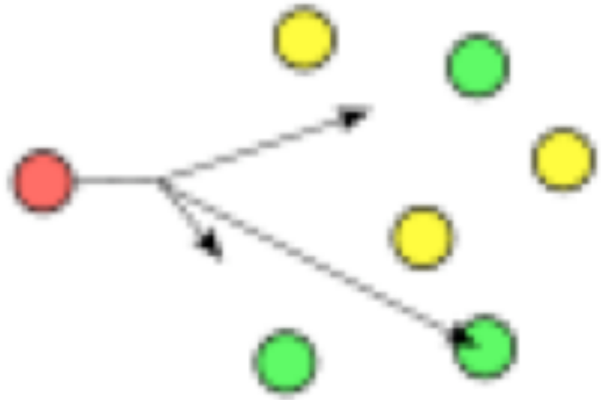

ANYCAST and MULTICAST

READING: SECTION 4.4

COS 461: Computer Networks
Spring 2011

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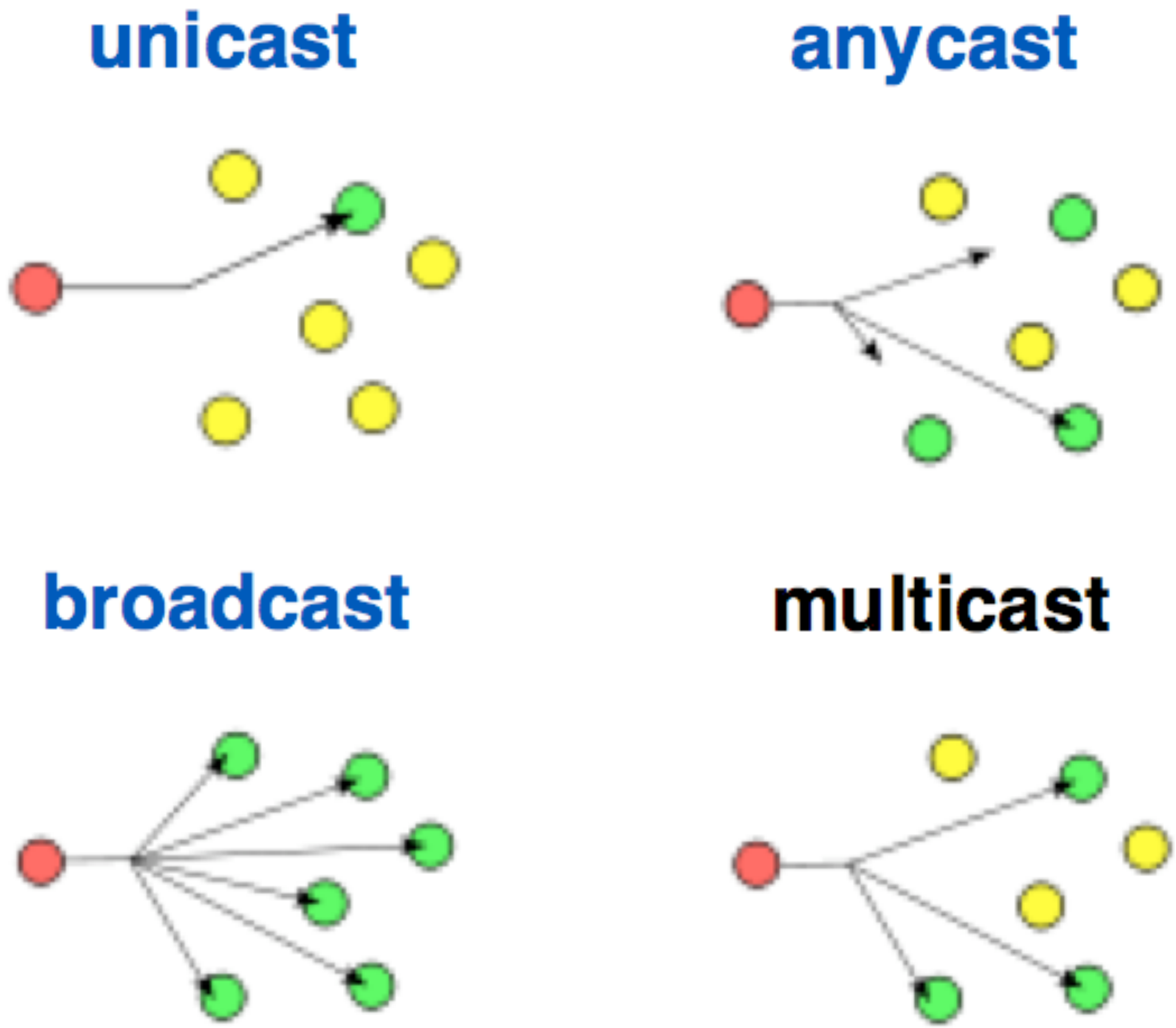
http://www.cs.princeton.edu/courses/archive/spring11/cos461/

