Routing Basics

ISP/IXP Workshops

Routing Concepts

- IPv4
- Routing
- Forwarding
- Some definitions
- Policy options
- Routing Protocols

IPv4

- **Internet uses IPv4**
  - **addresses are 32 bits long**
  - **range from 1.0.0.0 to 223.255.255.255**
  - **0.0.0.0 to 0.255.255.255 and 224.0.0.0 to 255.255.255.255 have “special” uses**
- **IPv4 address has a network portion and a host portion**

IPv4 address format

- **Address and subnet mask**

  written as

  12.34.56.78 255.255.255.0 *or*

  12.34.56.78/24

  mask represents the number of network bits in the 32 bit address

  the remaining bits are the host bits

What does a router do?

A day in a life of a router

find path

forward packet, forward packet, forward packet, forward packet...

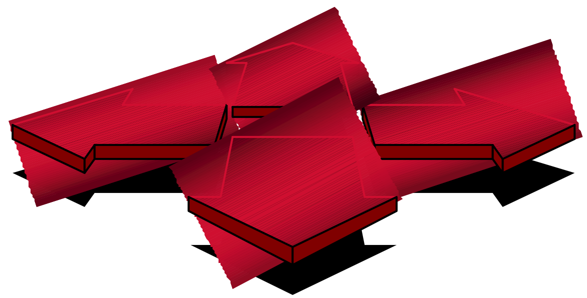
find alternate path

forward packet, forward packet, forward packet, forward packet…

repeat until powered off

Routing versus Forwarding

- **Routing = building maps and giving directions**
- **Forwarding = moving packets between interfaces according to the “directions”**



IP Routing – finding the path

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- Path derived from information received from a routing protocol
- Several alternative paths may exist

  best next hop stored in forwarding table
- Decisions are updated periodically or as topology changes (event driven)
- Decisions are based on:

  topology, policies and metrics (hop count, filtering, delay, bandwidth, etc.)

IP route lookup

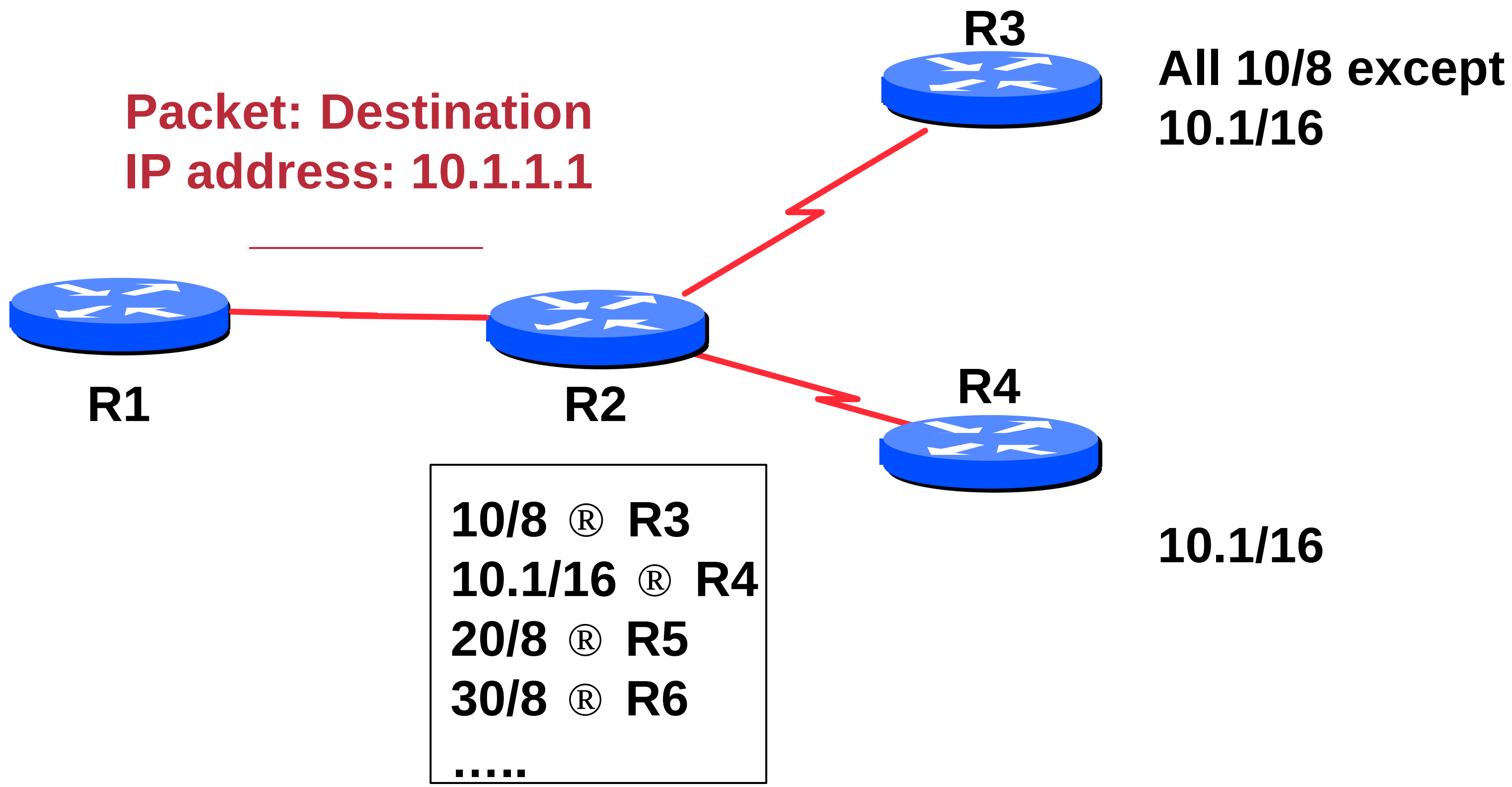
- Based on destination IP packet
- "longest match" routing

