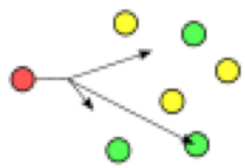

Multicast and Anycast

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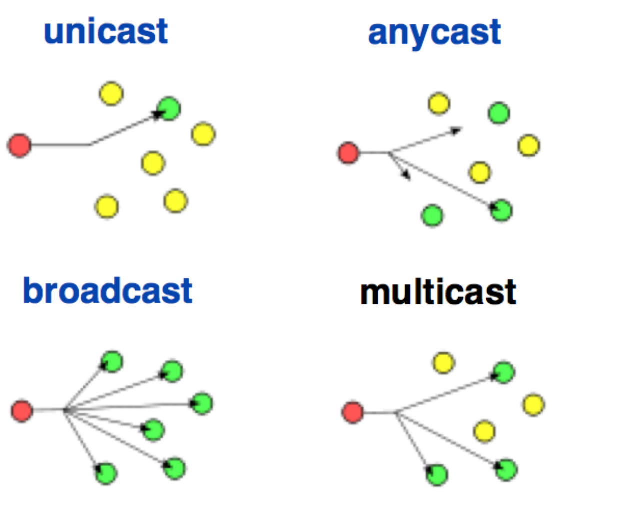
COS 461: Computer Networks

http://www.cs.princeton.edu/courses/archive/spr20/cos461/

Outline today

- IP Anycast
  - N destinations, 1 should receive the message
  - Providing a service from multiple network locations
  - Using routing protocols for automated failover
- Multicast protocols
  - N destinations, N should receive the message
  - Examples
    - IP Multicast
    - SRM (Scalable Reliable Multicast)
    - PGM (Pragmatic General Multicast)



Limitations of DNS-based failover

- Failover/load balancing via multiple A records

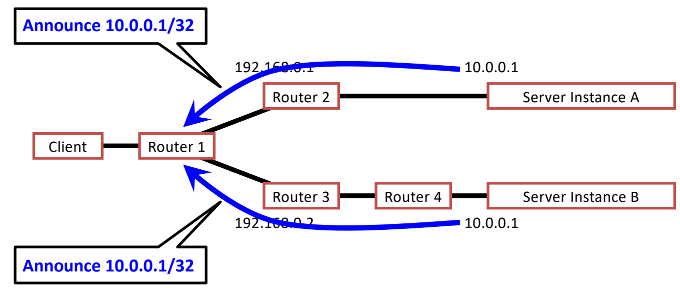
```
;; ANSWER SECTION:
www.cnn.com.    300   IN A  157.166.255.19
www.cnn.com.    300   IN A  157.166.224.25
www.cnn.com.    300   IN A  157.166.226.26
www.cnn.com.    300   IN A  157.166.255.18
```

- If server fails, service unavailable for TTL
  - Very low TTL: Extra load on DNS
  - Anyway, browsers cache DNS mappings ☹
- What if root NS fails? All DNS queries take > 3s?

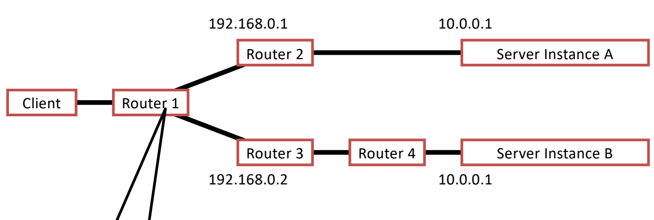
Motivation for IP anycast

- Failure problem: client has resolved IP address
  - What if IP address can represent many servers?
- Load-balancing/failover via IP addr, rather than DNS
- IP anycast is simple reuse of existing protocols
  - Multiple instances of a service share same IP address
  - Each instance announces IP address / prefix in BGP / IGP
  - Routing infrastructure directs packets to nearest instance of the service
    - Can use same selection criteria as installing routes in the FIB
  - No special capabilities in servers, clients, or network

