CS 3700

Networks and Distributed Systems

Lecture 12: Quality of Service (QoS)

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- Should the network give better quality to some packets?

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2. Bandwidth required to provide performance
   - How to meet performance goals…
   - While still offering general service to all applications
3. Complexity/cost of required mechanisms
   - How to modify the network to meet perf. goals?
   - Political concerns, e.g. network neutrality
   - Security

QoS: Quality of Service

- Idea: build some unfairness into the network
  - Some traffic is high priority, gets better service
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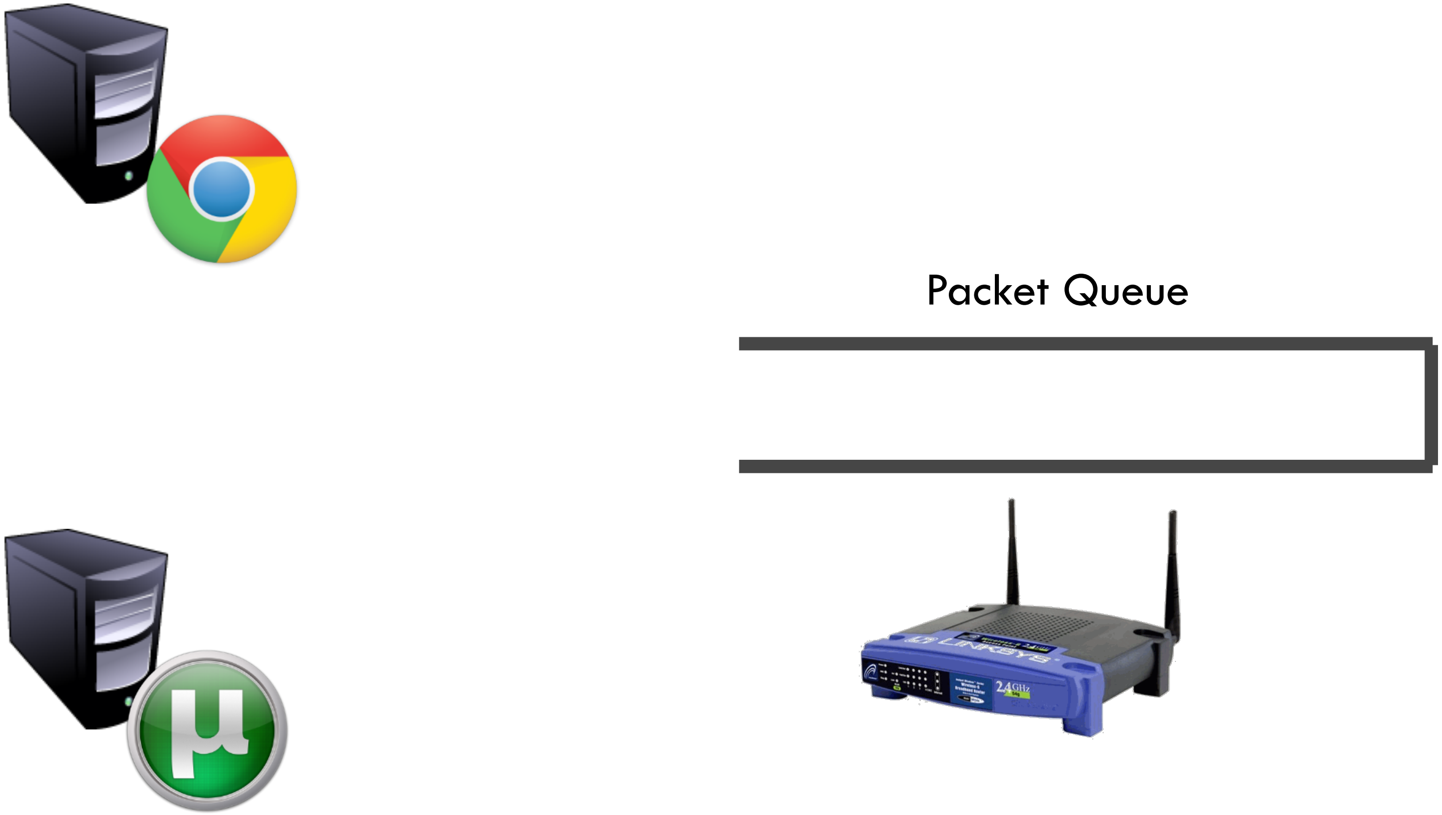
- Thus, “important” traffic receives “better” service
  - What traffic is important?
  - What do we mean by “better” service?
    - Is the gain guaranteed and strictly defined?
    - Is the gain relative and fungible?

Outline

- “Soft” QoS
  - Packet shaping/prioritization
  - DiffServ
- “Hard” QoS
  - IntServ

The Problem at the Edge

□ Problem: sharing resources between applications



Packet Queue

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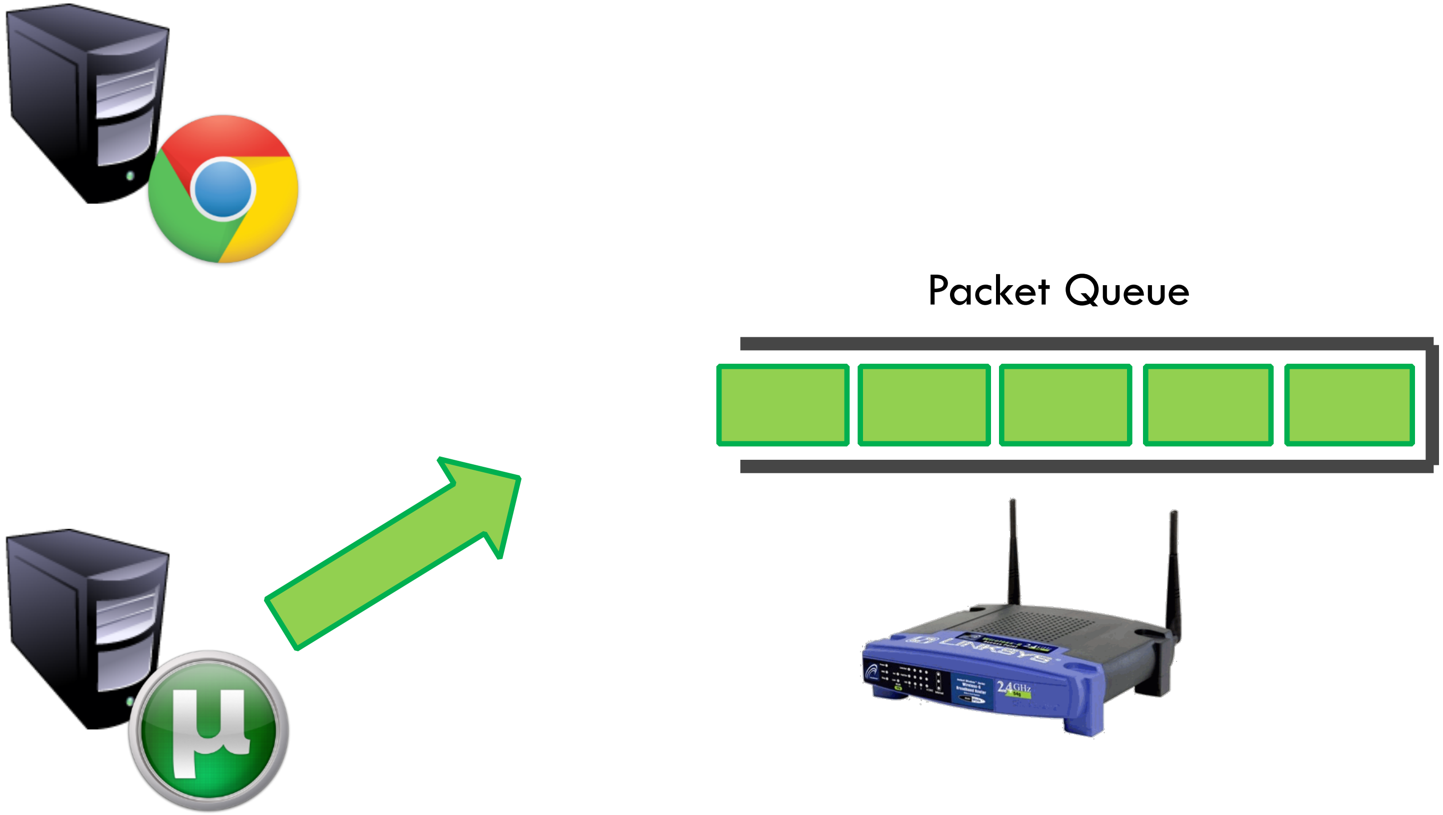

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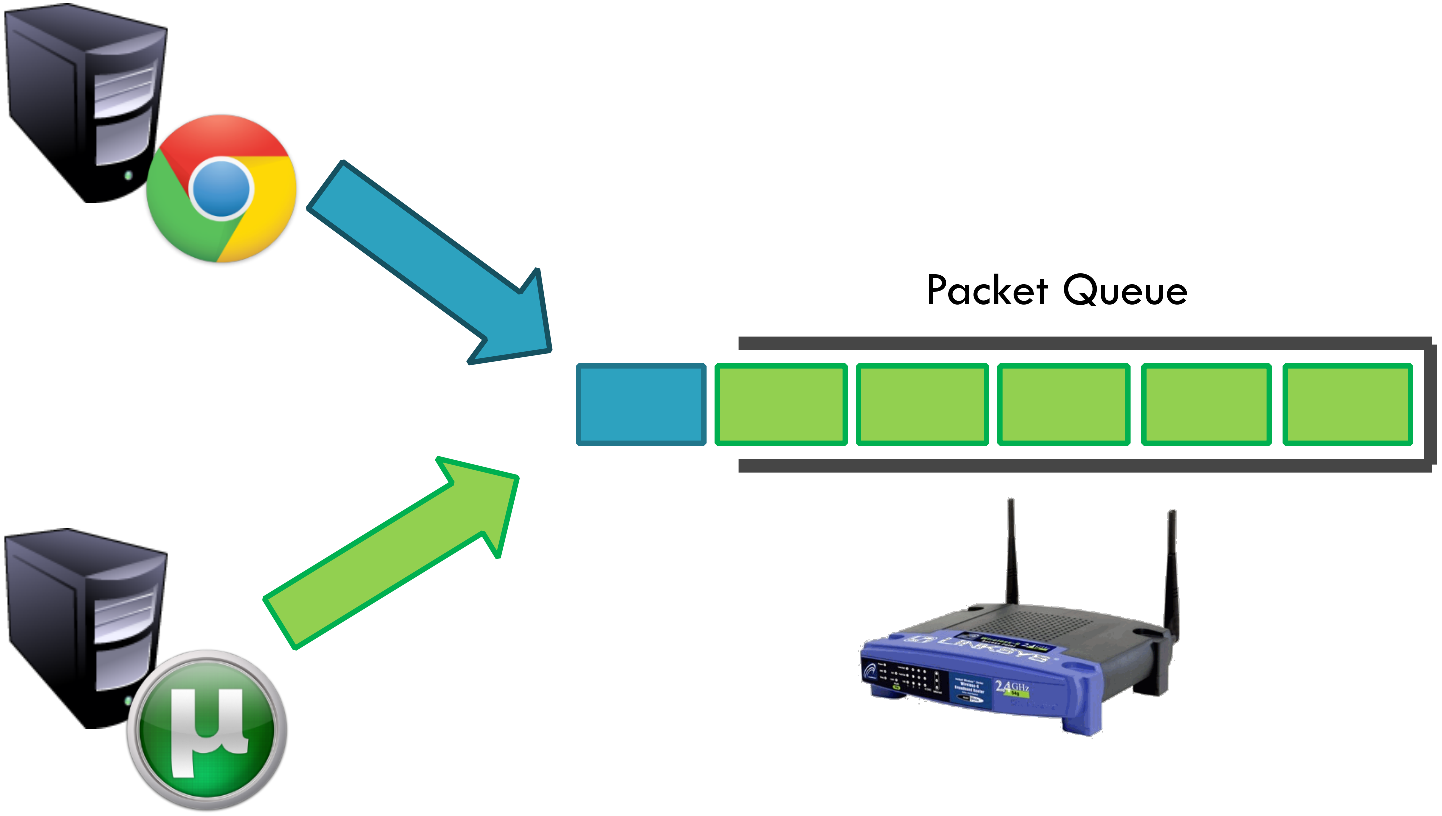