  more specific prefix preferred over less specific prefix

  example: packet with destination of 10.1.1.1/32 is sent to the router announcing 10.1/16 rather than the router announcing 10/8.

IP route lookup

- Based on destination IP packet



R2’s IP routing table

IP route lookup: Longest match routing

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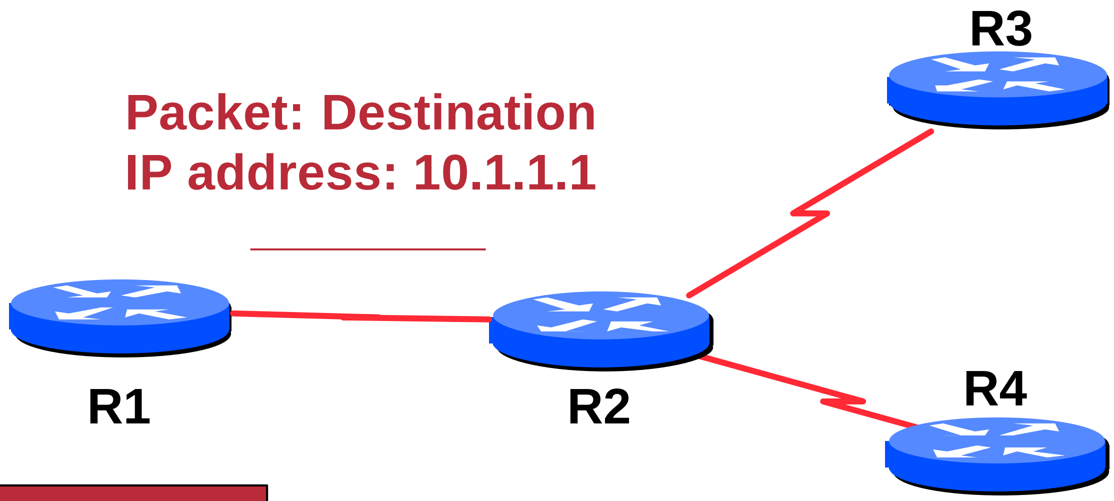
- Based on destination IP packet



All 10/8 except 10.1/16

10/8 ® R3	→ 10.1.1.1 && FF.0.0.0
10.1/16 ® R4	vs.
20/8 ® R5	10.0.0.0 && FF.0.0.0
30/8 ® R6	
…..	

