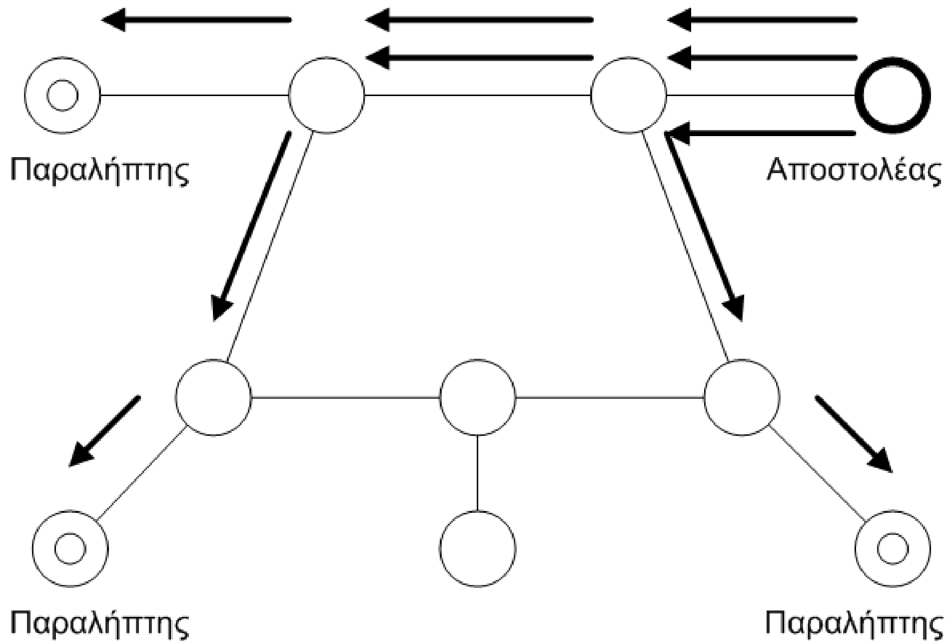
- Unicast: one to one
  - Inherited from telephony
  - Basic model on the Internet
- Broadcast: one to all
  - Inherited from radio and TV
  - Only allowed locally on the Internet
- Multicast: one to many
  - Communication with multiple receivers

Communication models (2 of 5)



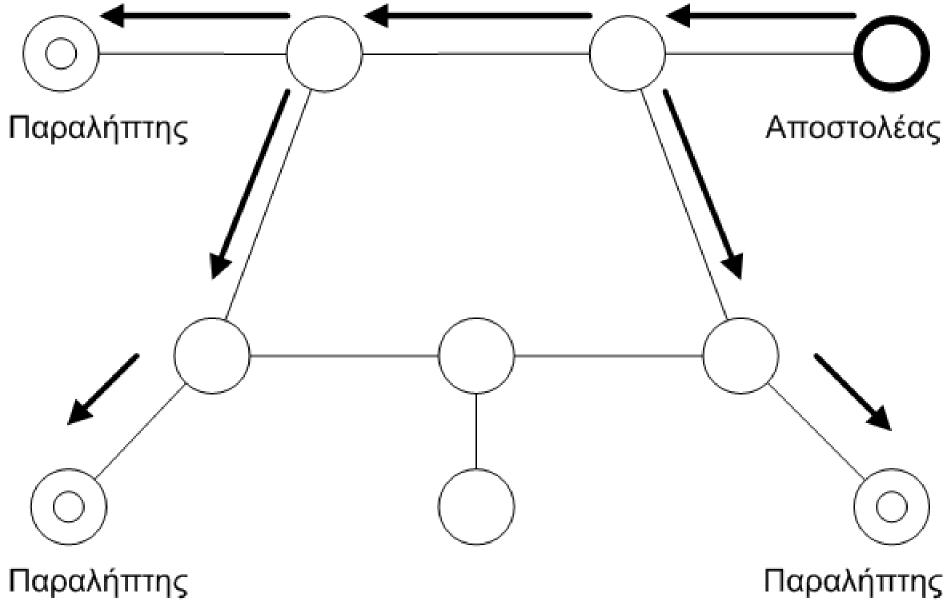
- Multicast via one to all transmission
  - Wastes resources
  - Used only locally
    - E.g., ARP, DHCP