IP anycast in action



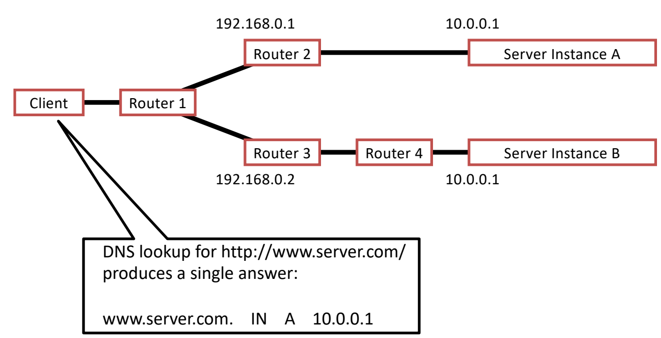
IP anycast in action



Routing Table from Router 1:

Destination	Mask	Next-Hop	Distance
192.168.0.0	/29	127.0.0.1	0
10.0.0.1	/32	192.168.0.1	1
10.0.0.1	/32	192.168.0.2	2

IP anycast in action



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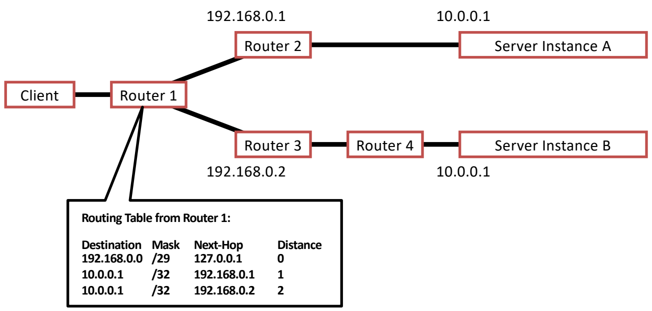
IP anycast in action



Destination	Mask	Next-Hop	Distance
192.168.0.0	/29	127.0.0.1	0
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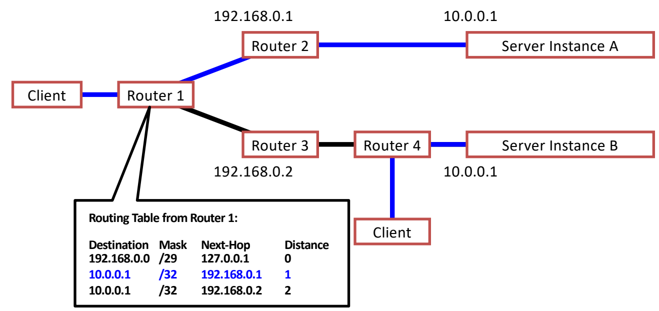
IP anycast in action



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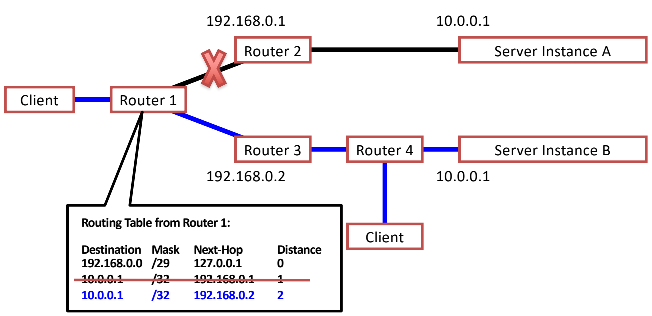
IP anycast in action



Destination	Mask	Next-Hop	Distance
192.168.0.0	/29	127.0.0.1	0
~~10.0.0.1~~	~~/32~~	~~192.168.0.1~~	~~1~~
10.0.0.1	/32	192.168.0.2	2

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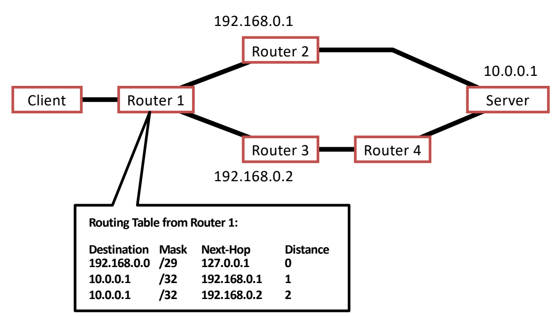
IP anycast in action

From client/router perspective, topology could as well be:



Destination	Mask	Next-Hop	Distance
192.168.0.0	/29	127.0.0.1	0
10.0.0.1	/32	192.168.0.1	1
10.0.0.1	/32	192.168.0.2	2

Downsides of IP anycast

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- Many Tier-1 ISPs ingress filter prefixes > /24
  - Publish a /24 to get a “single” anycasted address: Poor utilization
- Scales poorly with the # anycast groups
  - Each group needs entry in global routing table
- Not trivial to deploy
  - Obtain an IP prefix and AS number; speak BGP