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 and IGMP
    - SRM (Scalable Reliable Multicast)
    - PGM (Pragmatic General Multicast)



http://en.wikipedia.org/wiki/Multicast

Limitations of DNS-based failover

- Failover/load balancing via multiple A records

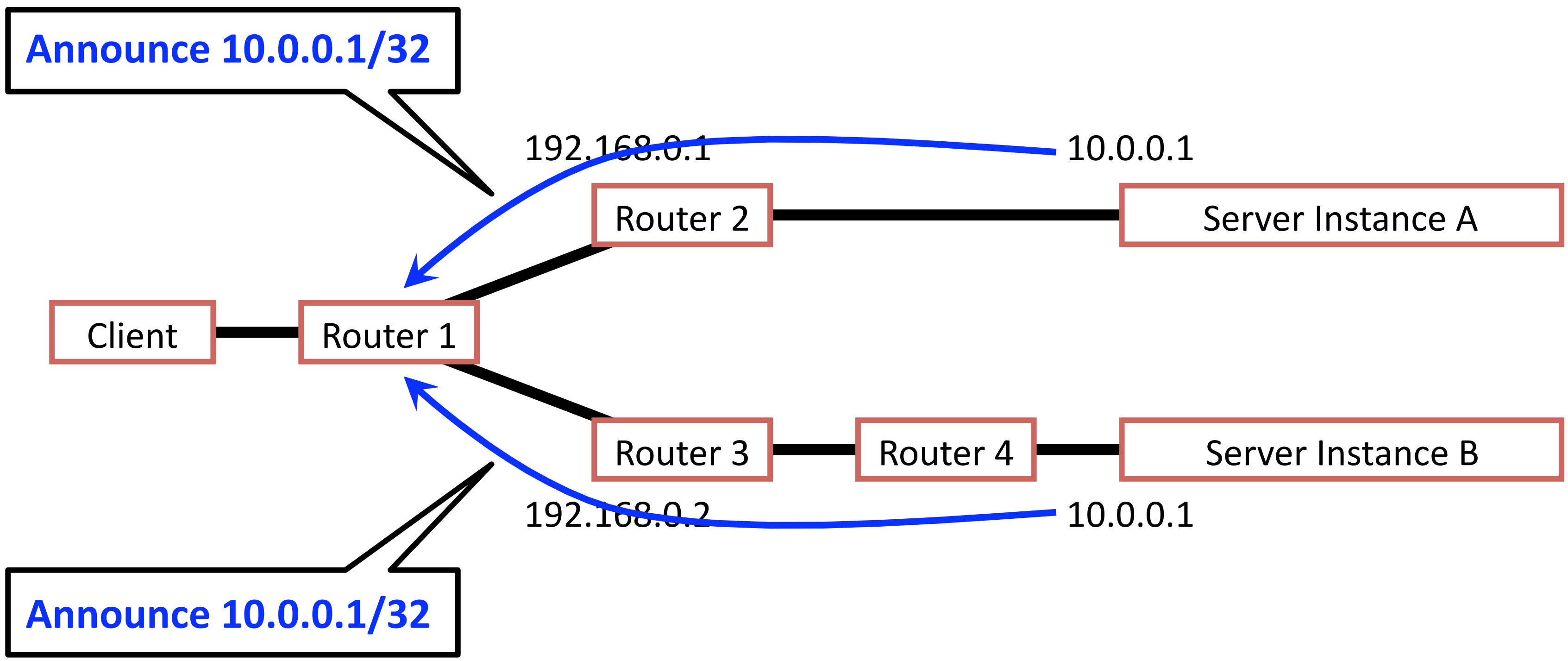
```
;; ANSWER SECTION:
www.cnn.com.     300    IN A   157.166.255.19
www.cnn.com.     300    IN A   157.166.224.25
www.cnn.com.     300    IN A   157.166.226.26
www.cnn.com.     300    IN A   157.166.255.18
```