Communication models (3 of 5)



- Multicast via one to one transmission
  - No need for network support
  - Wastes resources due to multiple transmissions
  - Network congestion close to the sender

Communication models (4 of 5)



- Real one to many transmission
  - Requires (considerable) network support
  - Most economical media distribution

Communication models (5 of 5)

- Where does multicasting make sense?
  - Live media transmission
    - IPTV, pay per view
  - Essentially, replaces broadcast
- Where does it (probably) not make sense?
  - Streaming video
    - Netflix, Youtube
  - But: can be used to seed caches!

Multicasting models

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What does multicast mean? (1 of 4)

- What does multicast really mean?
  - Arbitrary set of receivers (group members)
  - Packets transmitted only to them (not everyone)
  - Packets transmitted only once per link
- Implementation requirements
  - Dynamic tracking of group members
  - Routing packets towards group members

What does multicast mean? (2 of 4)

- Multicast tree
  - A tree with the recipients as the leaves
    - Does not have to be optimal
    - There are different notions of optimal
      - Shortest paths vs. lowest cost
  - Multicast trees save resources
    - Each packet only crosses each link once
    - Must be duplicated at each branching point

What does multicast mean? (3 of 4)

- The Host Group model
  - Set of receivers identified by Class D IP address
  - All receivers (may) receive all packets
  - Anyone can send packets to the group
  - Also known as Any Source Multicast (ASM)
- Source-Specific Multicast (SSM)
  - Extension of the Host Group model
  - Receivers join group for specific senders only

What does multicast mean? (4 of 4)

- Atomic multicast: very different model
  - Each packet reaches everyone or none
    - And packet are received in the same order
  - Much harder to implement
  - Used for distributed synchronization
  - Not offered on the Internet
    - Implemented by middleware