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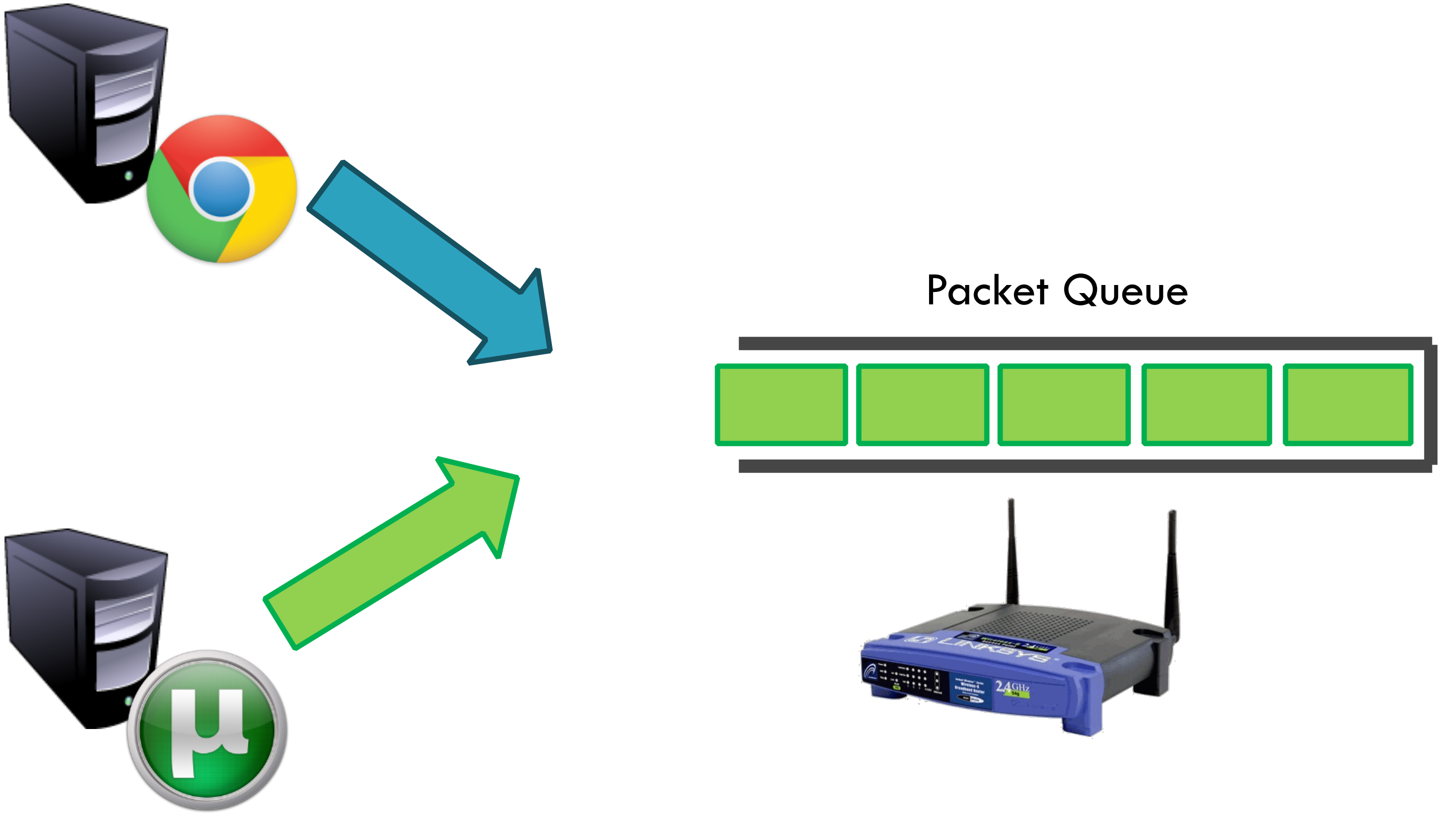
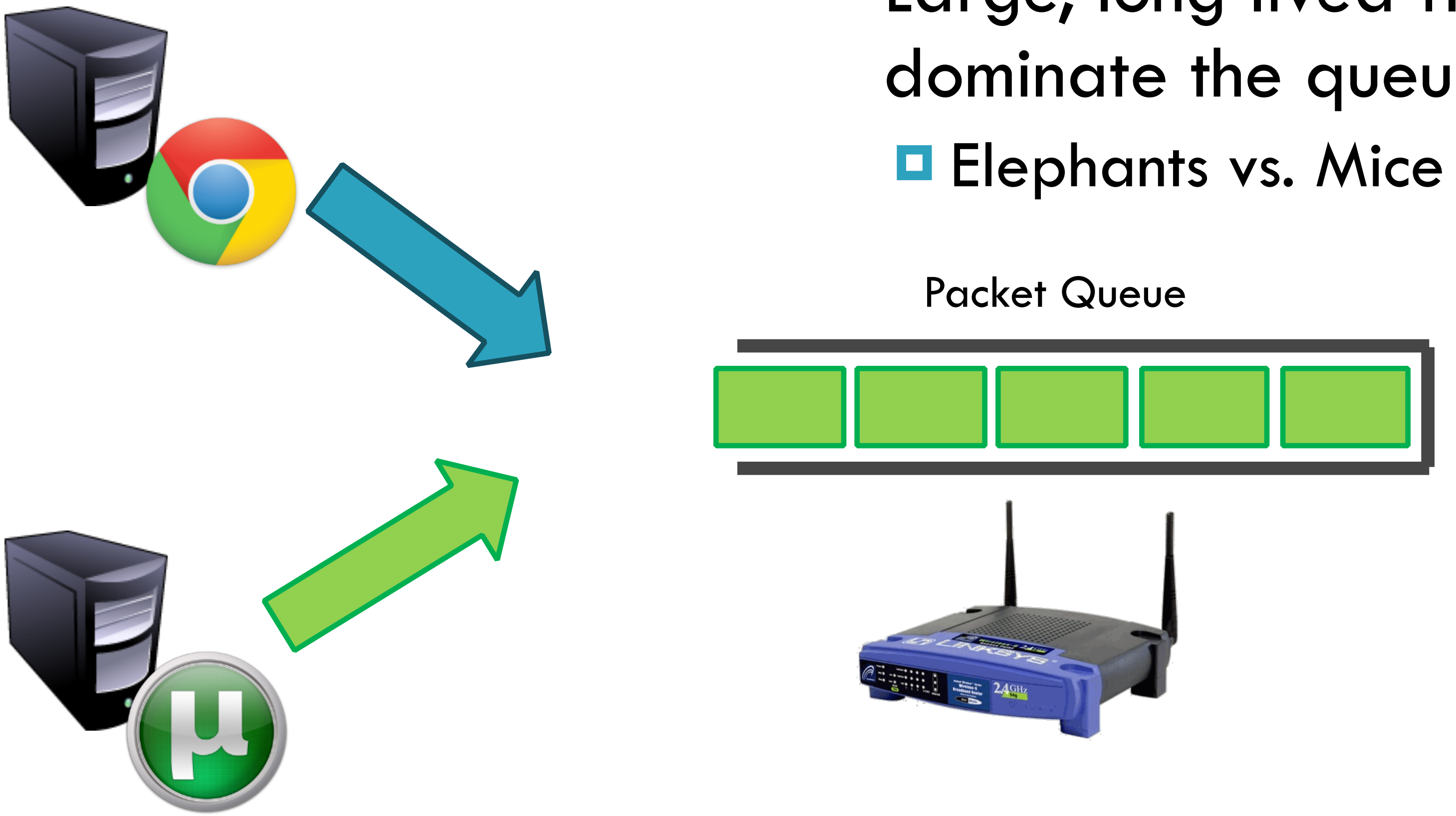


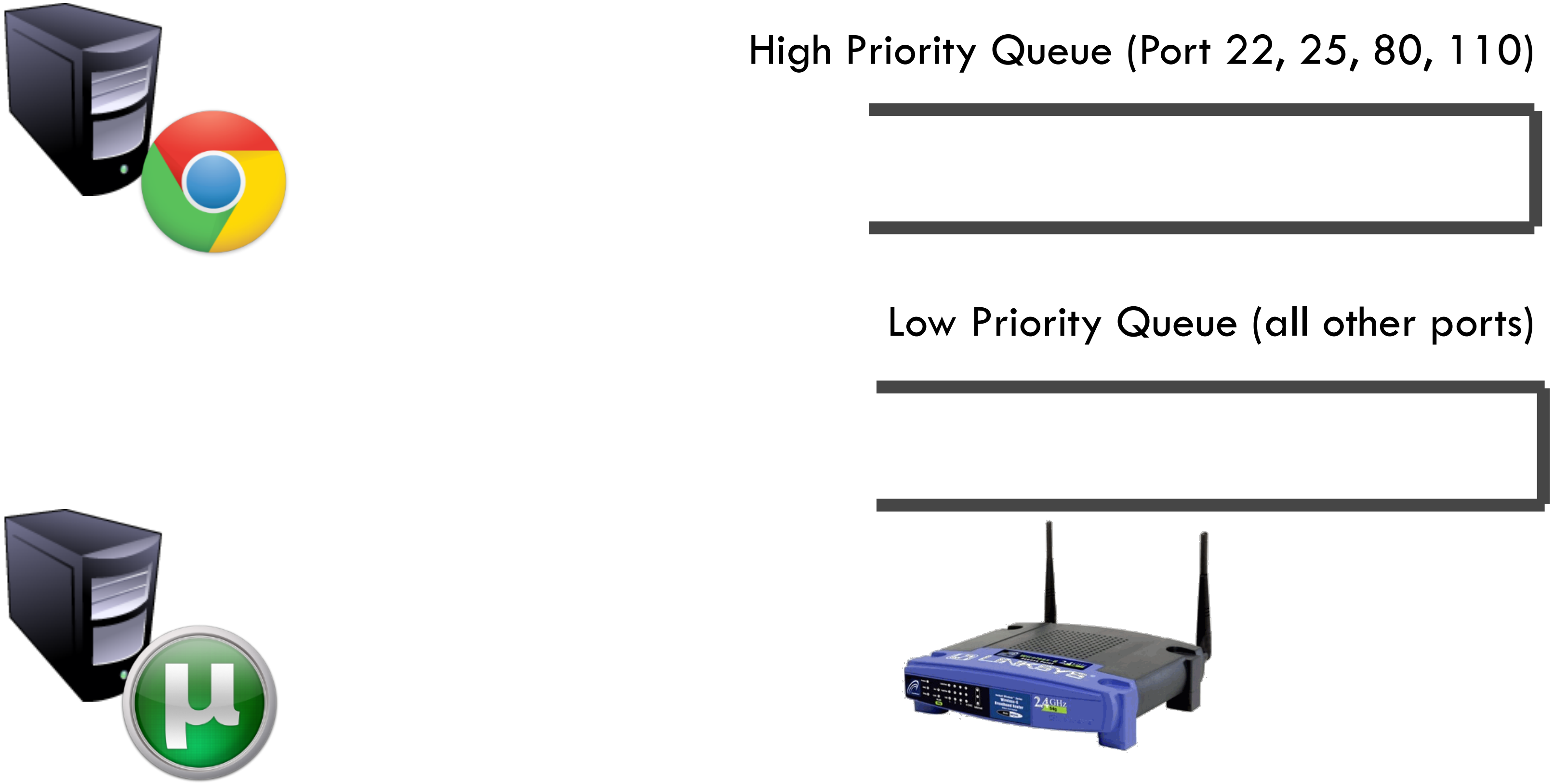
The Problem at the Edge

- Problem: sharing resources between applications
  - Large, long lived flows can dominate the queue
    - Elephants vs. Mice



Port-Based Priority Queues

- Port-based QoS
  - Very common in home routers



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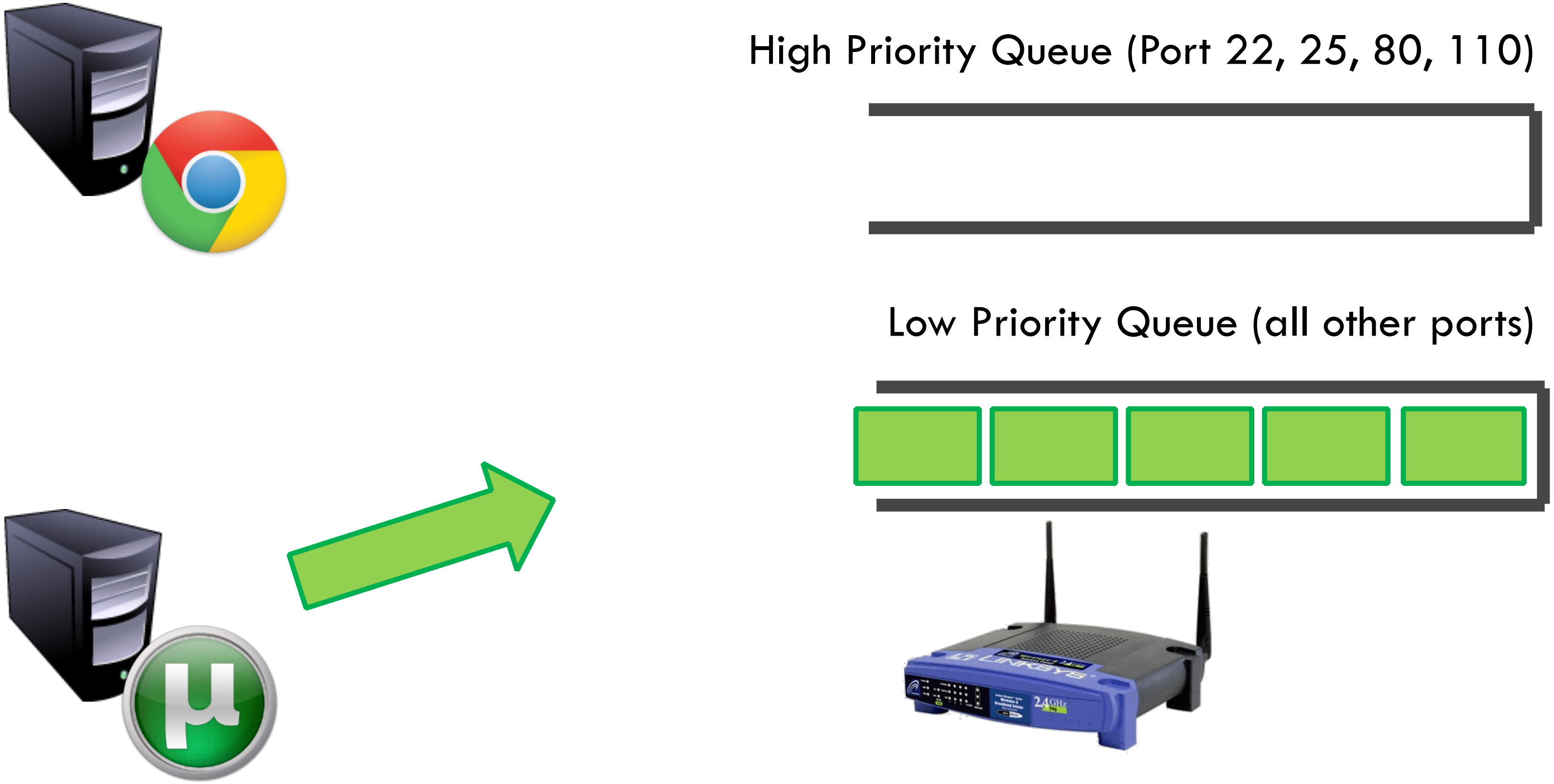
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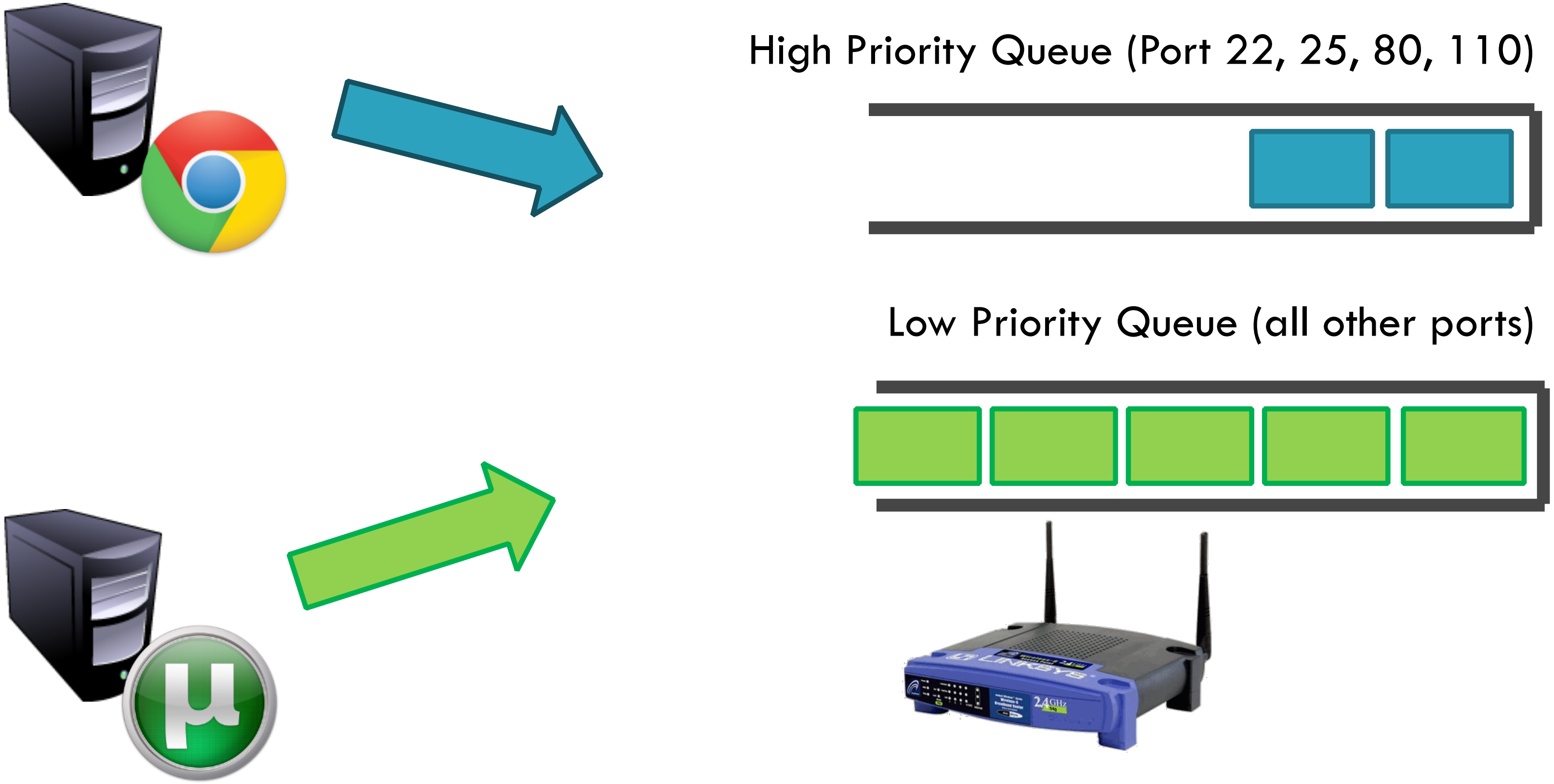