- 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?

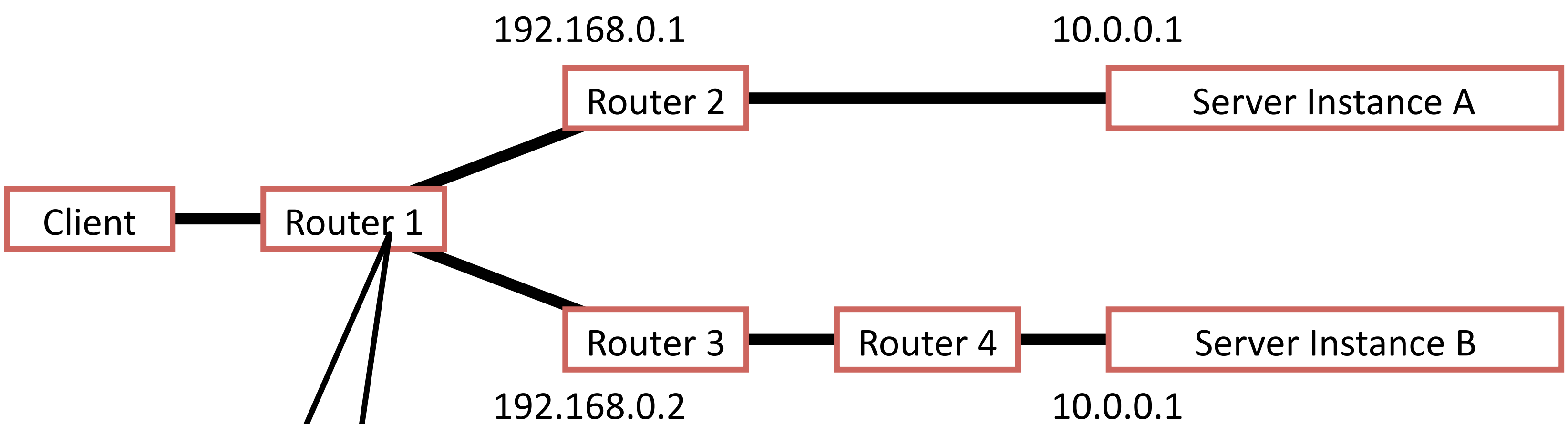
Motivation for IP anycast

- 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