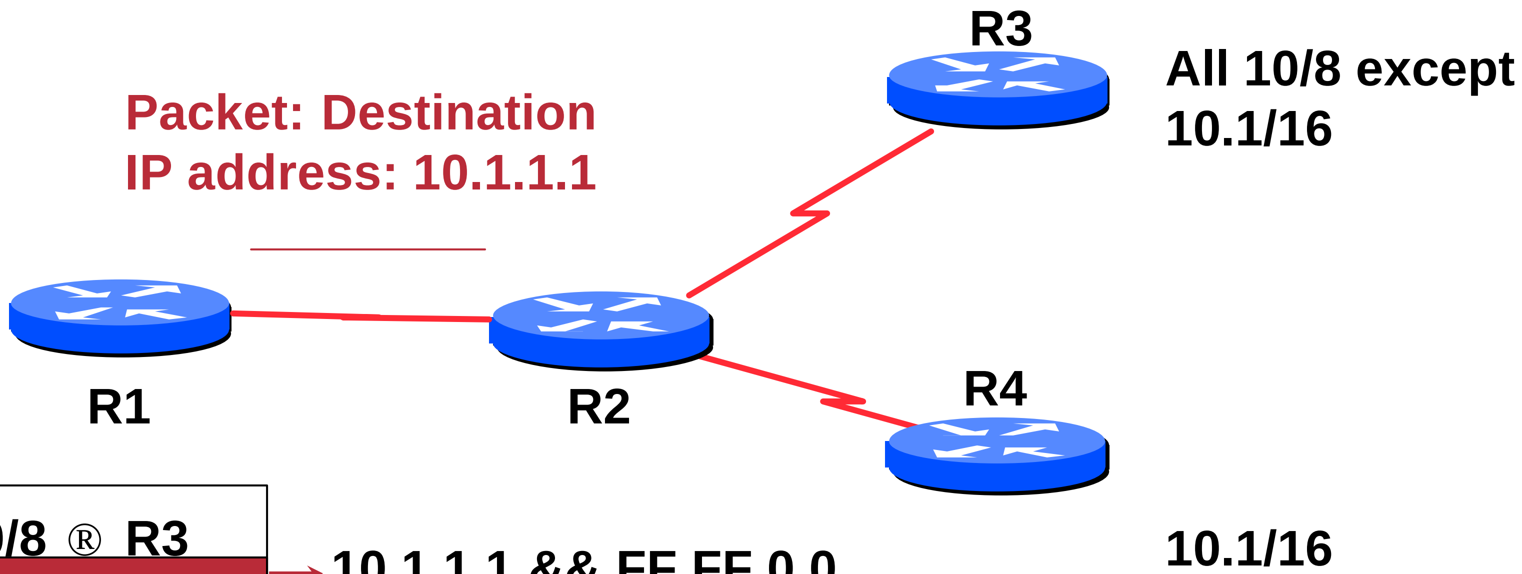
Match!