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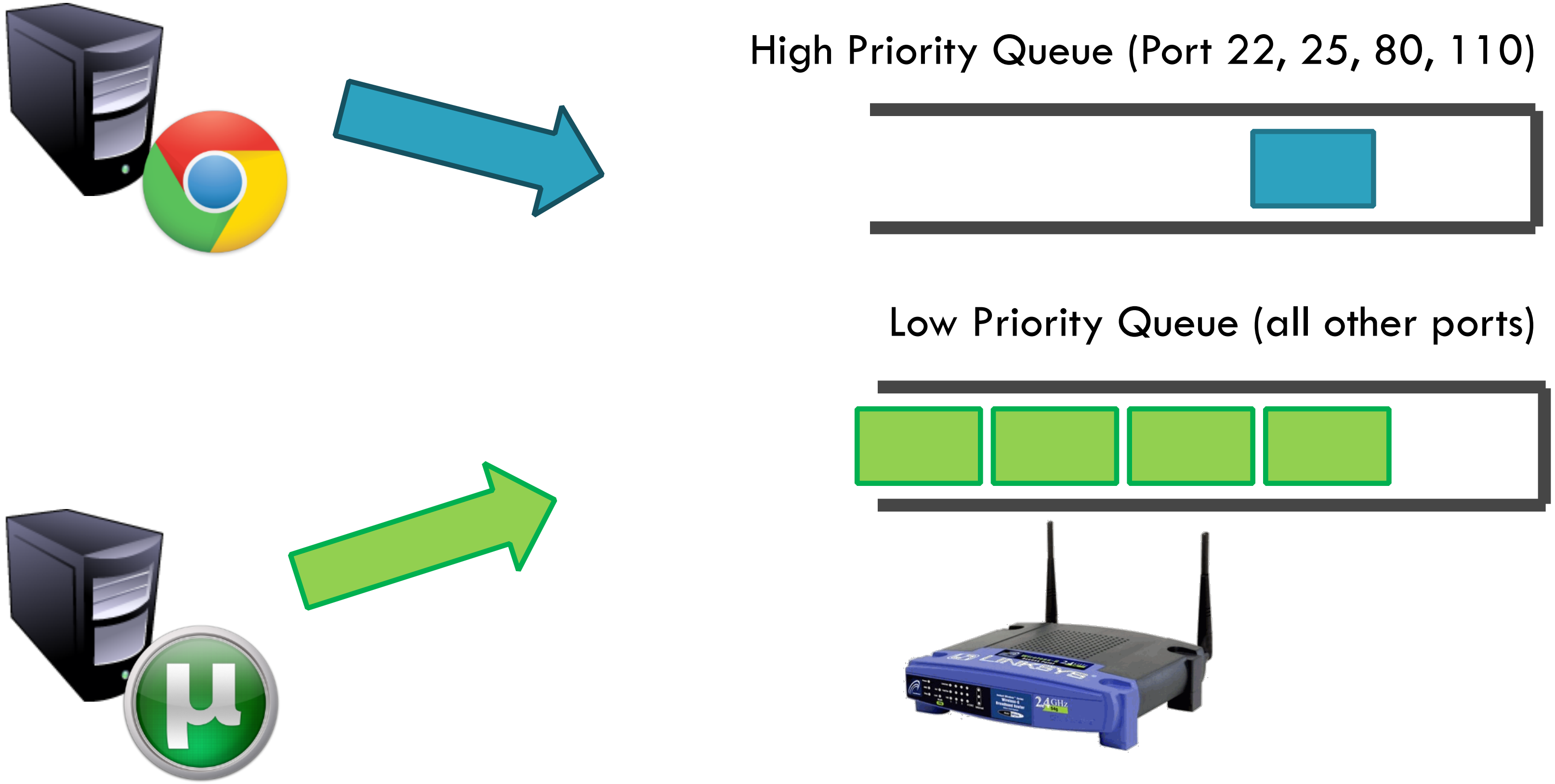

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  - Differentiated Service (DiffServ)
    - Class-based traffic management mechanism
    - Coarse grain control
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  - Differentiated Service (DiffServ)
    - Class-based traffic management mechanism
    - Coarse grain control
    - Relative performance improvements / lower overhead
  - Integrated Service (IntServ)
    - Flow-based traffic management mechanism
    - Fine grained control
    - Guaranteed performance / high overhead

Differentiated Services (DiffServ)

- Goal: offer different levels of service to packets
  - Organized around domains (ASs)
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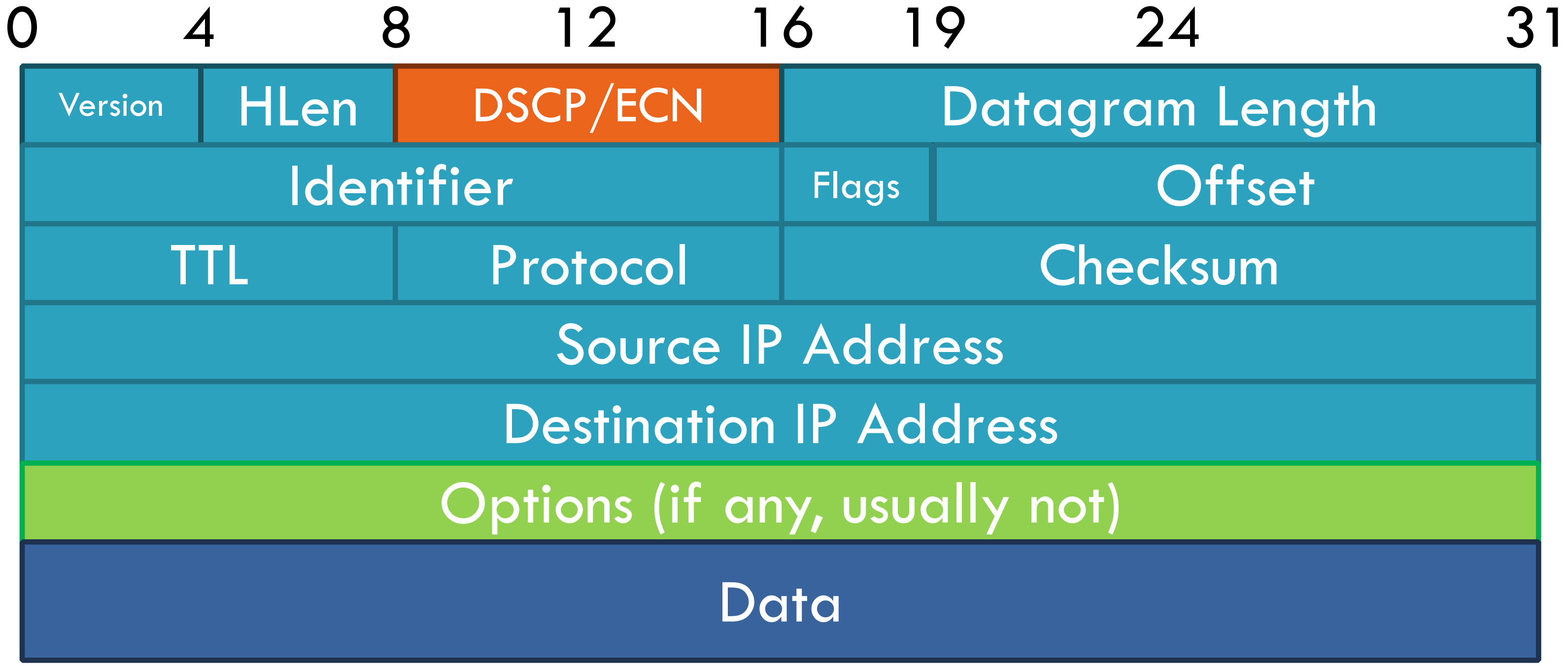
- Core Routers
  - Handle per-hop packet behavior based on DSCP

IP Header, Revisited



0 4 8 12 16 19 24 31

Version HLen DSCP/ECN Datagram Length

Identifier Flags Offset

TTL Protocol Checksum

Source IP Address

Destination IP Address

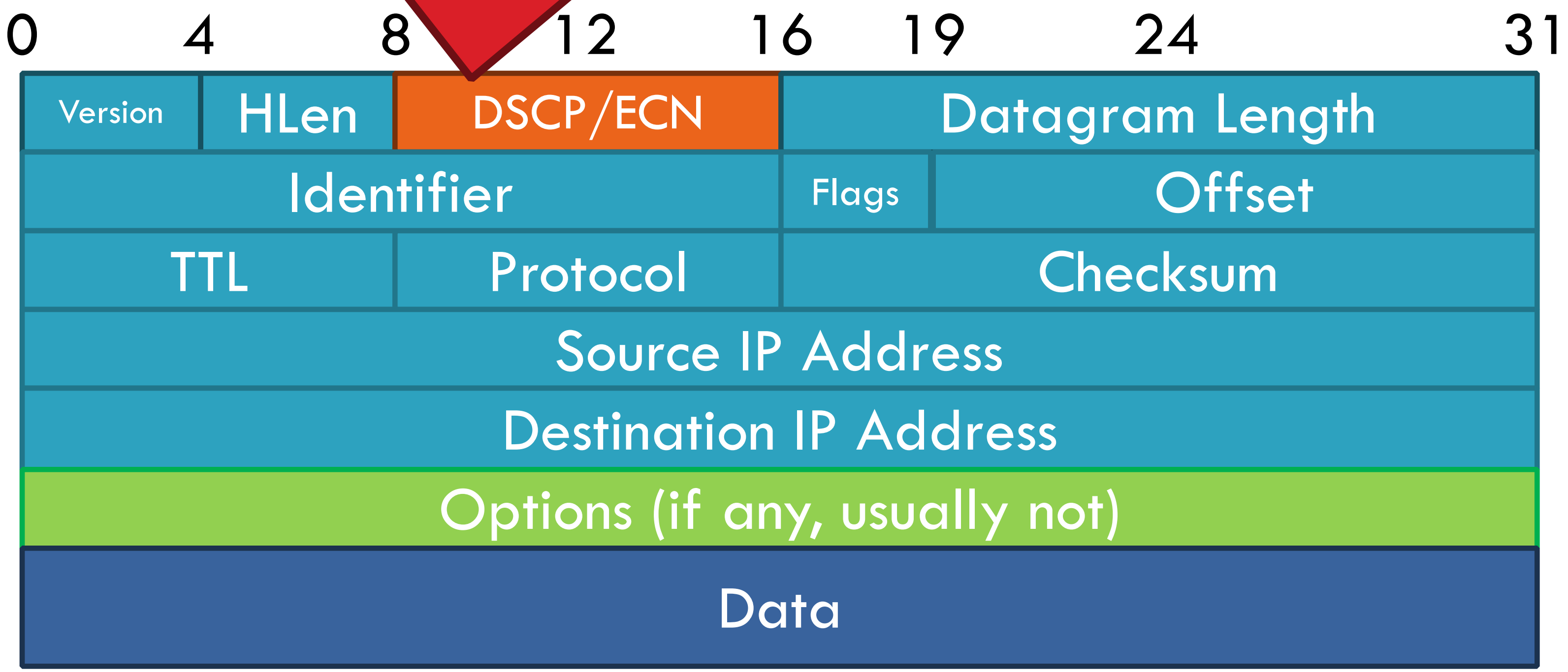
Options (if any, usually not)