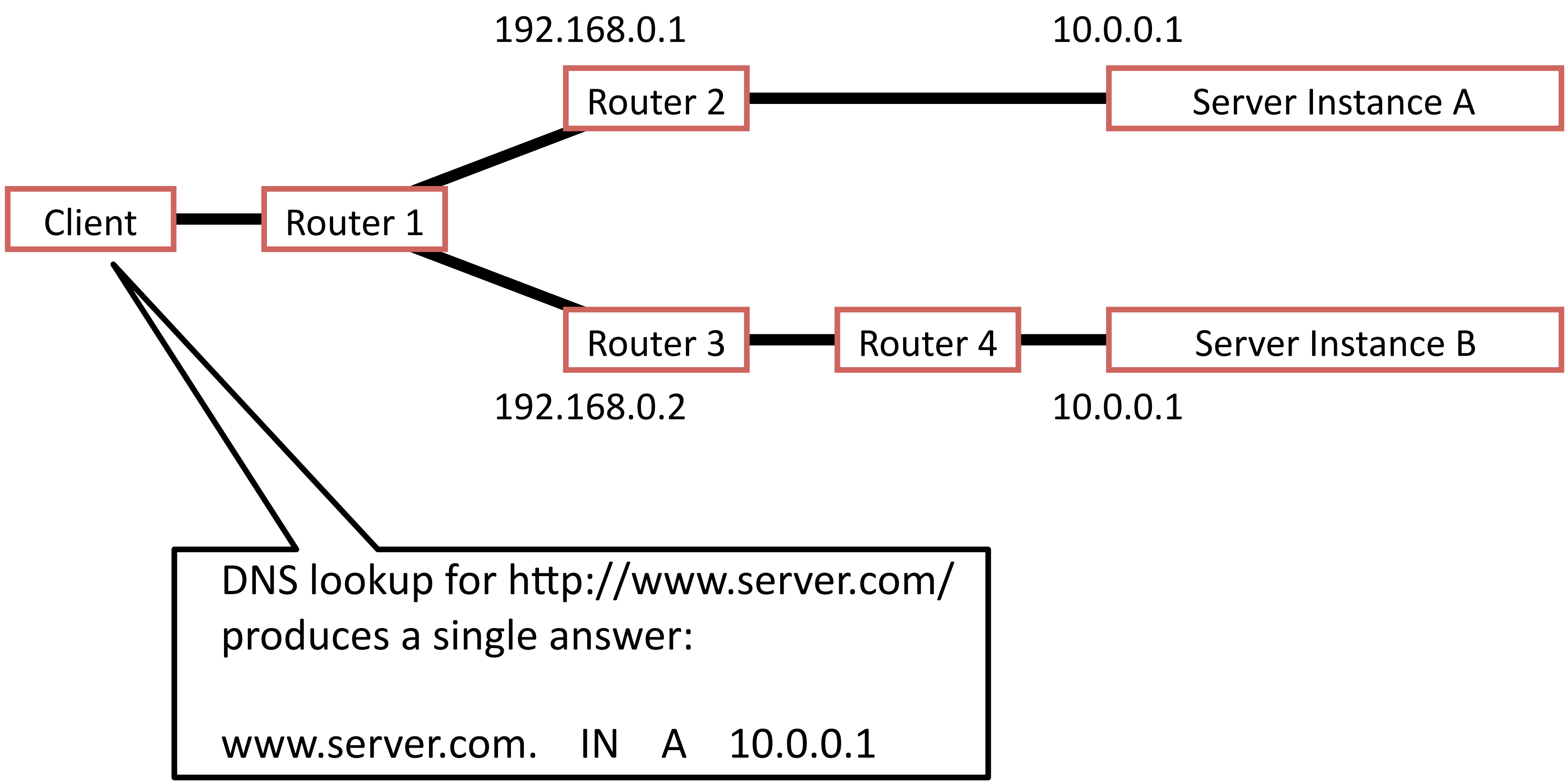
IP anycast in action



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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