10.1/16

R2's IP routing table

IP route lookup: Longest match routing

- **Based on destination IP packet**

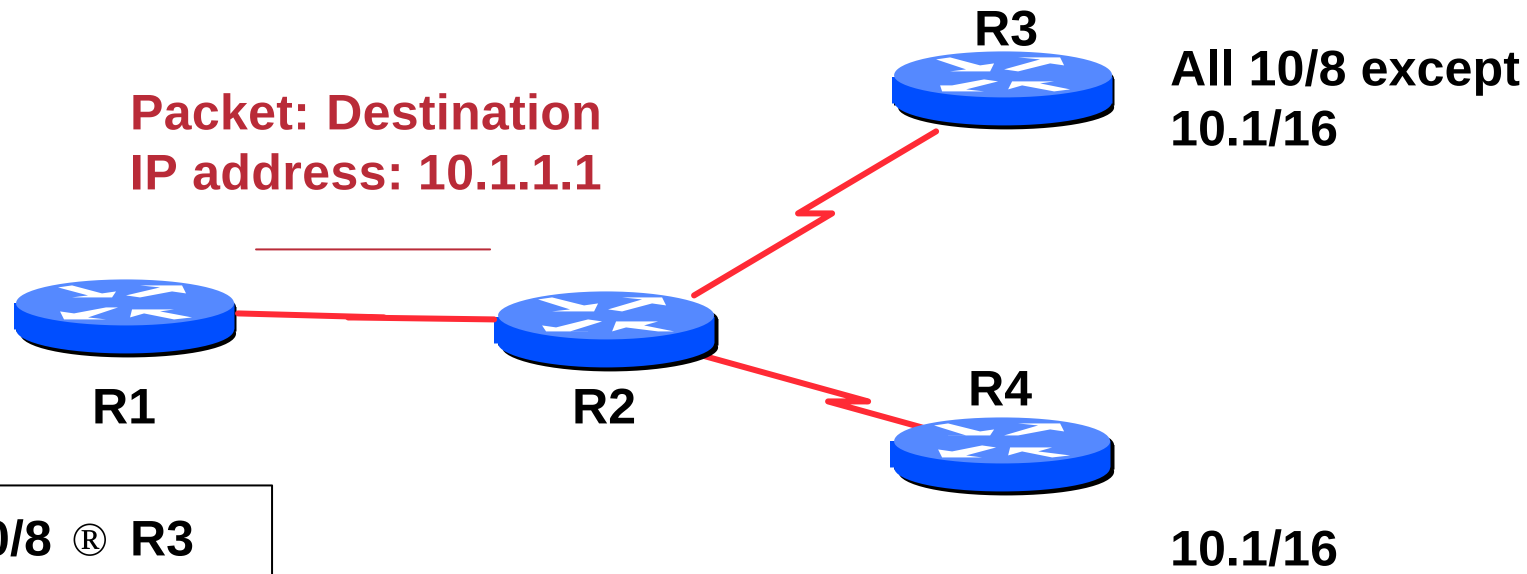


10/8 ® R3	
10.1/16 ® R4	→ 10.1.1.1 && FF.FF.0.0 vs. 10.1.0.0 && FF.FF.0.0 — Match as well!
20/8 ® R5	
30/8 ® R6	
…..	

R2's IP routing table

IP route lookup: Longest match routing

- Based on destination IP packet



10/8 ® R3
10.1/16 ® R4
20/8 ® R5
30/8 ® R6
…..

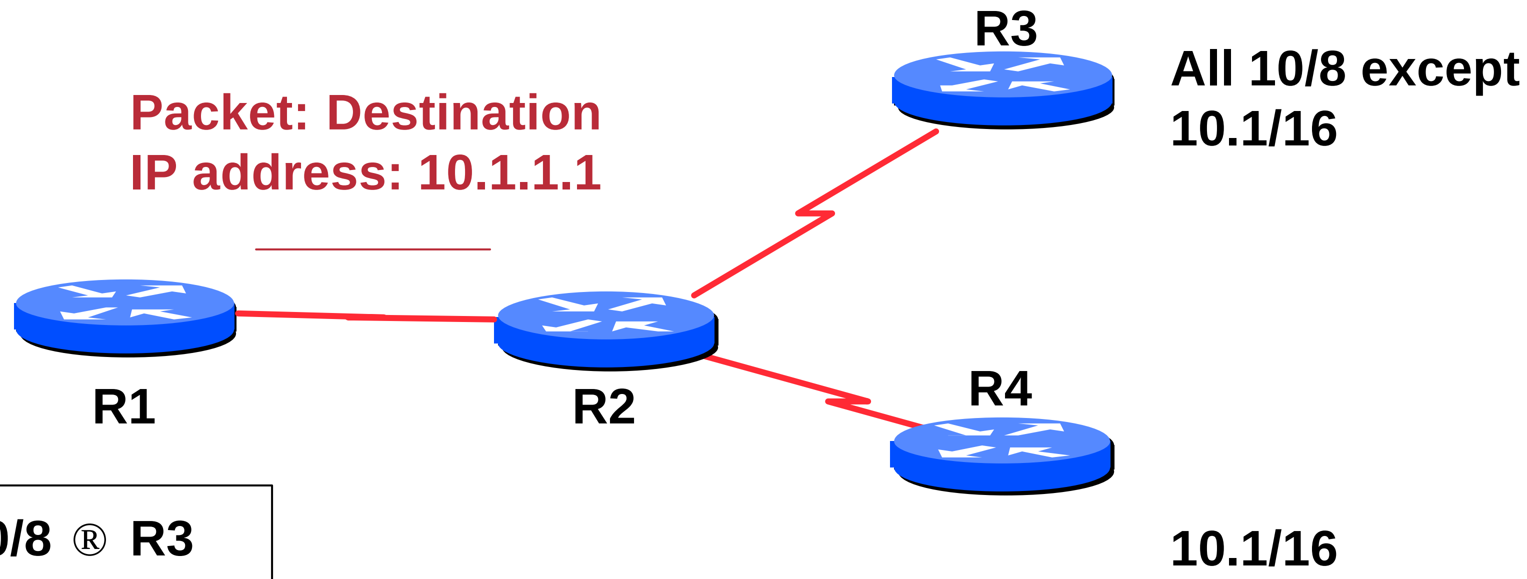
10.1.1.1 && FF.0.0.0
vs.
20.0.0.0 && FF.0.0.0

Does not match!