Data

IP Header, Revisited

DiffServ Code Point

Used to label the class of the packet



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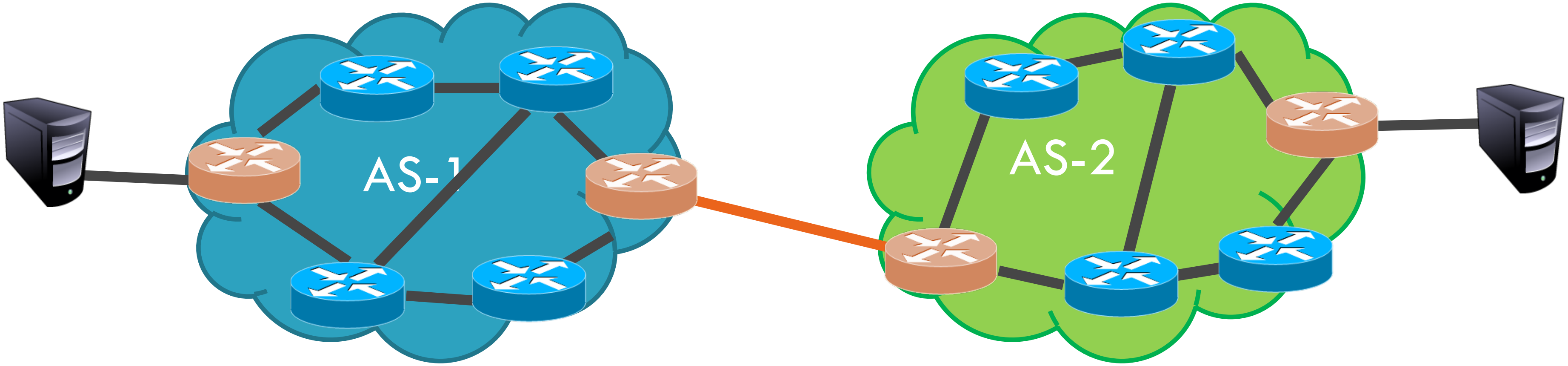
DiffServ at a High-Level



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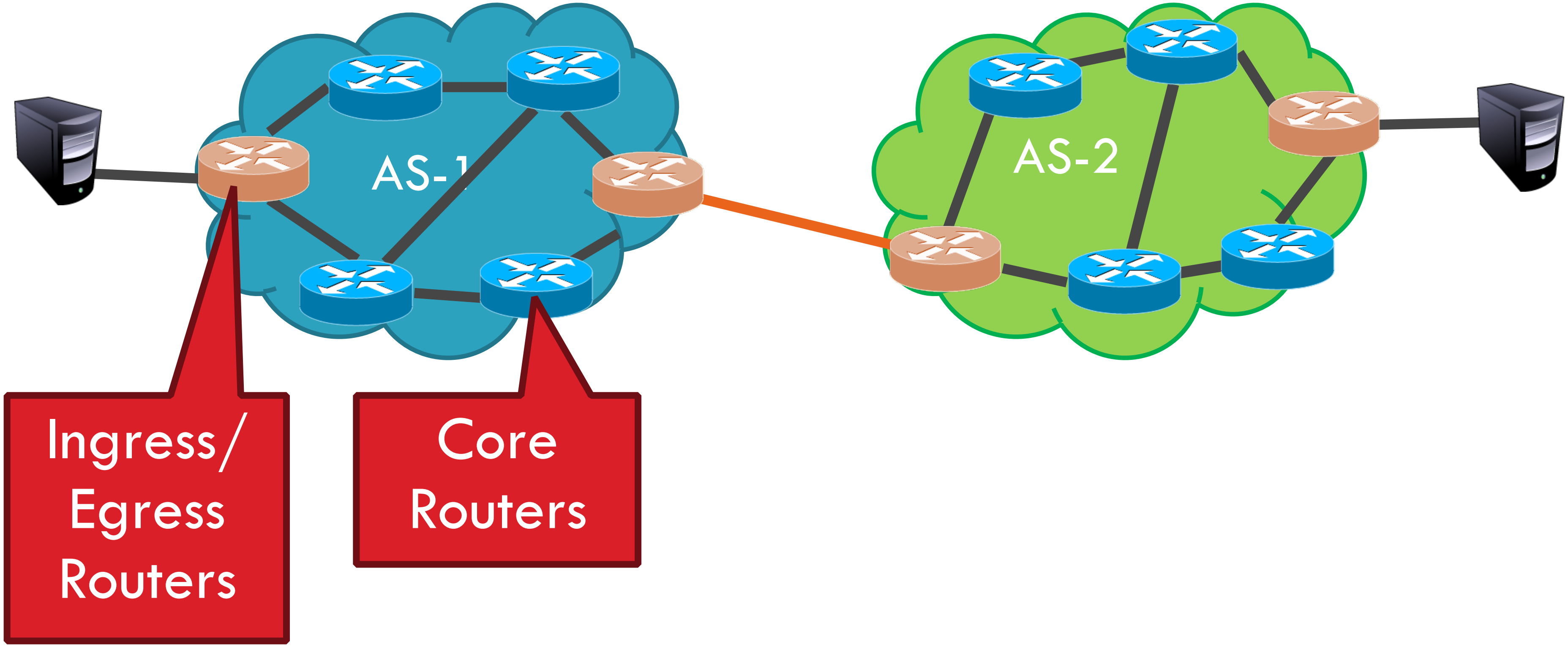

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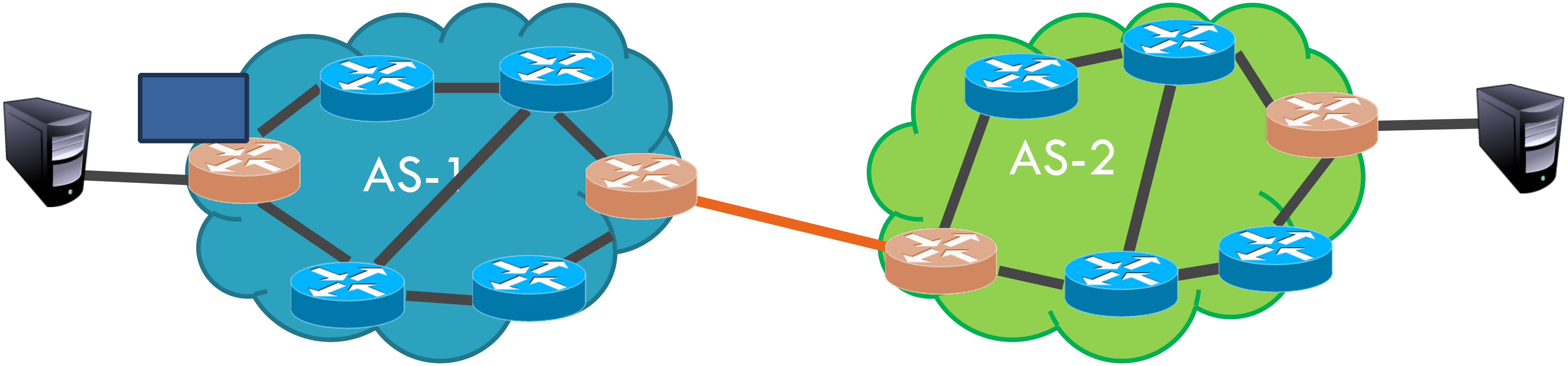

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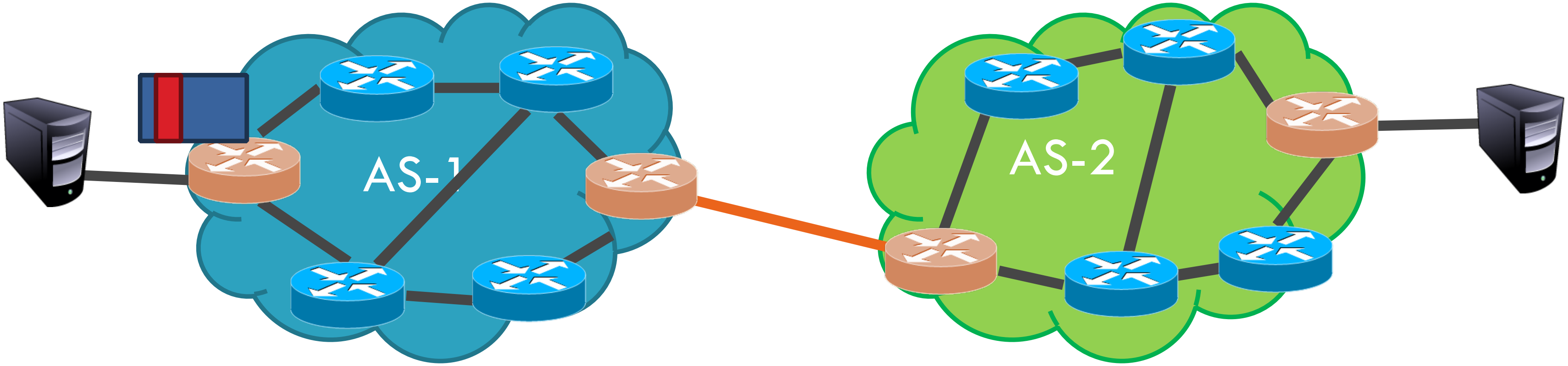

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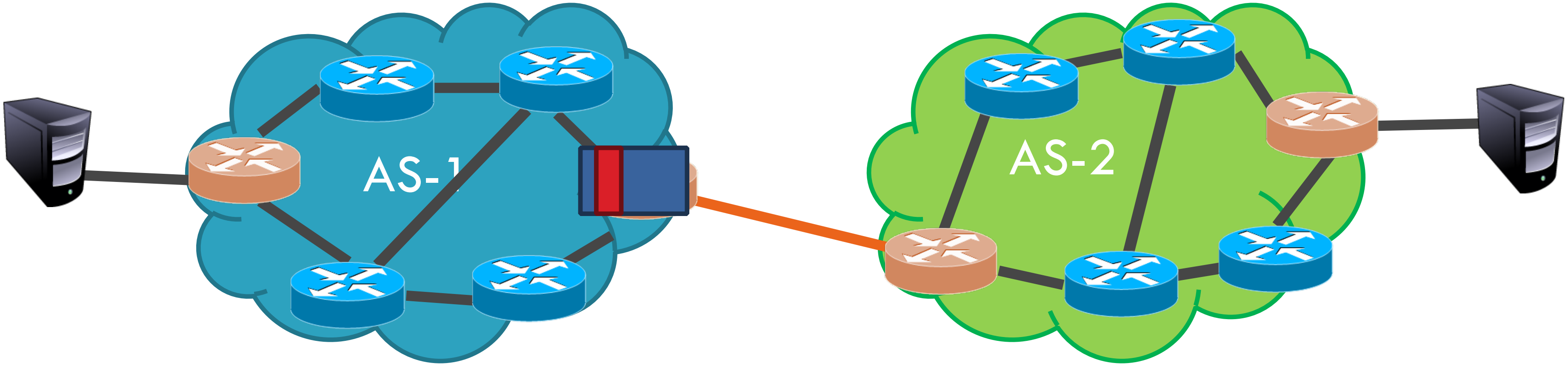

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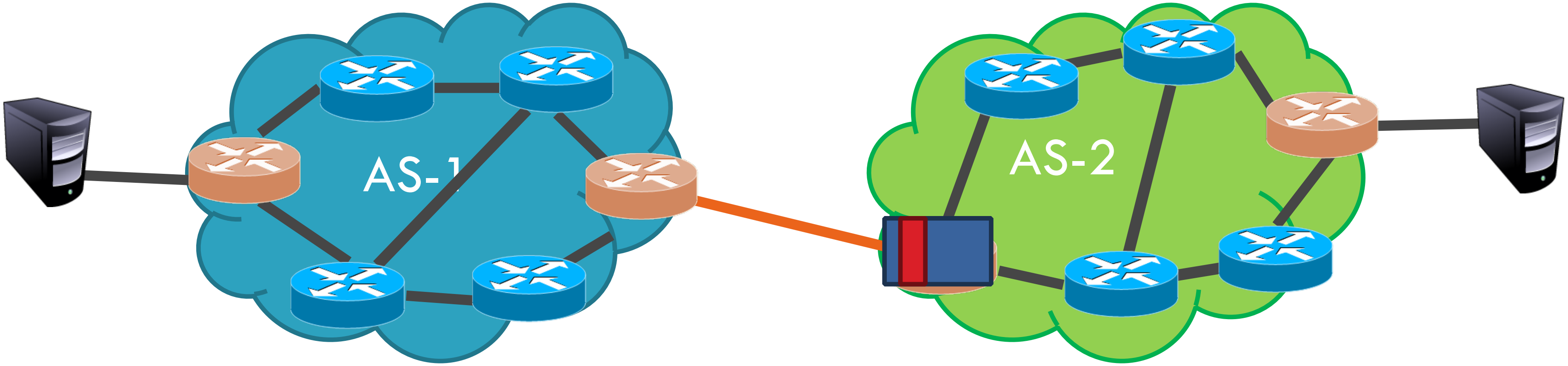

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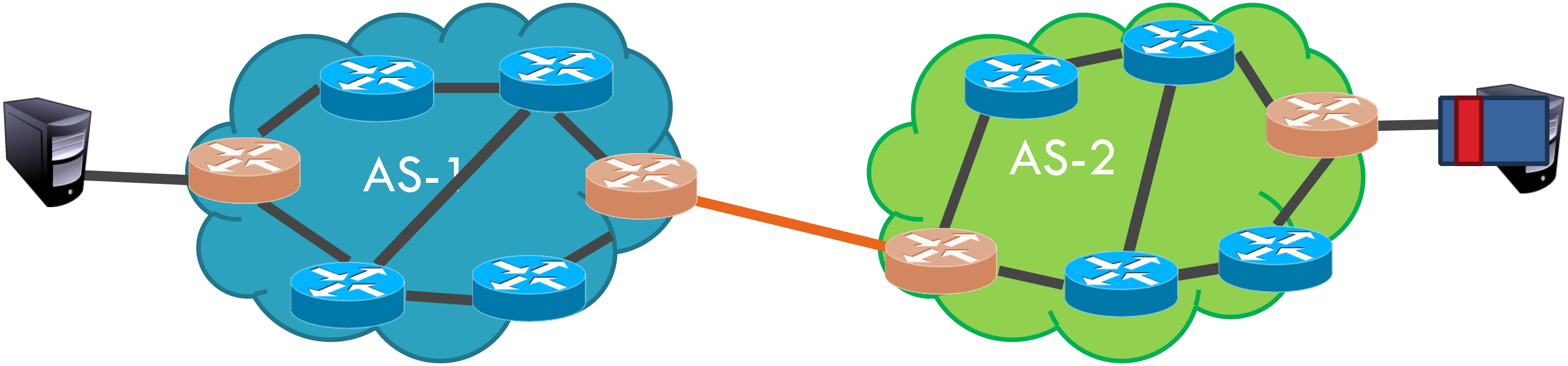

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- Classes may switch between AS boundaries

Per-Hop Behavior

- Traffic classes indicated by 6-bit DSCP in IP header
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3. Assured Forwarding (AF) PHB
   - More general class with assurance of delivery
   - Only if traffic rate < subscribed rate

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  - Based on who pays more $$$
    - $100 for “premium” Internet vs. $25 “value” Internet