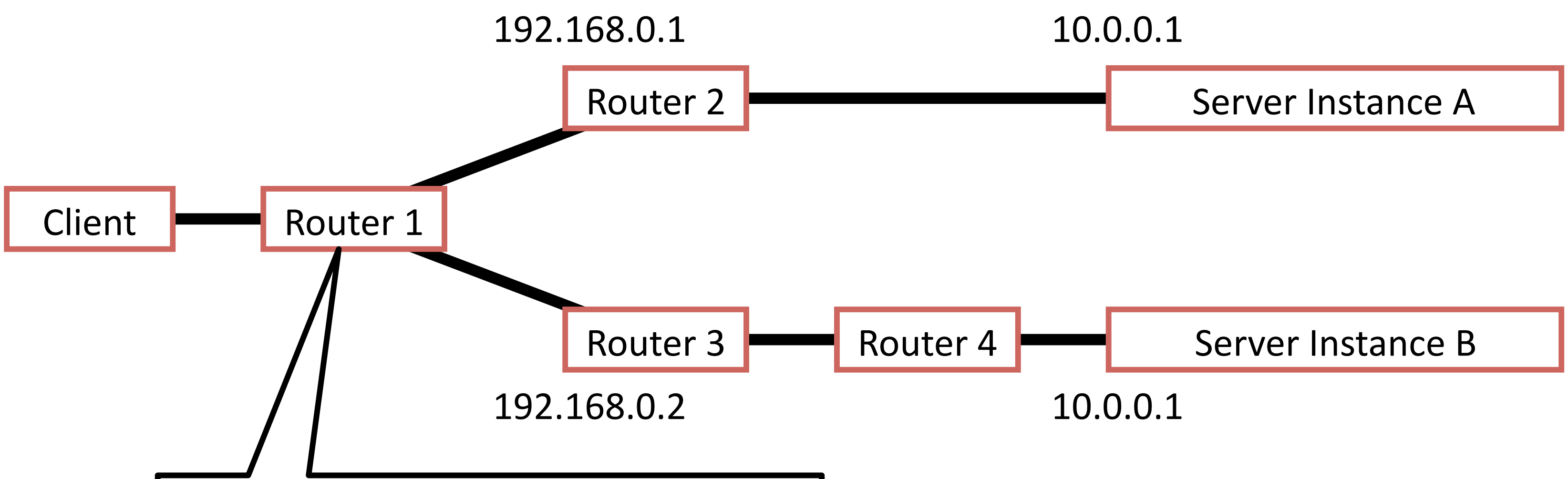

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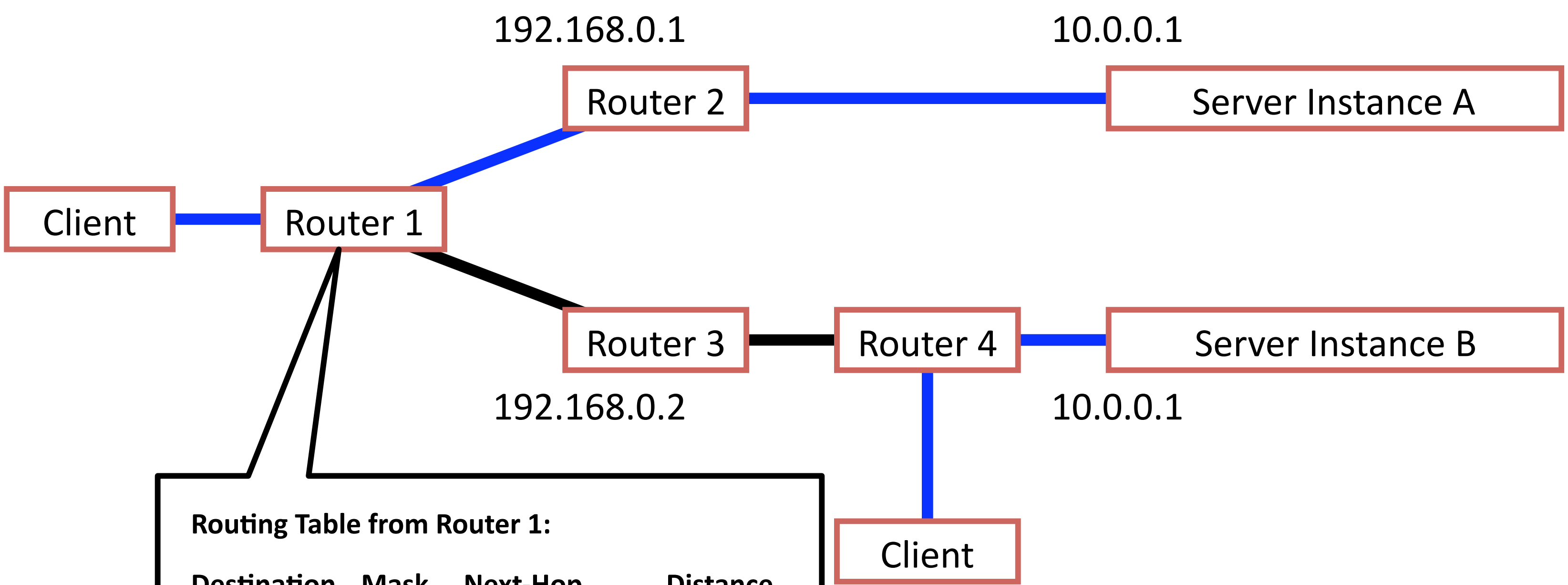
IP anycast in action