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Routing algorithms

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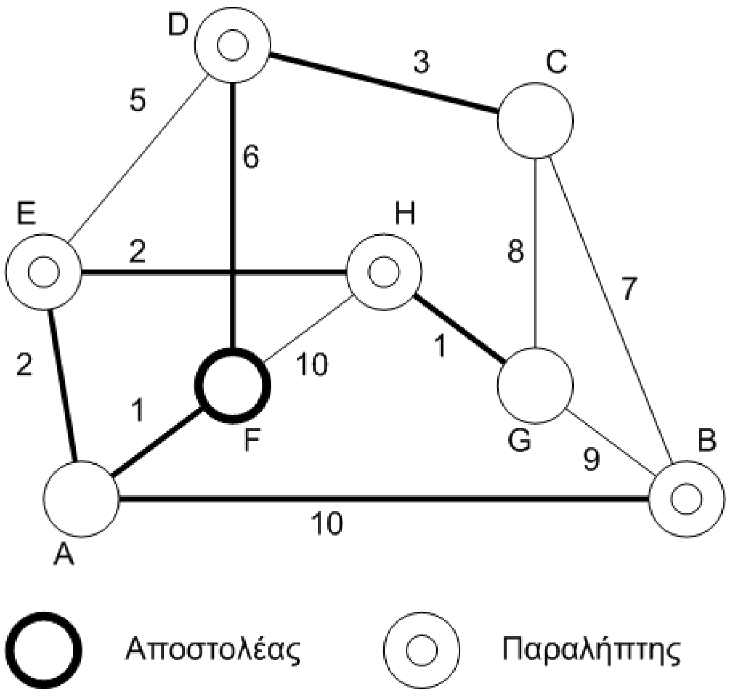
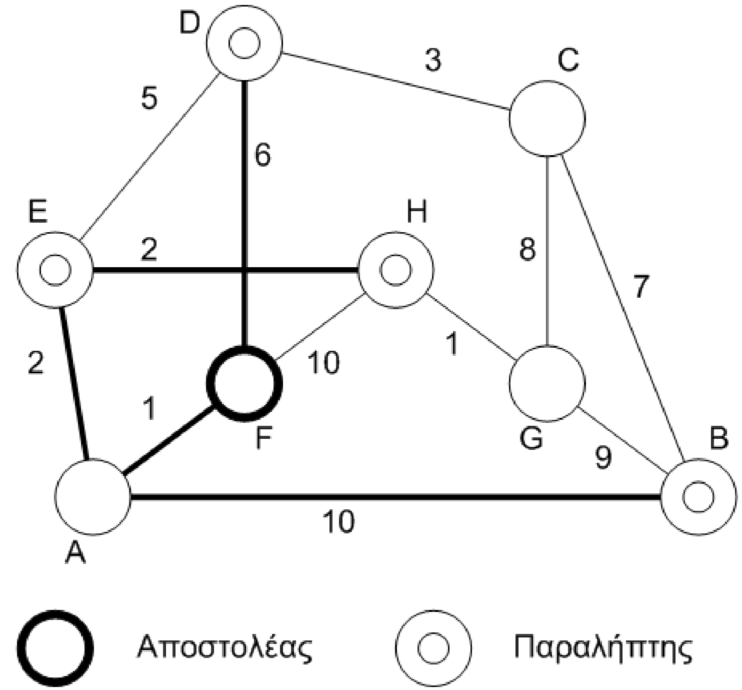
Routing (1 of 5)



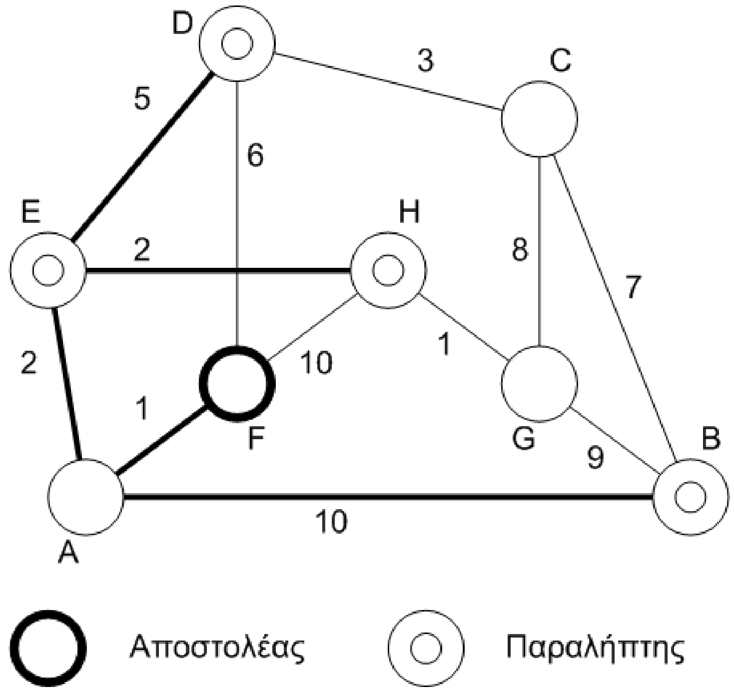


- Multicast routing: 1st approach
  - Join the optimal unicast paths
    - Calculate optimal paths to all (Dijkstra)
    - Recursively remove links not leading to members

Routing (2 of 5)

- Advantages/Disadvantages
  - Exploits existing mechanisms
  - Not optimal in resources
- Multicast routing: 2^{nd} approach
  - Calculate Steiner tree
    - Least cost tree covering all participants
    - May contain other internal nodes
  - NP complete problem!
  - But there are good approximations