Traffic Policing/Shaping

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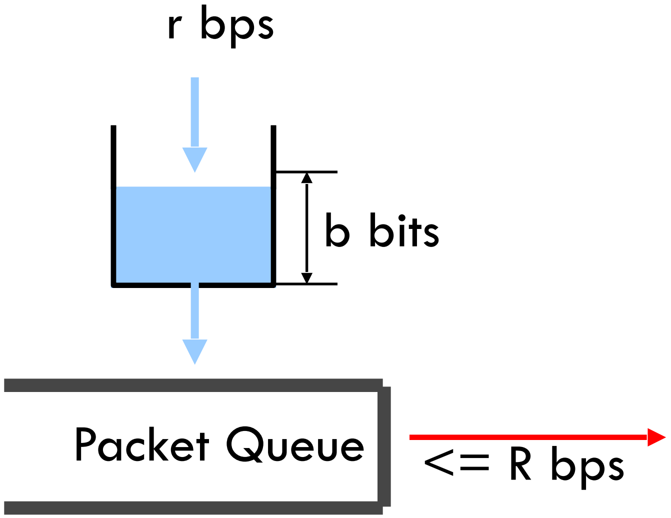
- Token bucket (r, b)
  - r → rate the bucket fills
  - b → size of tokens in the bucket
- Police: if token is available, packet may pass
  - Otherwise, packet is queued or dropped
  - Queuing packets "shapes" the traffic flow

Leaky Buckets

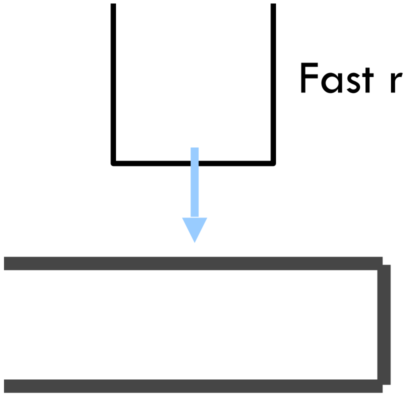
- Parameters
  - r –rate at which tokens fill the bucket
  - b – bucket depth
  - R – maximum link capacity or peak rate

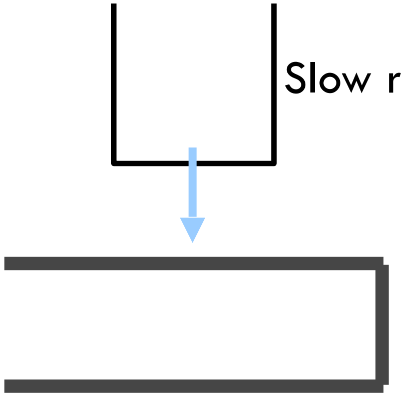


- Bits are only transmitted from a queue when there is a token of sufficient size available

Bucket Parameters, Intuitively

- r – speed packets can exit the queue





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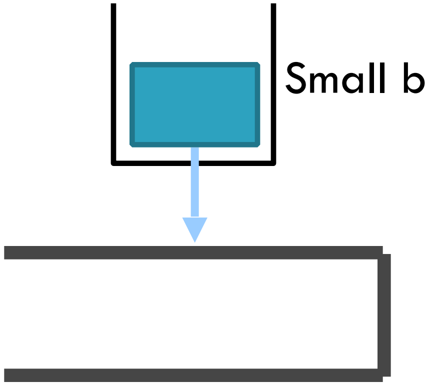

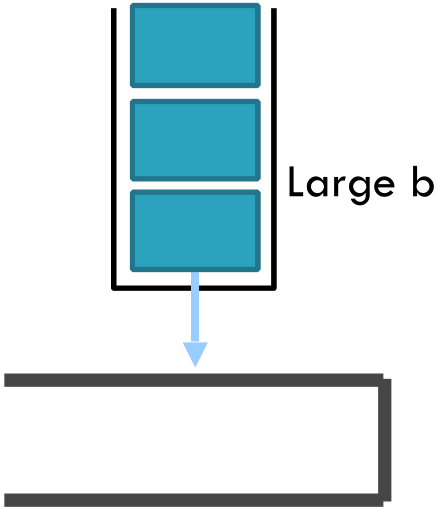

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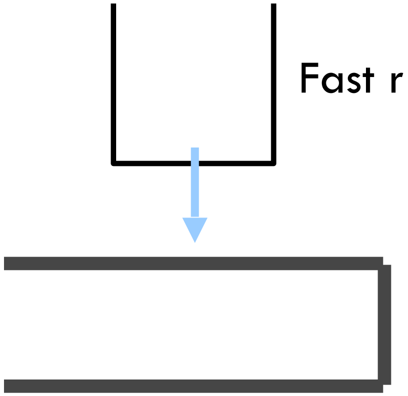

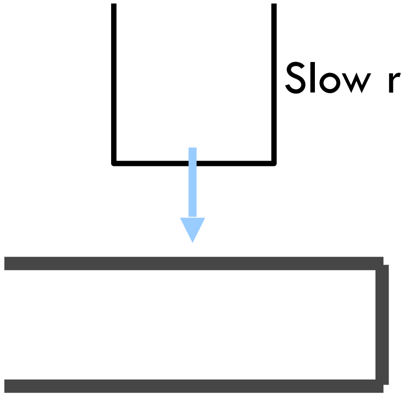

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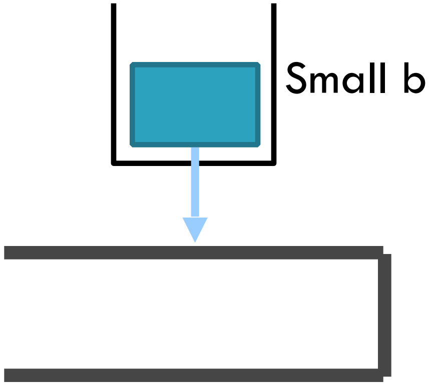

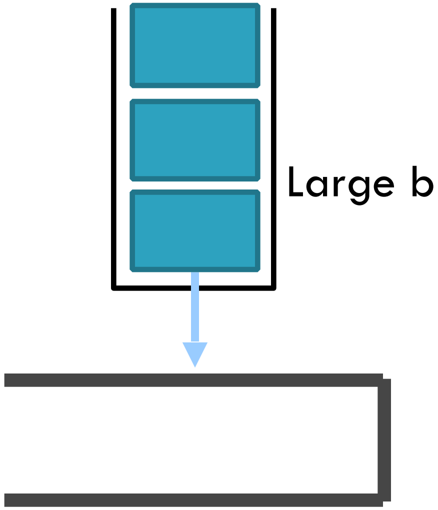

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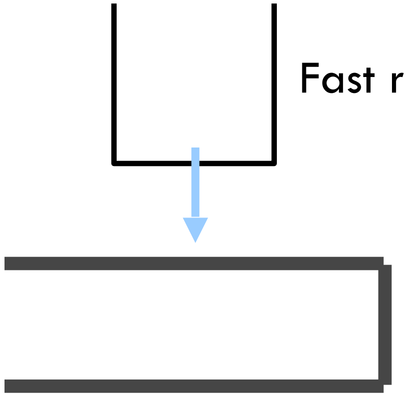

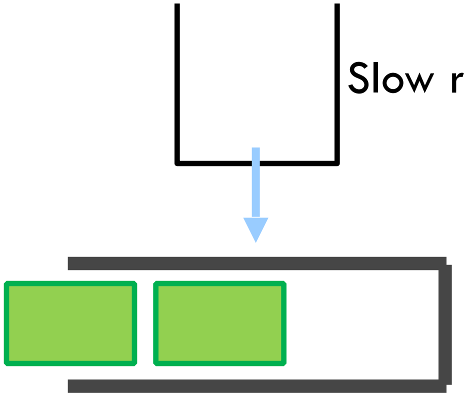

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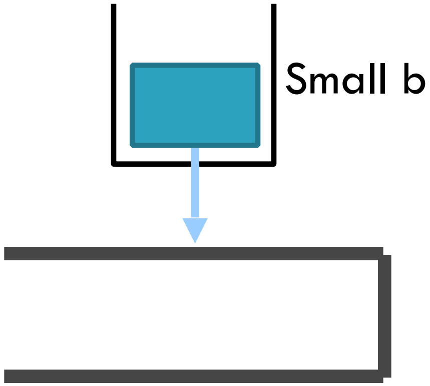

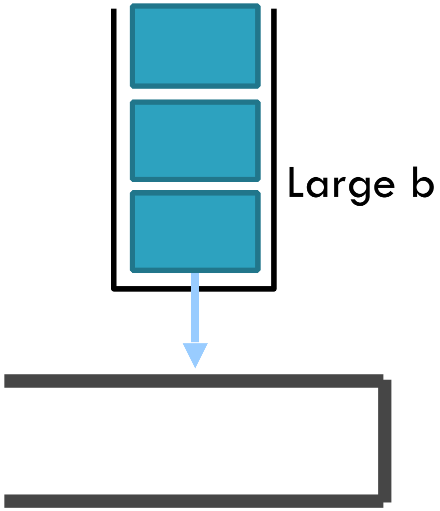

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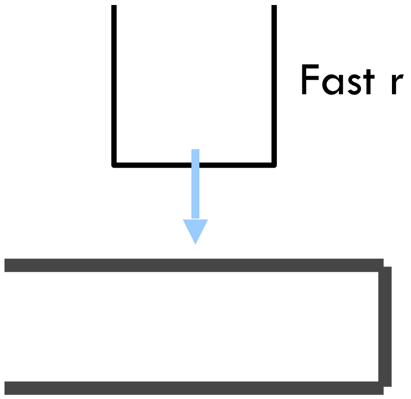

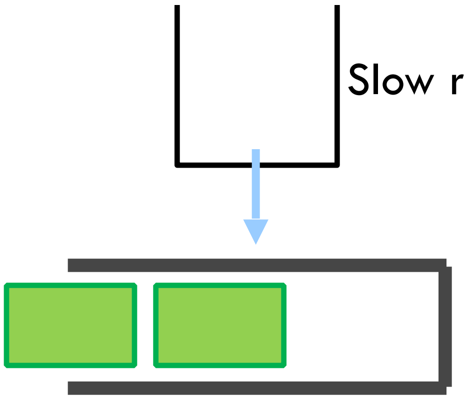

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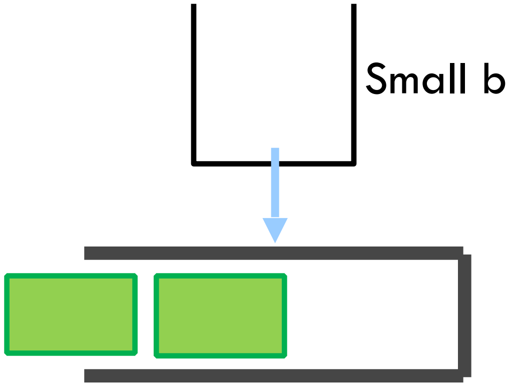

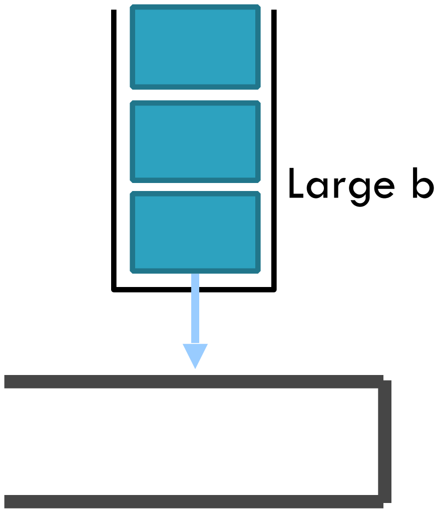

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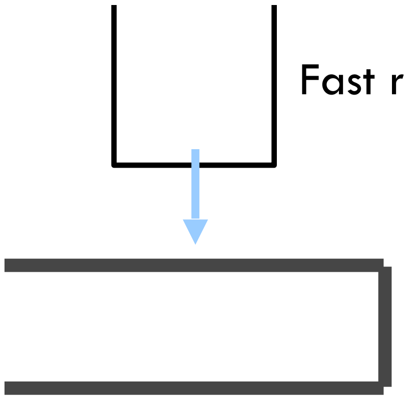

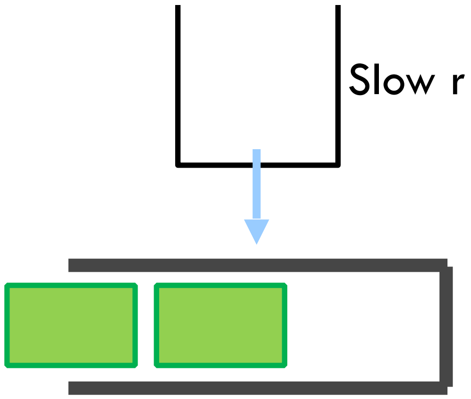

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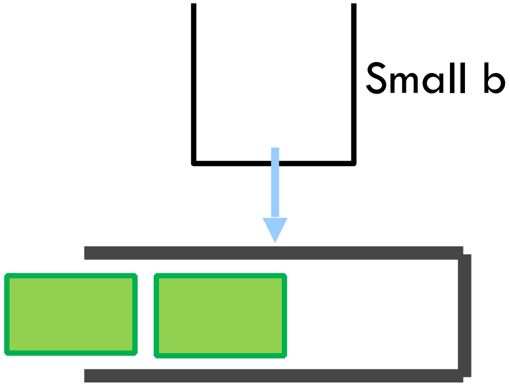

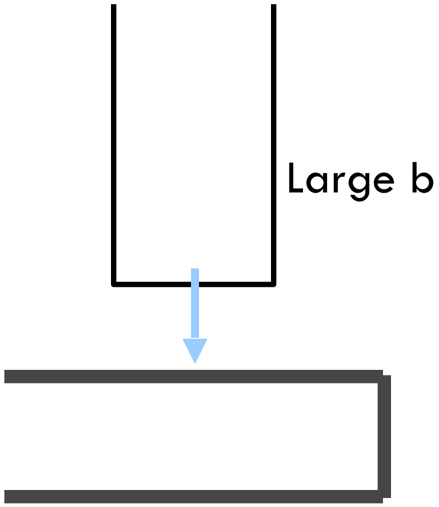

Advantages of DiffServ

- Giving priority does improve performance
  - … at the expense of reduced perf. for lower classes
- Relatively lightweight solution
  - Some overhead on ingress/egress routers
  - No per flow state, low overhead on core routers
- Easy to deploy
  - No hard reservations
  - No advanced setup of flows
  - No end-to-end negotiation

Disadvantages of DiffServ

- No performance guarantees
  - All gains are relative, not absolute
  - Classes are very coarse
    - i.e. all packets of a specific class get better performance
    - No per flow or per destination QoS
  - What if some ASs do not support DiffServ?
  - Impossible to predict end-to-end behavior
- Security
  - Any host can tag traffic as high priority
  - E.g. Win 2K tagged all traffic as high priority by default