Downsides of IP anycast

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- Subject to the limitations of IP routing
  - No notion of load or other application-layer metrics
  - Convergence time can be slow (as BGP or IGP converge)
- Failover doesn’t really work with TCP
  - TCP is stateful: if switch destination replicas, other server instances will just respond with RSTs
  - May react to network changes, even if server online
- Root nameservers (UDP) anycasted, little else

Multicast

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Multicast

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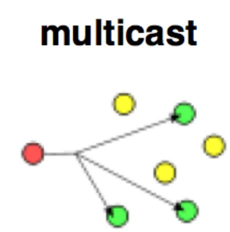
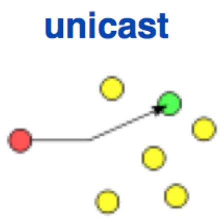
- Many receivers
  - Receiving the same content
- Applications
  - Video conferencing
  - Online gaming
  - IP television (IPTV)
  - Financial data feeds



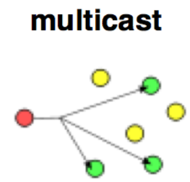
Iterated Unicast

- Unicast message to each recipient
- Advantages
  - Simple to implement
  - No modifications to network
- Disadvantages
  - High overhead on sender
  - Redundant packets on links
  - Sender must maintain list of receivers

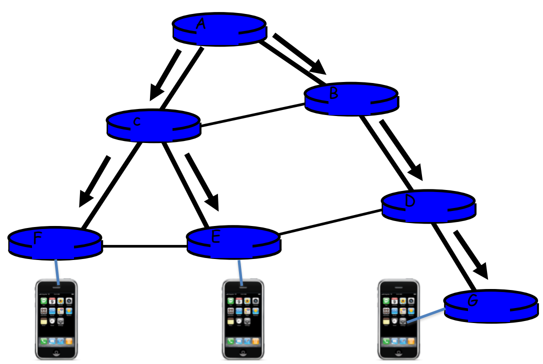


IP Multicast

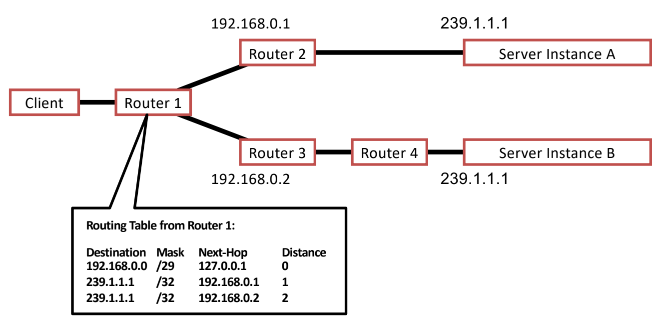
- Embed receiver-driven tree in network layer
  - Sender sends a single packet to the group
  - Receivers “join” and “leave” the tree
- Advantages
  - Low overhead on the sender
  - Avoids redundant network traffic
- Disadvantages
  - Control-plane protocols for multicast groups
  - Overhead of duplicating packets in the routers



Multicast Tree



IP multicast in action



Destination	Mask	Next-Hop	Distance
192.168.0.0	/29	127.0.0.1	0
239.1.1.1	/32	192.168.0.1	1
239.1.1.1	/32	192.168.0.2	2

Single vs. Multiple Senders

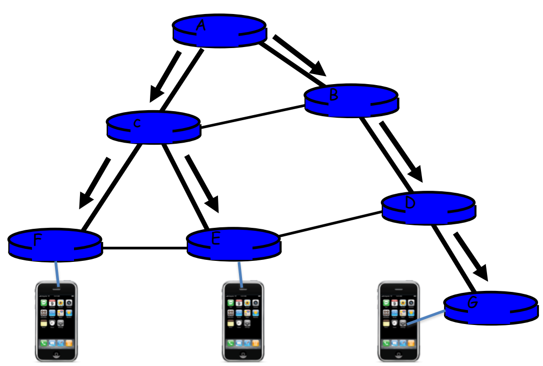
- Source-based tree
  - Separate tree for each sender
  - Tree is optimized for that sender
  - But, requires multiple trees for multiple senders
- Shared tree
  - One common tree
  - Spanning tree that reaches all participants
  - Single tree may be inefficient
  - But, avoids having many different trees