Routing (3 of 5)

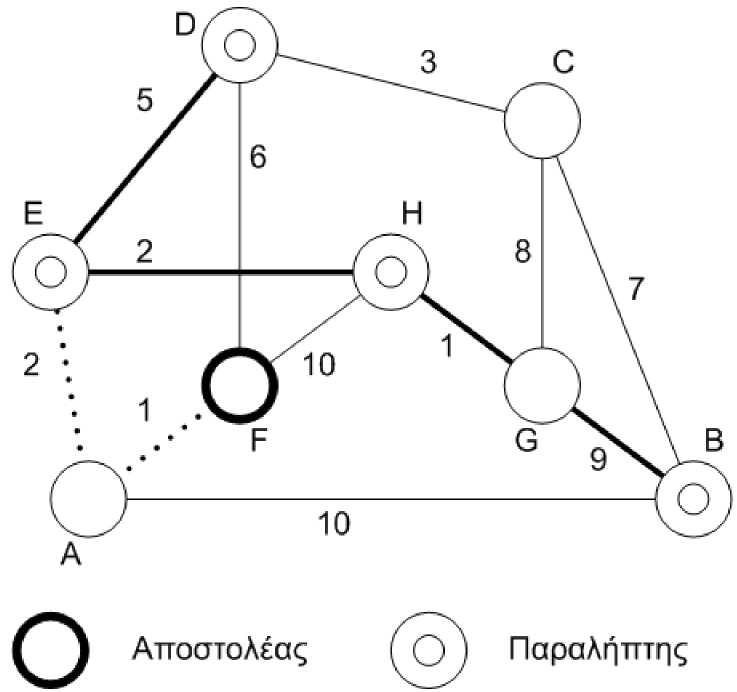


- Advantages/Disadvantages
  - Almost optimal solution (with approximation)
  - Requires running additional algorithm
    - And recalculate on every group change

Routing (4 of 5)

- Multicast routing: 3^{nd} approach
  - (Shared) tree based on common “core” point
    - The other solutions have per-sender trees
  - Core: topological center of receivers (ideally)
    - Which is also NP complete!
- Advantages/Disadvantages
  - No need to maintain multiple trees
  - Local modifications on group changes
  - Resource use is not optimal

Routing (5 of 5)



- Implementation of 3rd approach
  - Based on a core (or rendezvous point)
  - Senders transmit packets towards the core
  - The core transmits packets towards the receivers

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Heterogeneity

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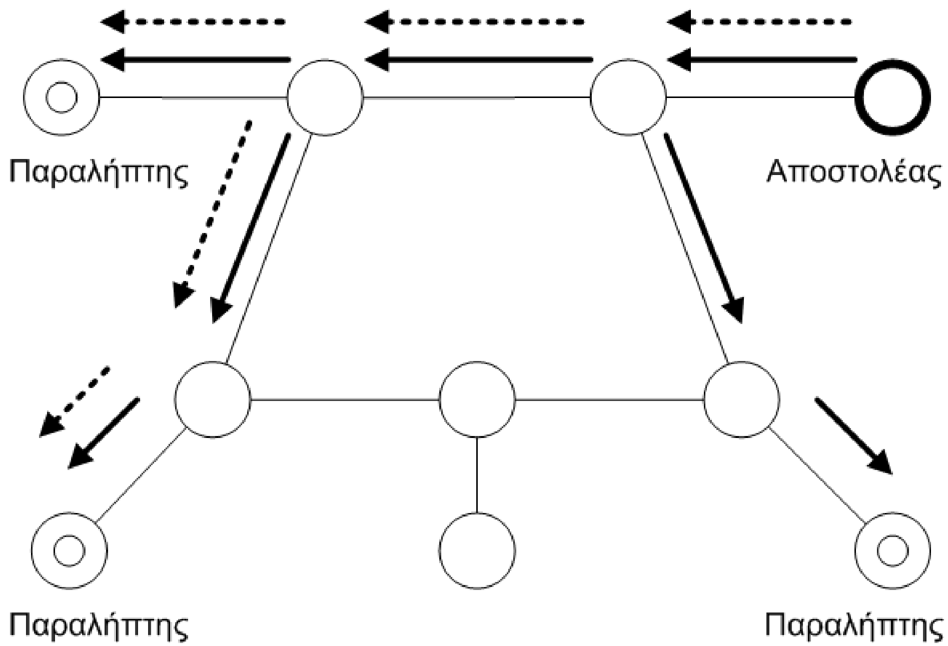
Heterogeneity (1 of 3)