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- Service Level Agreements (SLAs) specify:
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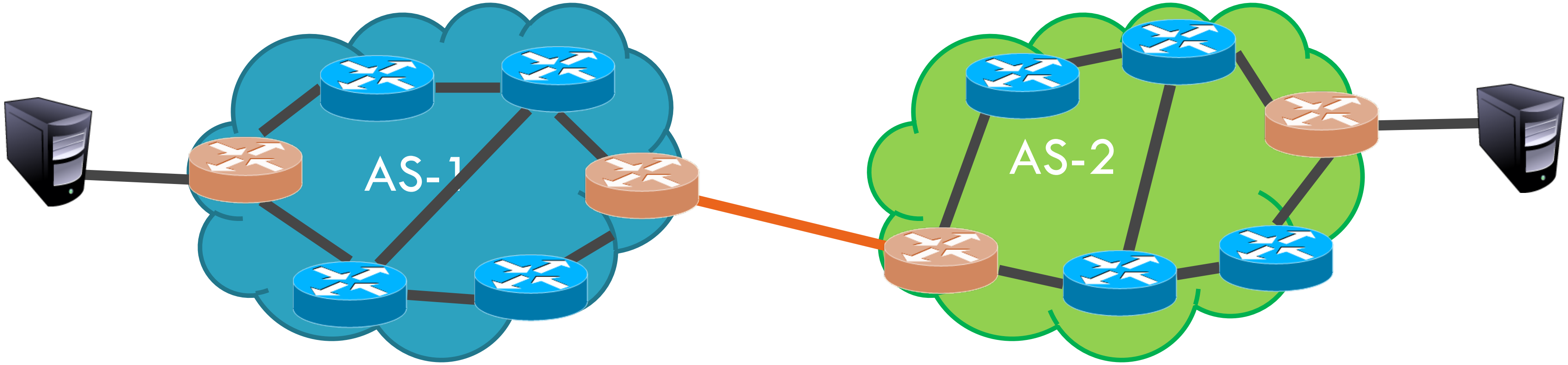
  - Level of service delivered to that traffic
- DiffServ offers low (but unspecified) delay and no drops
  - Acceptance of proposed SLAs managed by "Bandwidth Broker"
  - Only over long time scales

Inter-Domain Premium DiffServ

- Goal of IntServ: end-to-end bandwidth guarantees
- Mechanism: end-to-end bandwidth reservations
  - Like the telephone network, circuit reservations
  - End hosts ask for reserved capacity from the network



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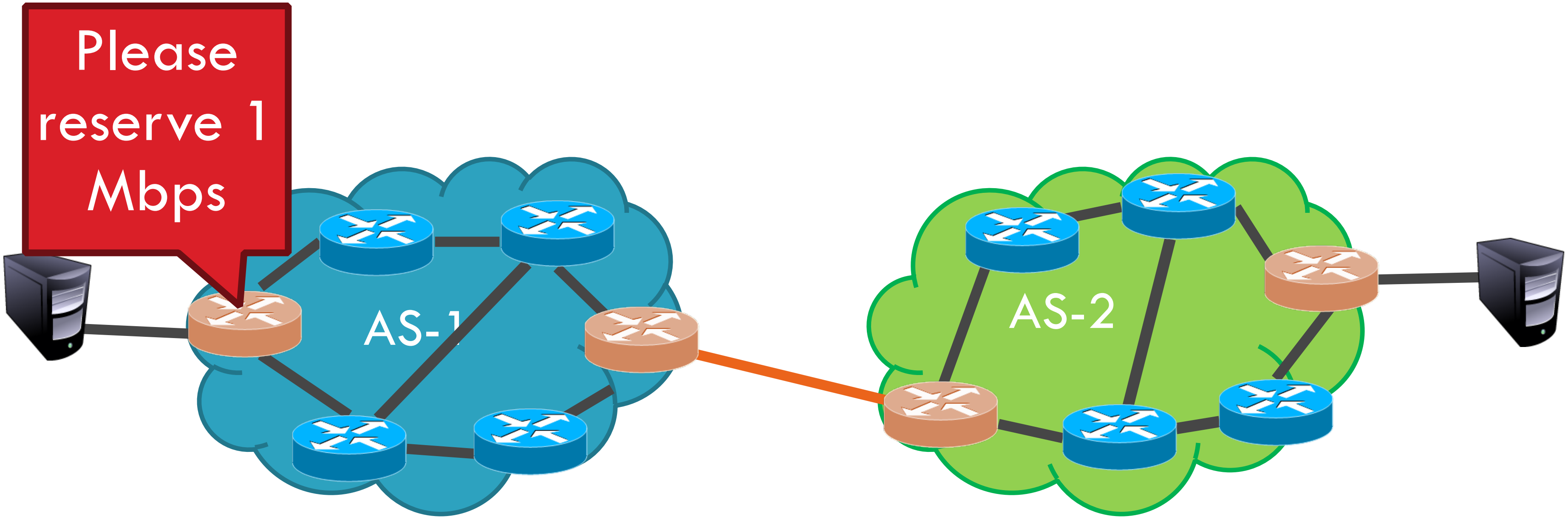

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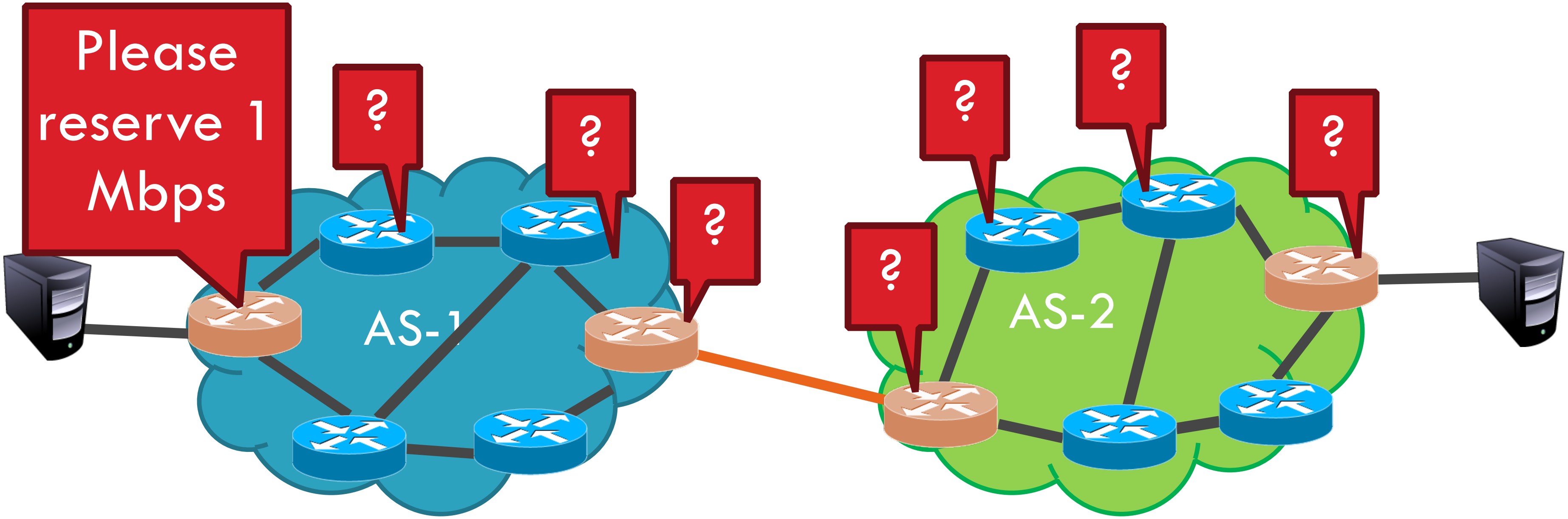

Philosophical Battle

- If your network allows reservations:
  - Then you must perform admission control
  - i.e. who can make reservations, and when?

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  - i.e. who can make reservations, and when?
- Basic Question:
  - Should all flows be admitted (current Internet)
  - Or, should we refuse some flows to guarantee good service for reserved flows (IntServ Internet)

Philosophical Battle

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  - i.e. who can make reservations, and when?
- Basic Question:
  - Should all flows be admitted (current Internet)
  - Or, should we refuse some flows to guarantee good service for reserved flows (IntServ Internet)
- Which one is right?!?!

High-Level IntServ Design

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  - Applications know their own requirements
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- IntServ is multicast-oriented
  - Assumed that large broadcasts would drive multicast and IntServ deployment
  - This is why reservations are made by receivers

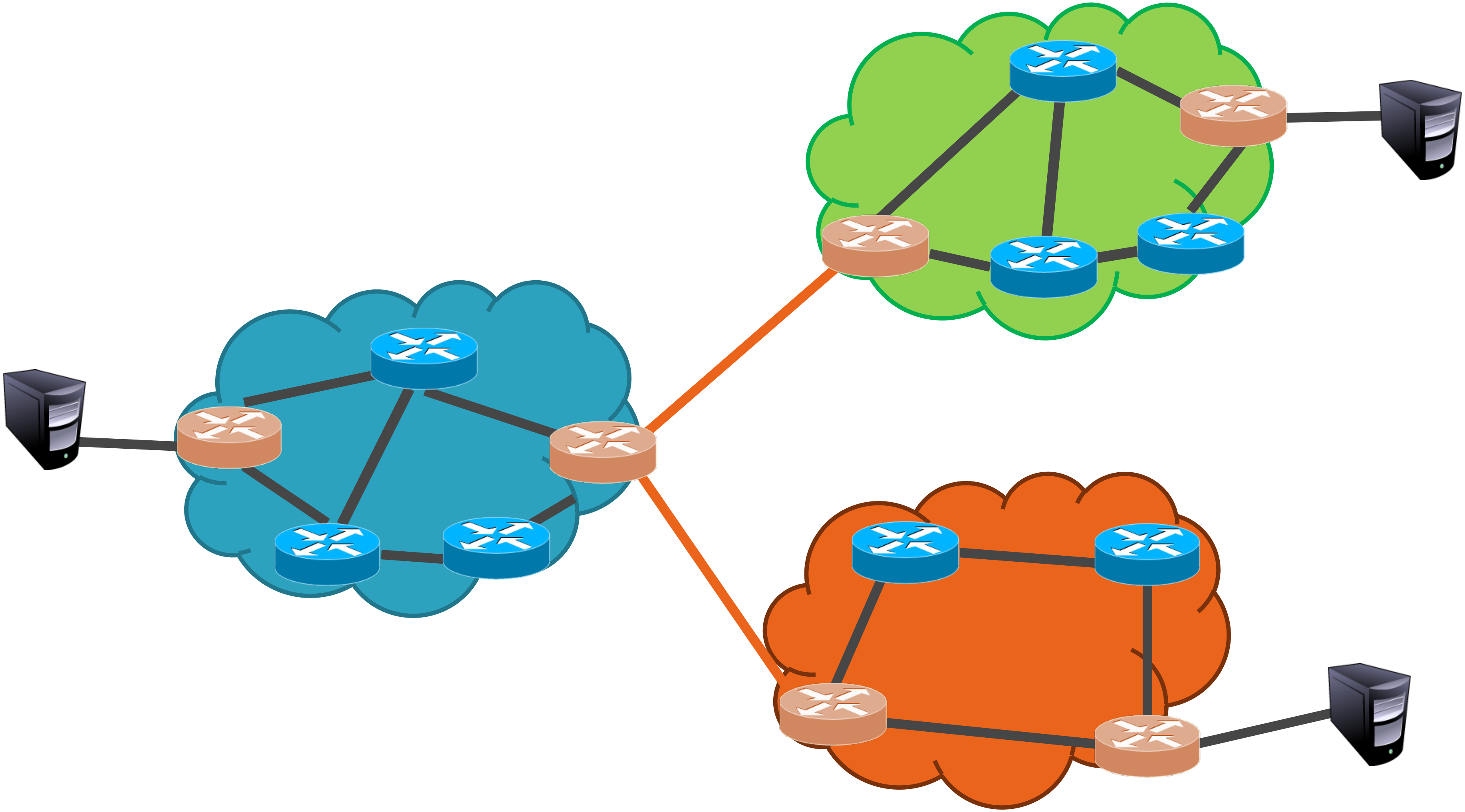
Requirements for IntServ

- Fixed, stable paths
  - Only routers on the path know about the reservation
  - Current Internet cannot guarantee this
- Routers maintain per-flow state
  - Very high overhead (even with soft-state)
- State is used to reserve bandwidth
  - Guarantees QoS for reserved flows
  - … but some flows may not be admitted
  - Security?