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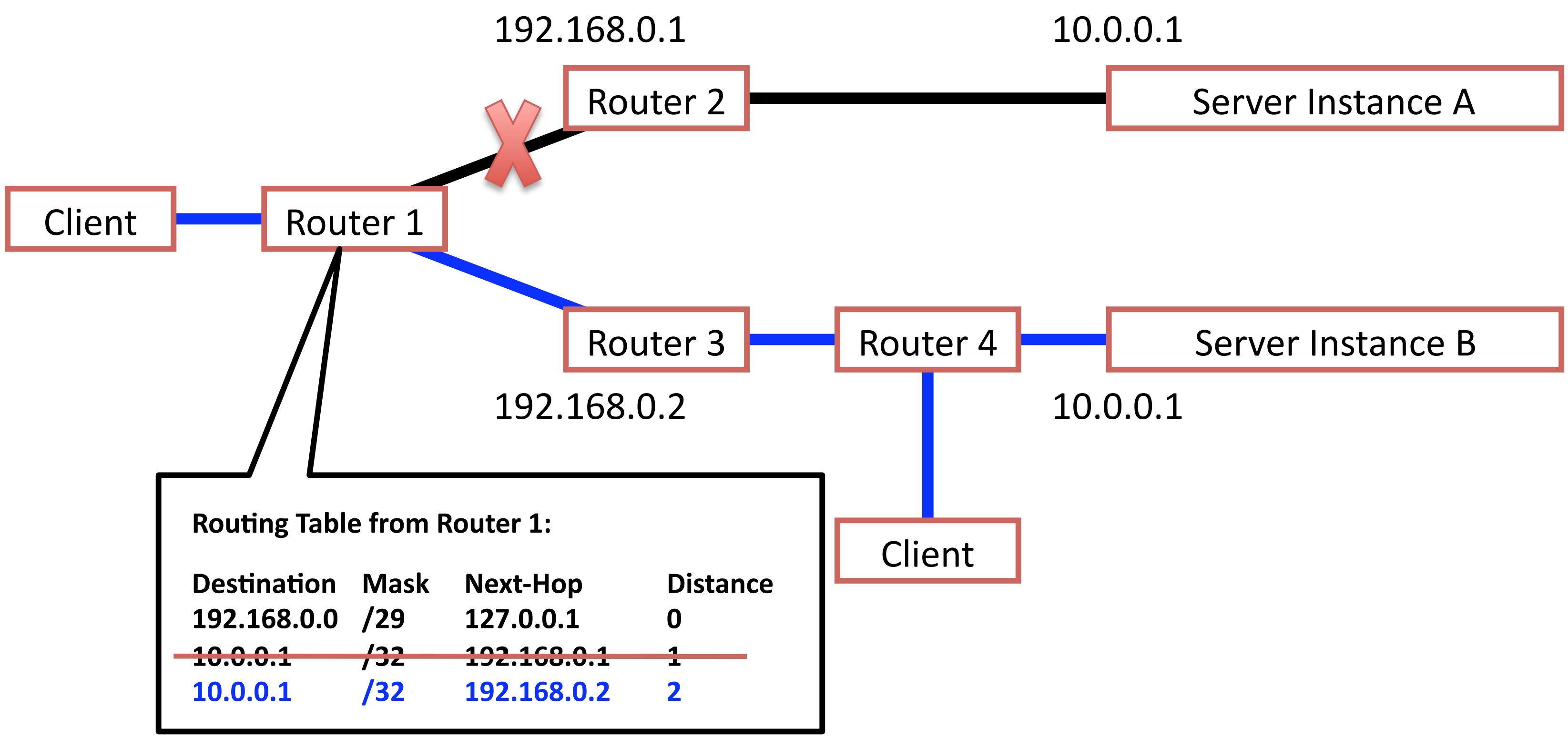