- Multicast and heteoregeneity
  - More receivers -> more divergence
    - Different preferences
    - Different terminals
    - Different networks
- Splitting receivers into groups
  - One group per quality level
    - Each receiver joins the right group
  - Same media transmitted many times (simulcast)

Heterogeneity (2 of 3)

- Layered coding
  - Media split into k layers
  - Each layer sent to different groups
  - Each receivers joins groups 1-n
    - Depending on preferences / capabilities
  - Each extra layer improves quality
  - Media transmitted only once

Heterogeneity (3 of 3)



- Example
  - Base layer: solid line
  - Enhancement layer: dashed line

Feedback control

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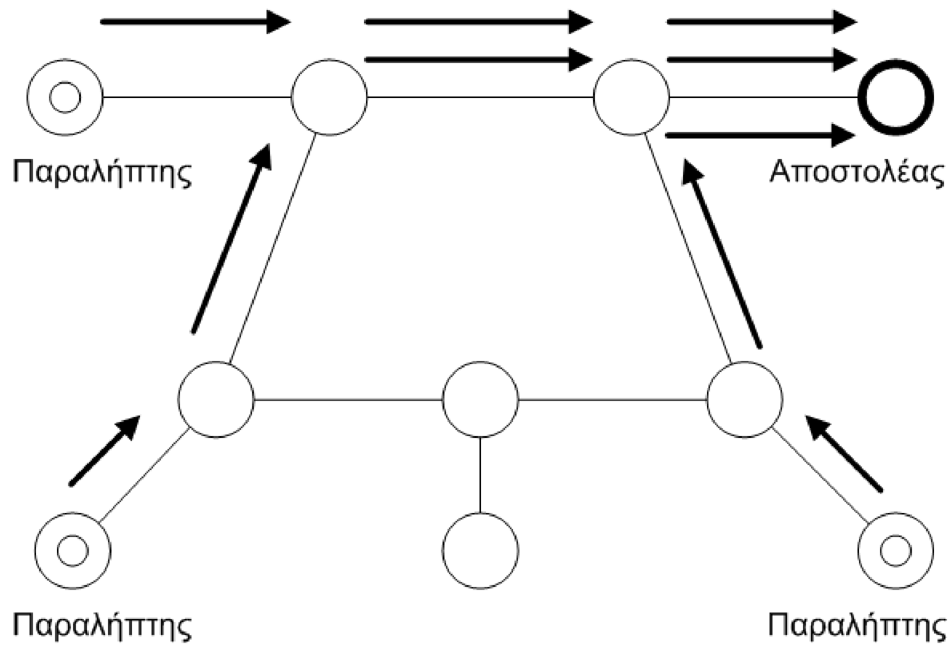
Feedback implosion



- Flow, congestion and error control
  - In multicast we have many receivers
  - Feedback implosion: sender overloaded by feedback