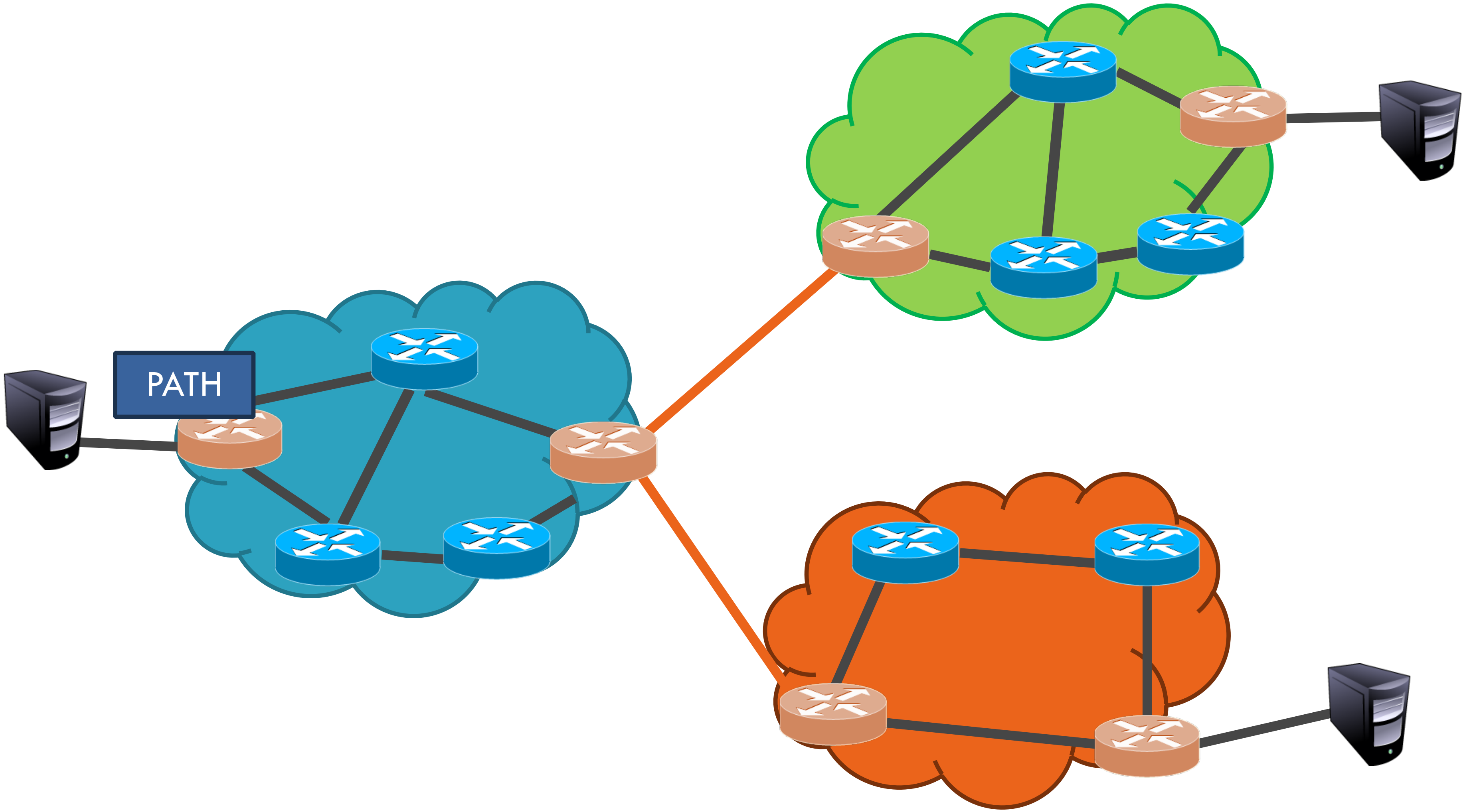
RSVP Reservation Protocol

- Performs signaling to set up reservation state
  - Initiated by the receiver
- Each reservation is a simplex data flow sent to a unicast or multicast address
  - <Destination IP, protocol # (TCP, UDP), port #>
- Multiple senders/receivers can be in the same session

RSVP Example



RSVP Example



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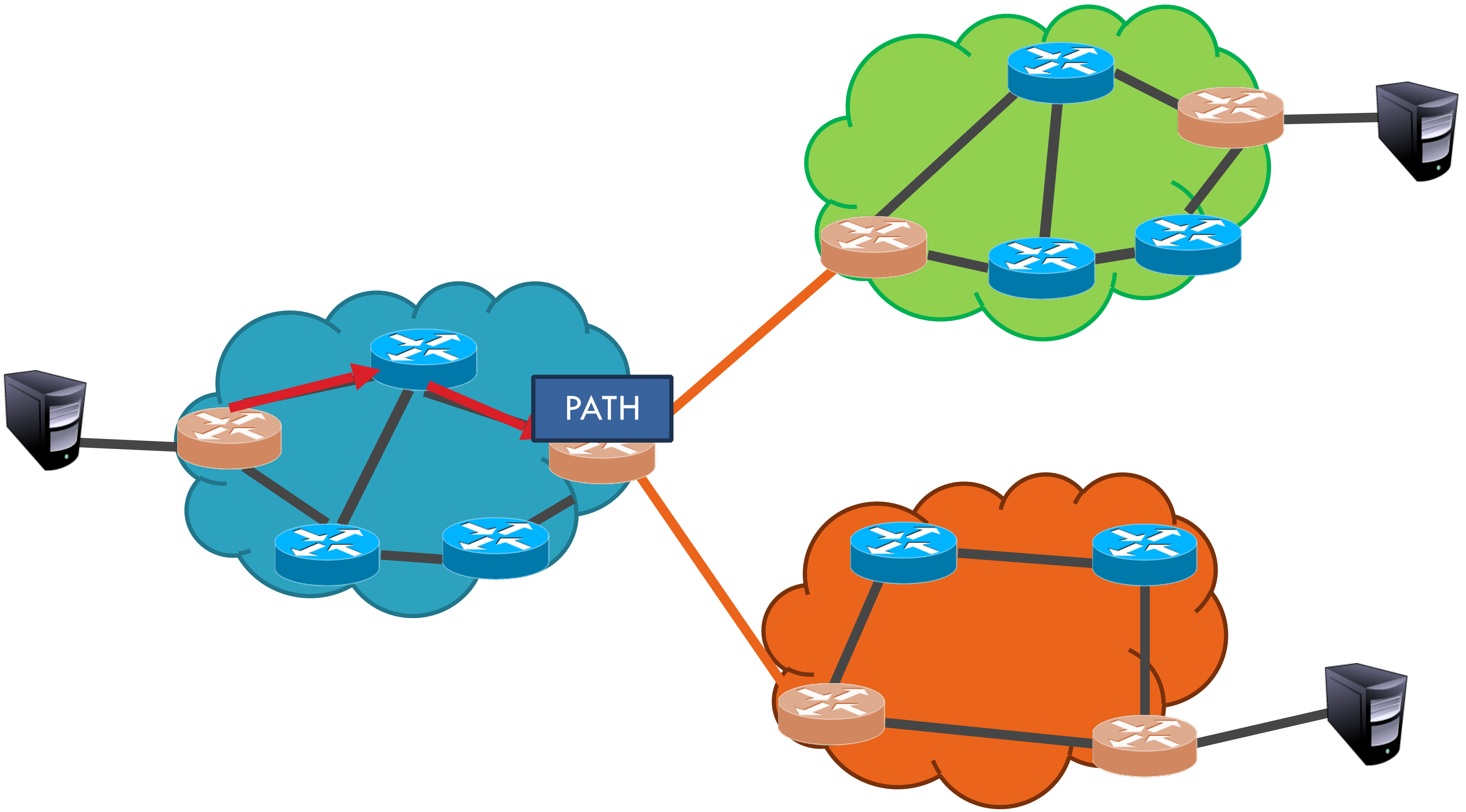

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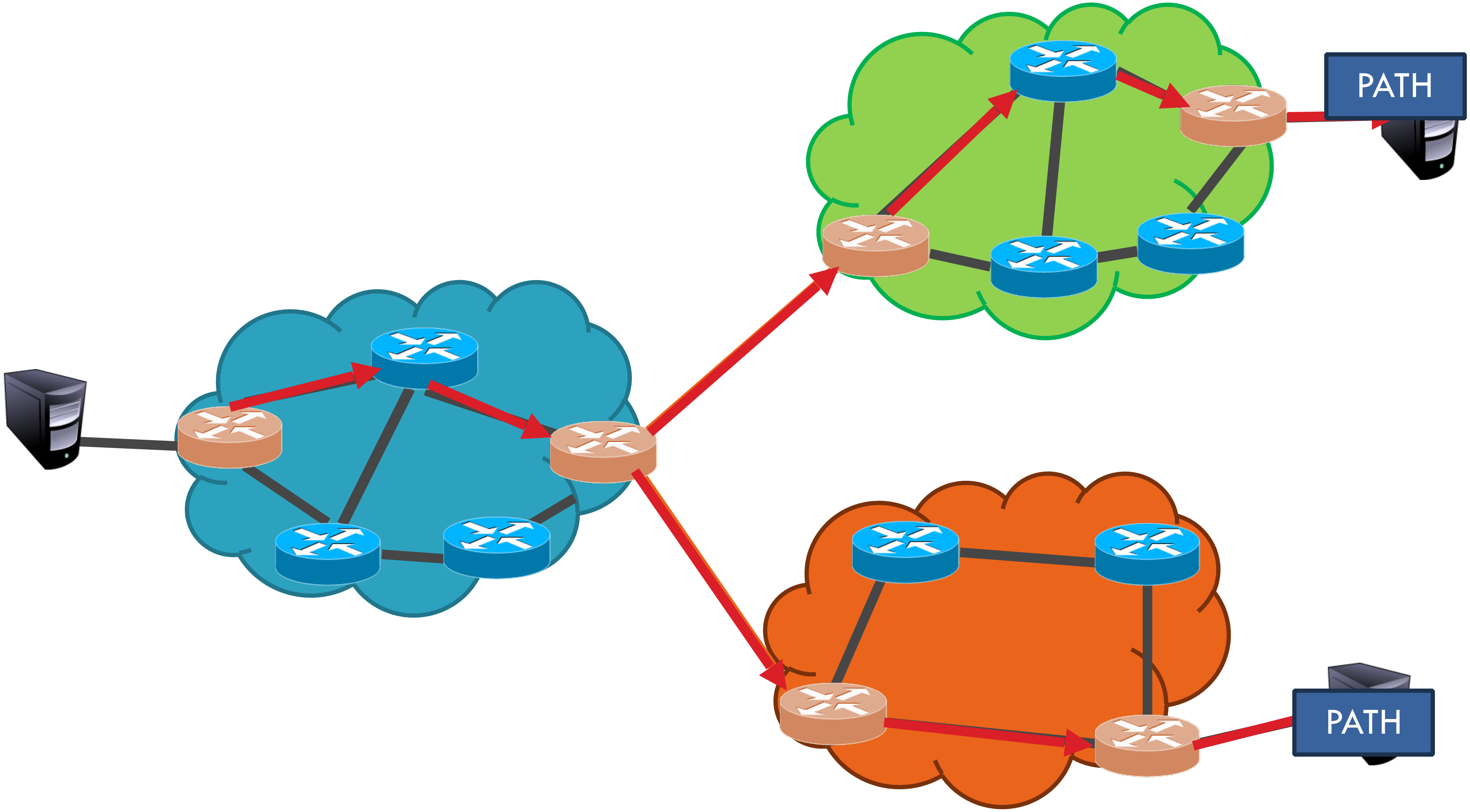

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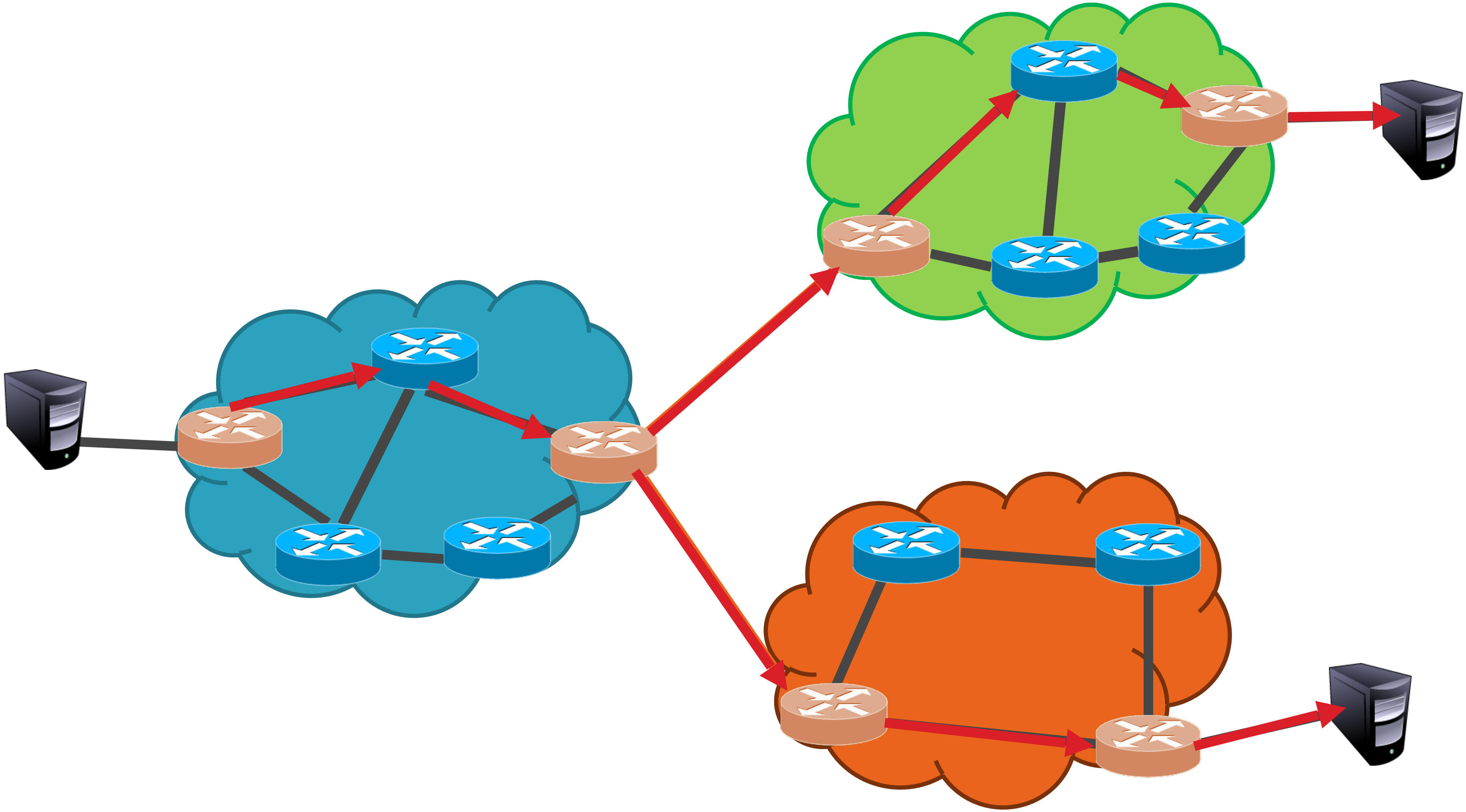