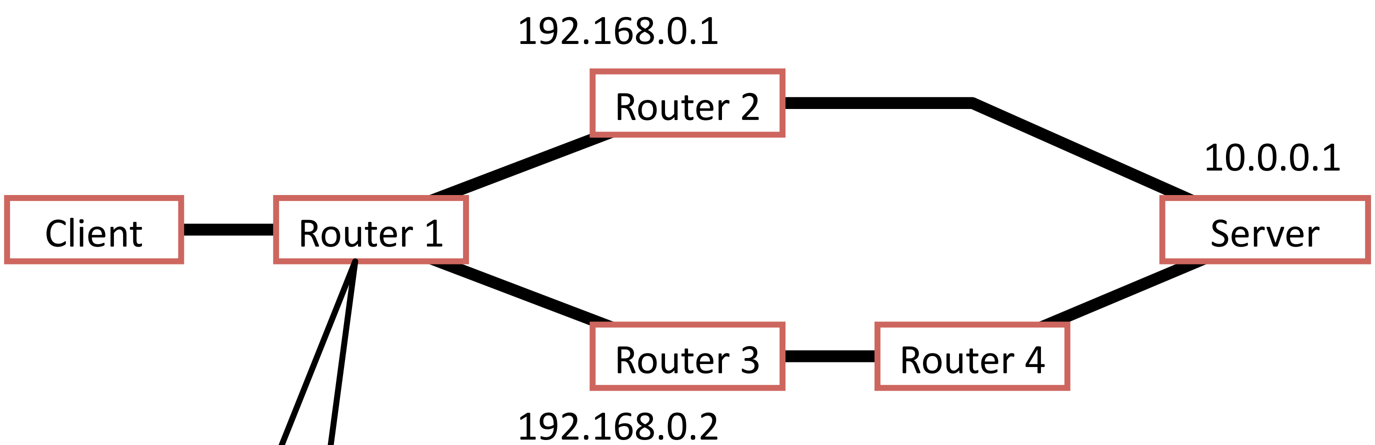
IP anycast in action