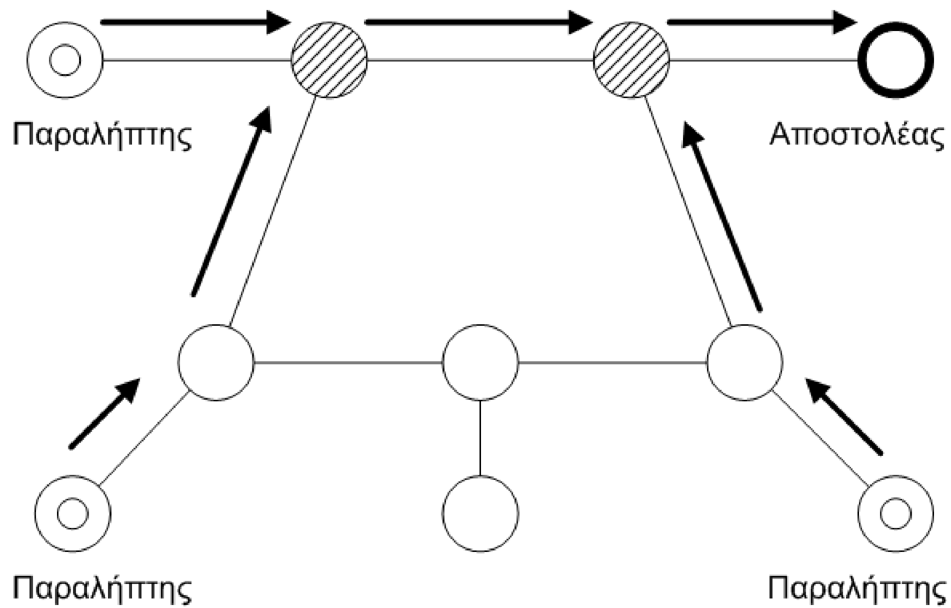
Handling feedback (1 of 5)

- Handling multicast feedback
  - Ideally, handle everyone together
  - But what if we get different feedback?
    - Do we care about the best or the worst case?
- Option 1: pass the buck to higher layers
  - Of course, the problem re-appears there
  - Makes sense when they do know better
    - Do I need full error correction?

Handling feedback (2 of 5)

- Option 2: per-receiver state
  - Sender waits for everyone to sync
    - Example: everyone receives each packet
  - Works best with negative feedback
    - Reduces the chance of feedback implosion
  - Essentially, sender adapts to worst receiver
    - Waits until it syncs with others

Handling feedback (3 of 5)



- Option 3: hierarchical feedback control
  - Control distributed in the multicast tree
  - Intermediate nodes merge the feedback
  - If possible, local handling of issues

Handling feedback (4 of 5)

- Option 4: exploit multicast
  - Good for error control
  - Sender and receivers co-operate
  - Receivers multicast negative feedback
    - I lost packet x
  - Whoever gets them, can respond
    - Not just the sender, but intermediate nodes
    - Responses are multicast, to silence others

Handling feedback (5 of 5)

- Local scope for reports / retransmissions
  - Reduces the distance travelled
  - Does not reach faraway nodes
- Delay depending on distance
  - Multicast responses from nearest nodes
  - Other nodes hear the response and keep quiet
- Local recovery from errors

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Multicasting on the Internet

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Basic elements

- Class D IP addresses for groups
  - Same packet format as for unicast
- Routing up to subnet
  - Then, local solution for transmit / receive
- Group member monitoring
  - Maintains a list of groups present on subnet
- Routers exchange group info

Routing: DVRMP (1 of 2)

- Distance vector routing
  - Based on reverse optimal paths
  - Per-sender trees formed
- Exploits existing routing protocol
  - We know the next hop for each destination
  - Say a new multicast packet arrives
  - Did it come from the next hop for that node?
    - That is, from the reverse best path?