Multicast Addresses

- Multicast "group" defined by IP address
  - Multicast addresses look like unicast addresses
  - 224.0.0.0 to 239.255.255.255
- Using multicast IP addresses
  - Sender sends to the IP address
  - Receivers join the group based on IP address
  - Network sends packets along the tree

Example Multicast Protocol

- Receiver sends a "join" messages to the sender
  - And grafts to the tree at the nearest point



IGMP v1

- Two types of IGMP msgs (both have IP TTL of 1)
  - Host membership query: Routers query local networks to discover which groups have members
  - Host membership report: Hosts report each group (e.g., multicast addr) to which belong, by broadcast on net interface from which query was received
- Routers maintain group membership
  - Host senders an IGMP "report" to join a group
  - Multicast routers periodically issue host membership query to determine liveness of group members
  - Note: No explicit "leave" message from clients

IGMP: Improvements

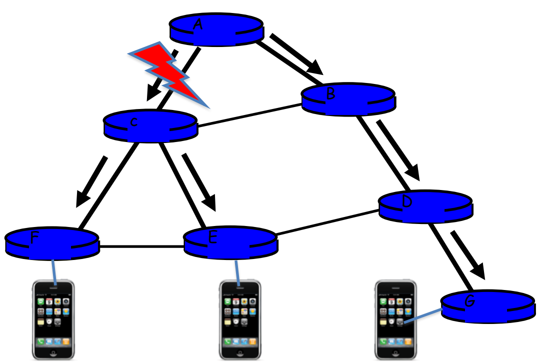
- IGMP v2 added:
  - If multiple routers, one with lowest IP elected querier
  - Explicit leave messages for faster pruning
  - Group-specific query messages
- IGMP v3 added:
  - Source filtering: Join specifies multicast "only from" or "all but from" specific source addresses

IGMP: Parameters and Design

- Parameters
  - Maximum report delay: 10 sec
  - Membership query internal default: 125 sec
  - Time-out interval: 270 sec = 2 * (query interval + max delay)
- Router tracks each attached network, not each peer
- Should clients respond immediately to queries?
  - Random delay (from 0..D) to minimize responses to queries
  - Only one response from single broadcast domain needed
- What if local networks are layer-2 switched?
  - L2 switches typically broadcast multicast traffic out all ports
  - Or, IGMP snooping (sneak peek into layer-3 contents), Cisco's proprietary protocols, or static forwarding tables

IP Multicast is Best Effort

- Sender sends packet to IP multicast address
  - Loss may affect multiple receivers



Challenges for Reliable Multicast

- Send an ACK, much like TCP?
  - ACK-implosion if all destinations ACK at once
  - Source does not know # of destinations
- How to retransmit?
  - To all? One bad link effects entire group
  - Only where losses? Loss near sender makes retransmission as inefficient as replicated unicast
- Negative acknowledgments more common

Scalable Reliable Multicast

- Data packets sent via IP multicast
  - Data includes sequence numbers
- Upon packet failure
  - If failures relatively rare, use Negative ACKs (NAKs) instead: "Did not receive expected packet"
  - Sender issues heartbeats if no real traffic. Receiver knows when to expect (and thus NAK)

Handling Failure in SRM

- Receiver multicasts a NAK
  - Or send NAK to sender, who multicasts confirmation
- Scale through NAK suppression
  - If received a NAK or NCF, don't NAK yourself
  - Add random delays before NAK'ing
- Repair through packet retransmission
  - From initial sender
  - From designated local repairer

Pragmatic General Multicast (RFC 3208)

- Similar approach as SRM: IP multicast + NAKs
  - … but more techniques for scalability
- Hierarchy of PGM-aware network elements
  - NAK suppression: Similar to SRM
  - NAK elimination: Send at most one NAK upstream
    - Or completely handle with local repair!
  - Constrained forwarding: Repair data can be suppressed downstream if no NAK seen on that port
  - Forward-error correction: Reduce need to NAK
- Works when only sender is multicast-able

Outline today

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  - N destinations, 1 should receive the message
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  - Using routing protocols for automated failover
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  - N destinations, N should receive the message
  - Examples
    - IP Multicast and IGMP
    - SRM (Scalable Reliable Multicast)
    - PGM (Pragmatic General Multicast)