IP anycast in action

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



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10.0.0.1	/32	192.168.0.2	2

Downsides of IP anycast

- 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

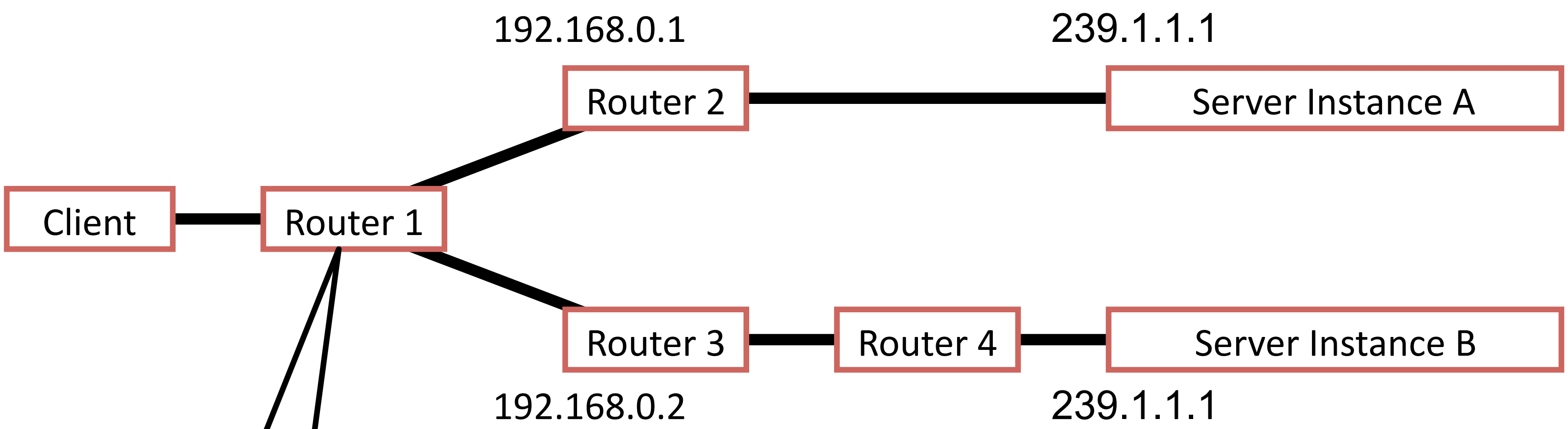
- Subject to the limitations of IP routing
  - No notion of load or other application-layer metrics
  - Convergence time can be slow (as BGP or IGP converge)
- Failover doesn't really work with TCP
  - TCP is stateful: if switch destination replicas, other server instances will just respond with RSTs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

Multicast protocols

Multicasting messages

- Simple application multicast: Iterated unicast
  - Client simply unicasts message to every recipient
  - Pros: simple to implement, no network modifications
  - Cons: O(n) work on sender, network
- Advanced overlay multicast ("peer-to-peer")
  - Build receiver-driven tree
  - Pros: Scalable, no network modifications
  - Cons: O(log n) work on sender, network; complex to implement
- IP multicast
  - Embed receiver-driven tree in network layer
  - Pros: O(1) work on client, O(# receivers) on network
  - Cons: requires network modifications; scalability concerns?

IP multicast in action



Routing Table from Router 1:

Destination	Mask	Next-Hop	Distance
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239.1.1.1	/32	192.168.0.1	1
239.1.1.1	/32	192.168.0.2	2

IP Multicast

- Simple to use in applications
  - Multicast "group" defined by IP multicast address
    - IP multicast addresses look similar to IP unicast addrs
    - 224.0.0.0 to 239.255.255.255 (RPC 3171)
      - 265 M multicast groups at most
  - Best effort delivery only
    - Sender issues single datagram to IP multicast address
    - Routers delivery packets to all subnetworks that have a receiver "belonging" to the group
- Receiver-driven membership
  - Receivers join groups by informing upstream routers
  - Internet Group Management Protocol (v3: RFC 3376)

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)
- Is a router tracking each attached peer?
  - No, only each network, which are broadcast media
- 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 often best effort

- Application protocols on top of UDP
  - Within enterprises
  - Commercial stock exchanges
  - Multimedia content delivery
    - Streaming audio, video, etc.
    - Everybody in group listening/watching same content
    - IPTV
  - Many applications insensitive to loss, and networks managed/provisioned so little/no loss

What if we want reliability?

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
- Once size fits all?
  - Heterogeneity: receivers, links, group sizes
  - Not all multicast apps need reliability of type offered by TCP. Some can tolerate reordering, delay, etc.

Scalable Reliable Multicast

- Receives all packets or unrecoverable data loss
- Data packets sent via IP multicast
  - ODATA includes sequence numbers
- Upon packet failure
  - ACK's don't scale, so…
  - If failures relatively rare, use Negative ACKs (NAKs) instead: "Did not receive expected packet"
  - What if it's the last 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 NAK confirmation (NCF)
- Scale through NAK suppression
  - If received a NAK or NCF, don't NAK yourself
  - What do we need to do to get adequate suppression?
    - Add random delays before NAK'ing
    - But what if the multicast group grows big?
      - Delay needs to grow → lack of efficiency
- Repair through packet retransmission (RDATA)
  - From initial sender
  - From designated local repairer (DLR – IETF loves acronyms!)

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

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