Routing: DVRMP (2 of 2)

- Exploits existing routing protocol
  – Packet sent through <u>all</u> other links
    - Essentially, limited flooding
  – Pruning links that lead nowhere
    - The next hop sends a prune message
- DVMRP does not really create trees
  – It just exploits the existing paths
    - Only maintains prune filters

Routing: MOSPF (1 of 2)

- Link state routing
  - All routers send their local groups
  - Link state flooded
  - Piggybacks on existing OSPF packets
  - Routers calculate optimal trees
  - Needs re-flooding whenever groups change
    - Much more often than network changes

Routing: MOSPF (2 of 2)

- MOSPF does maintain multicast trees
  - It can even calculate Steiner trees
  - In practice, it joins the unicast OSPF paths
    - Just looks at what groups are in which router
  - Piggybacks on OSPF
    - No need for new packets
  - But wasteful of messages
    - Especially with many group changes

Routing: CBT

- Shared tree for all senders
  - Its root is the core (or rendezvous point)
- Created bottom up (from leaves to root)
  - Leaf sends Join message towards core
  - State is established along the way
  - The core sends packets towards leaf
- Non-optimal tree, but low cost
  - As long as everyone knows the core

Routing: PIM (1 of 2)

- Two modes: dense and sparse
  - Combines CBT and DVMR/MOSPF
- Sparse mode (PIM-SM): similar to CBT
  - Good for small groups
  - Allows many rendezvous points (RP)
  - Can switch to per sender tree
    - When better performance is needed

Routing: PIM (2 of 2)

- Dense mode (PIM-DM): similar to DVMRP
  - Good for large groups
  - Creates per-sender trees
  - Does not rely on specific routing protocol
    - Works with RIP or OSPF
  - Allows pruning the tree

Scaling with BGMP

- Multicast between Autonomous Systems (AS)
  – Each AS can have different routing
  – How can we achieve global routing?
- BGMP creates shared AS trees
  – Core: the AS starting the group
  – Joins routing across ASes

Local schemes (1 of 4)

- Group management: IGMP v1
  - Router periodically multicast Query
  - Each receiver sends a Report per group
  - The first Report suppresses others
    - Reports send after random timeout
    - Reduces conflicts
  - Group deleted when no responses arrive
    - There is no explicit group leave scheme
  - Scheme designed for shared Ethernet

Local schemes (2 of 4)

- Group management: IGMP v2
  - Adds group Leave
    - From the last to send a Report
  - Followed by group-specific Query
- Group management: IGMP v3
  - Adds source-specific multicast
    - Queries can also specify a sender
    - Responses contain a sender field

Local schemes (3 of 4)

- Packet transmit /receive
- “Broadcast” in shared networks (Ethernet)
  - IP addresses mapped to MAC addresses
    - MAC address starts with 01
  - Network cards can filter MAC addresses
    - Normally, only a few addresses supported
  - Otherwise, multicasts are filtered in software
  - One transmission reaches entire LAN

Local schemes (4 of 4)

- What about non-shared LANs?
  - Star-like networks (ADSL/VDSL)
  - In practice, Ethernet is also like this
    - We have full duplex switches
    - Only WiFi is a broadcast network
  - Unfortunately, exactly the same protocol!
    - Periodically send queries
    - Exactly the same policy for reports

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Adoption issues

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Lack of support (1 of 3)

- Why is multicast not available everywhere?
  - All operating systems support it
  - But routers normally do not
    - Unless if there is a good use for it (IPTV)
- Security issues
  - Harder than with unicast
  - Key management needed for secure comms
    - The sender does not even know the receivers

Lack of support (2 of 3)

- Model issues
  - Senders cannot choose the receivers
    - Hard to support paid services
  - Receivers cannot choose the senders
    - Liable to spam!
    - This is why SSM was created
- Scalability issues
  - Multicast routing cannot be aggregated
    - Groups are not geographical

Lack of support (3 of 3)

- Where is multicast used?
  - Inside a local network
    - Example: all routers attached to a LAN
  - For specific applications
    - Used for IPTV (see following section)
    - Requires custom network to be efficient
  - Based on SSM
    - Without source selection, attracts spam

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End of Section # 16

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