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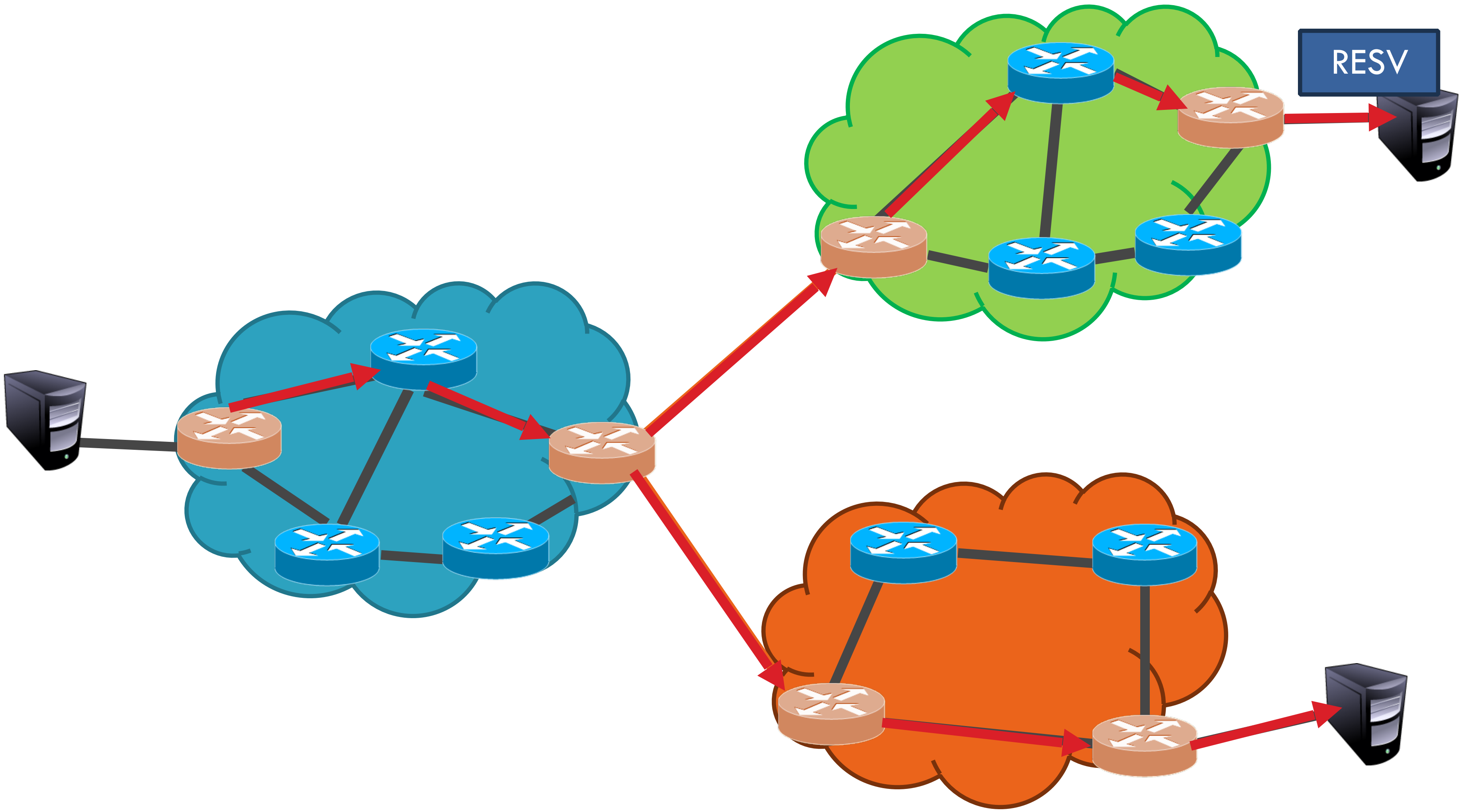

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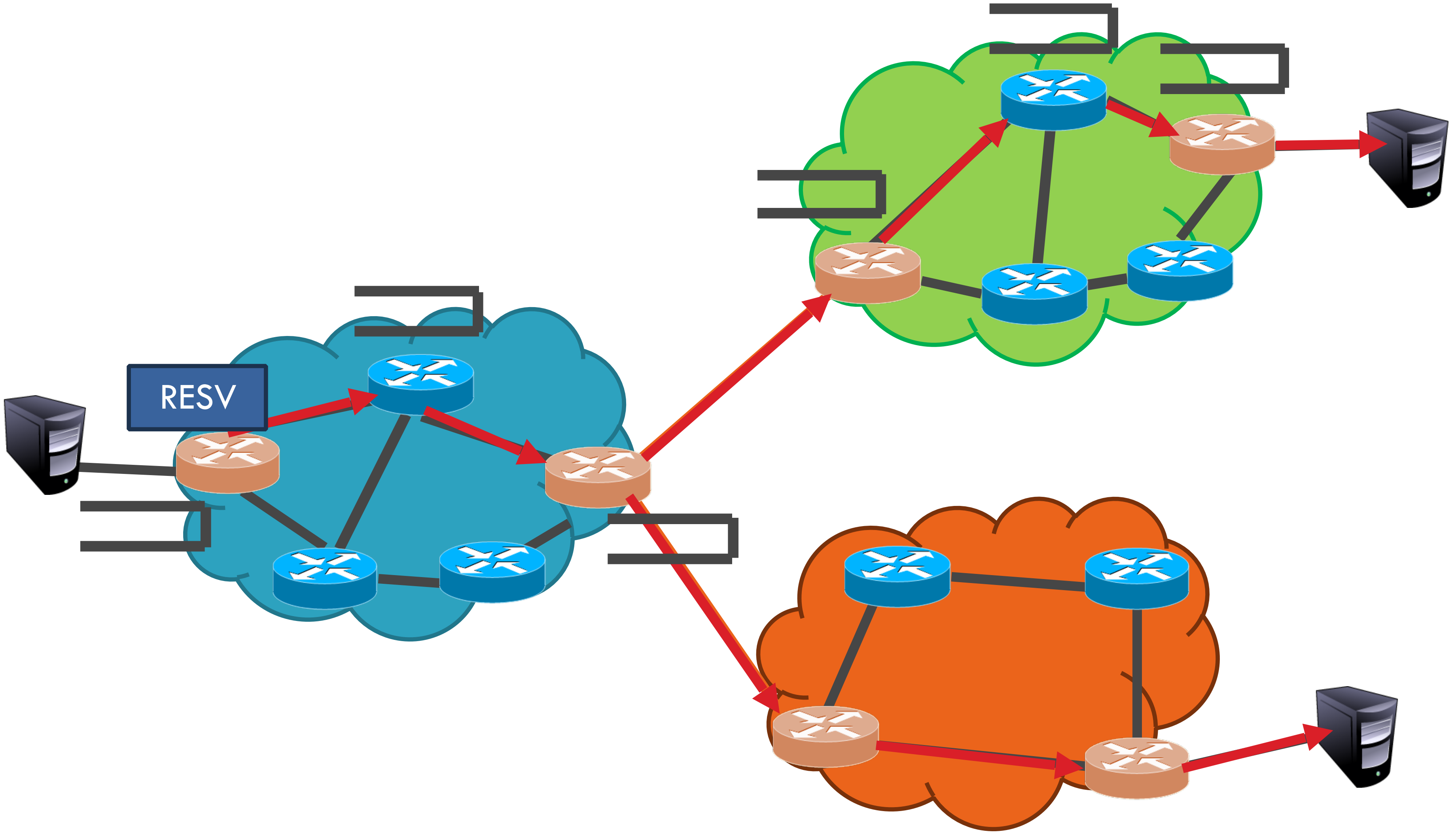

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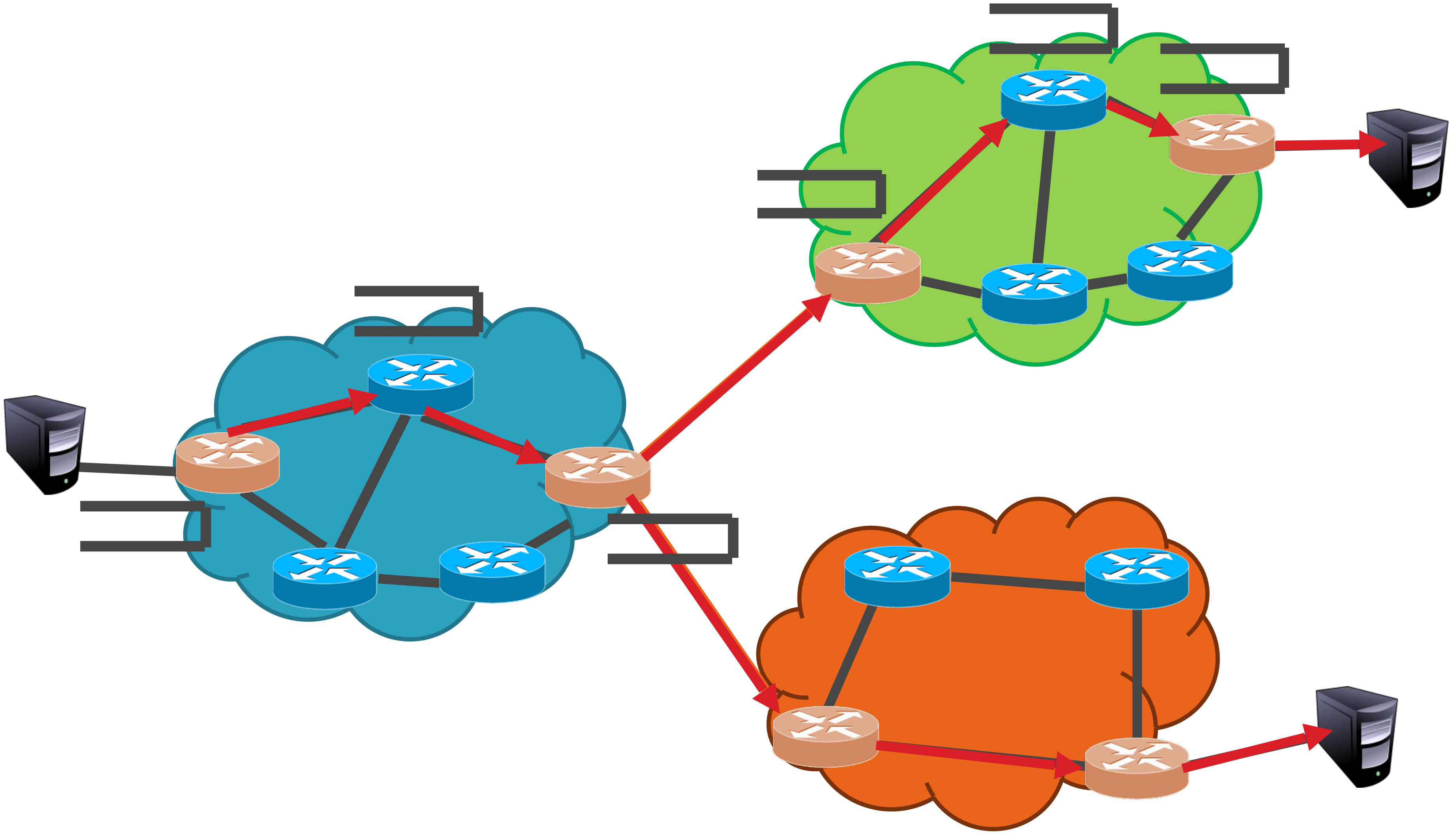
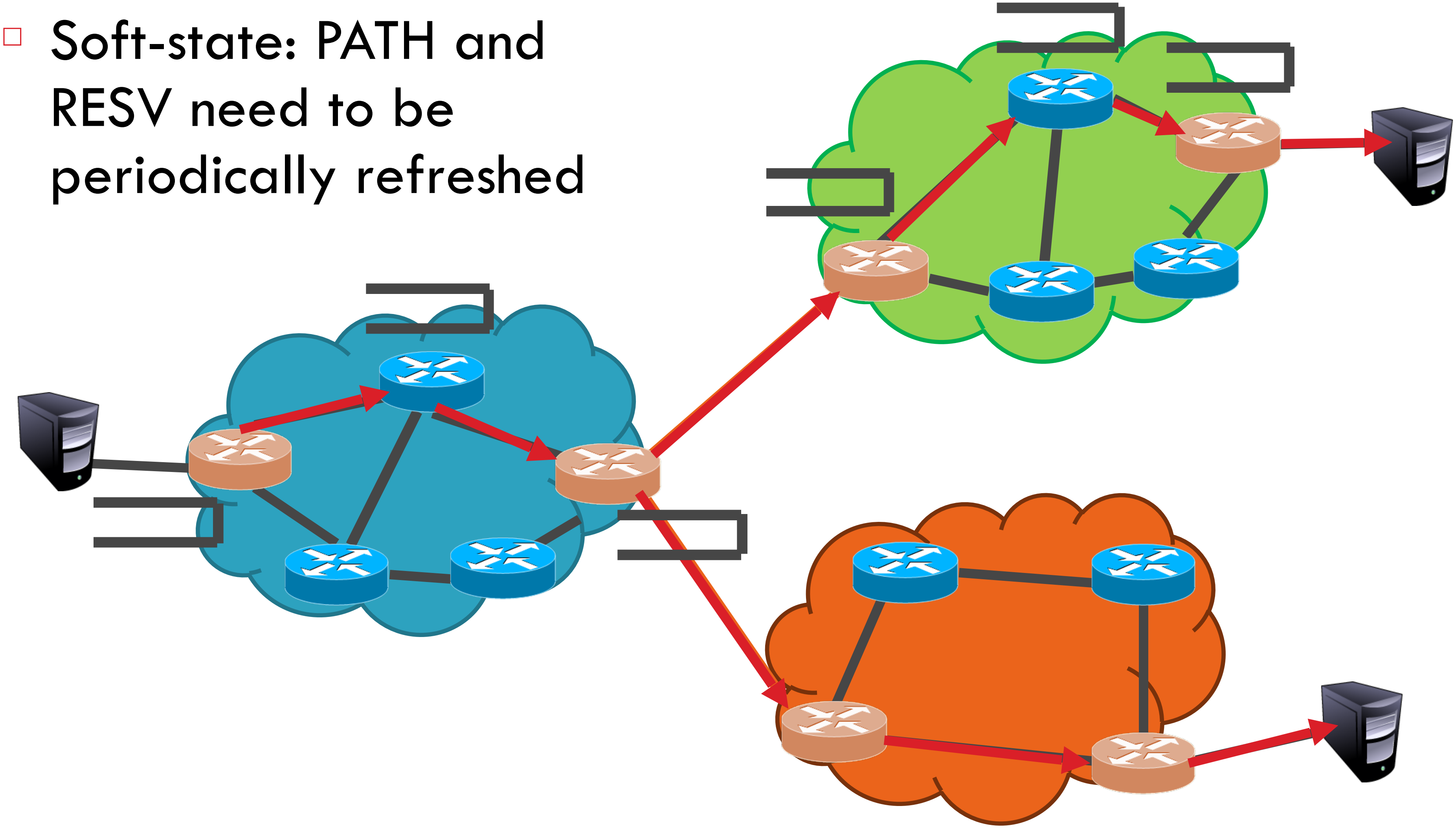


RSVP Example

- Soft-state: PATH and RESV need to be periodically refreshed



IntServ Summary

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- The bad:
  - IntServ is a whole Internet upgrade
  - Heavyweight mechanisms, per flow state
  - Security: end-hosts can DoS by reserving lots of bandwidth

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- Internet capacity explosion
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  - QoS is only useful if capacity is saturated
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- Another technical solution killed by economics

QoS is Controversial

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- Counterargument: BitTorrent negatively impacts other customers
  - Is it okay for your neighbors BitTorrent traffic to make your Skype calls sound choppy?
- Slippery slope:
  - Who decides which apps are favored?
  - Is it okay to ban apps entirely?
  - Is it okay to allow people to pay for higher priority?