R2’s IP routing table

IP route lookup: Longest match routing

- Based on destination IP packet



10/8 ® R3	
10.1/16 ® R4	
20/8 ® R5	
30/8 ® R6	→ 10.1.1.1 && FF.0.0.0 vs. 30.0.0.0 && FF.0.0.0 — Does not match!
…..	

R2's IP routing table

IP route lookup: Longest match routing

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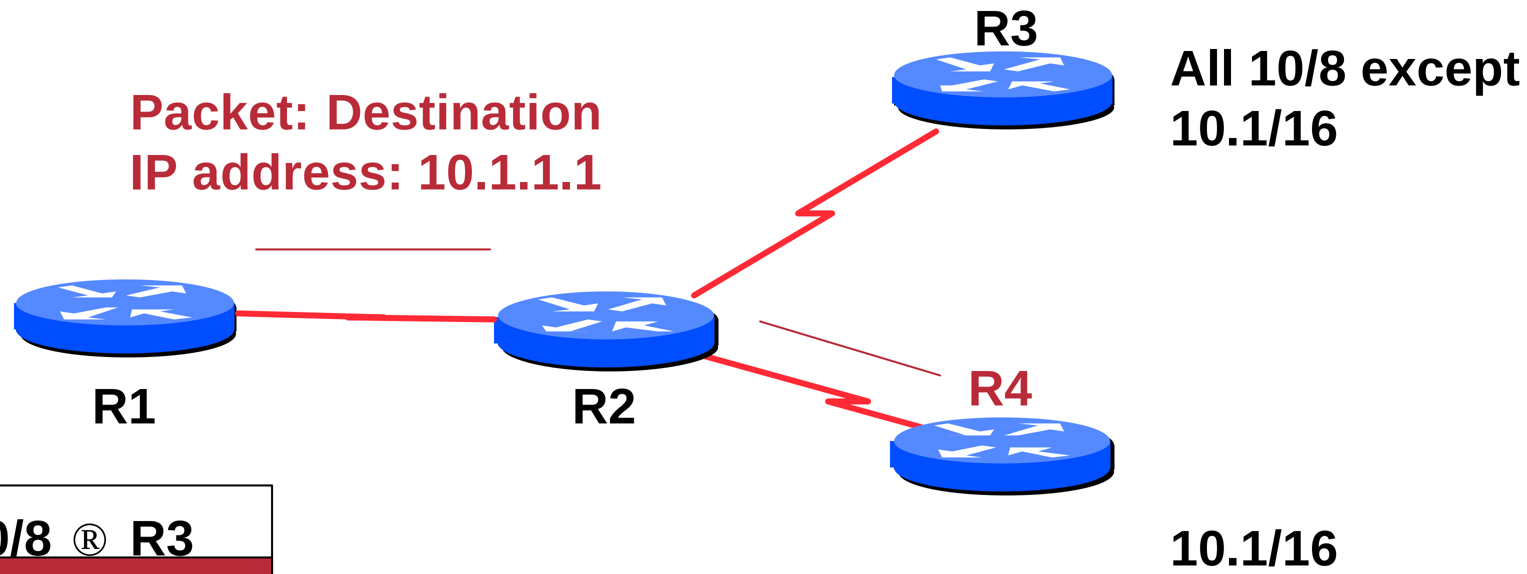
- **Based on destination IP packet**



10/8 ® R3
10.1/16 ® R4
20/8 ® R5
30/8 ® R6
…..

Longest match, 16 bit netmask

R2's IP routing table

IP Forwarding

- **Router makes decision on which interface a packet is sent to**
- **Forwarding table populated by routing process**
- **Forwarding decisions:**

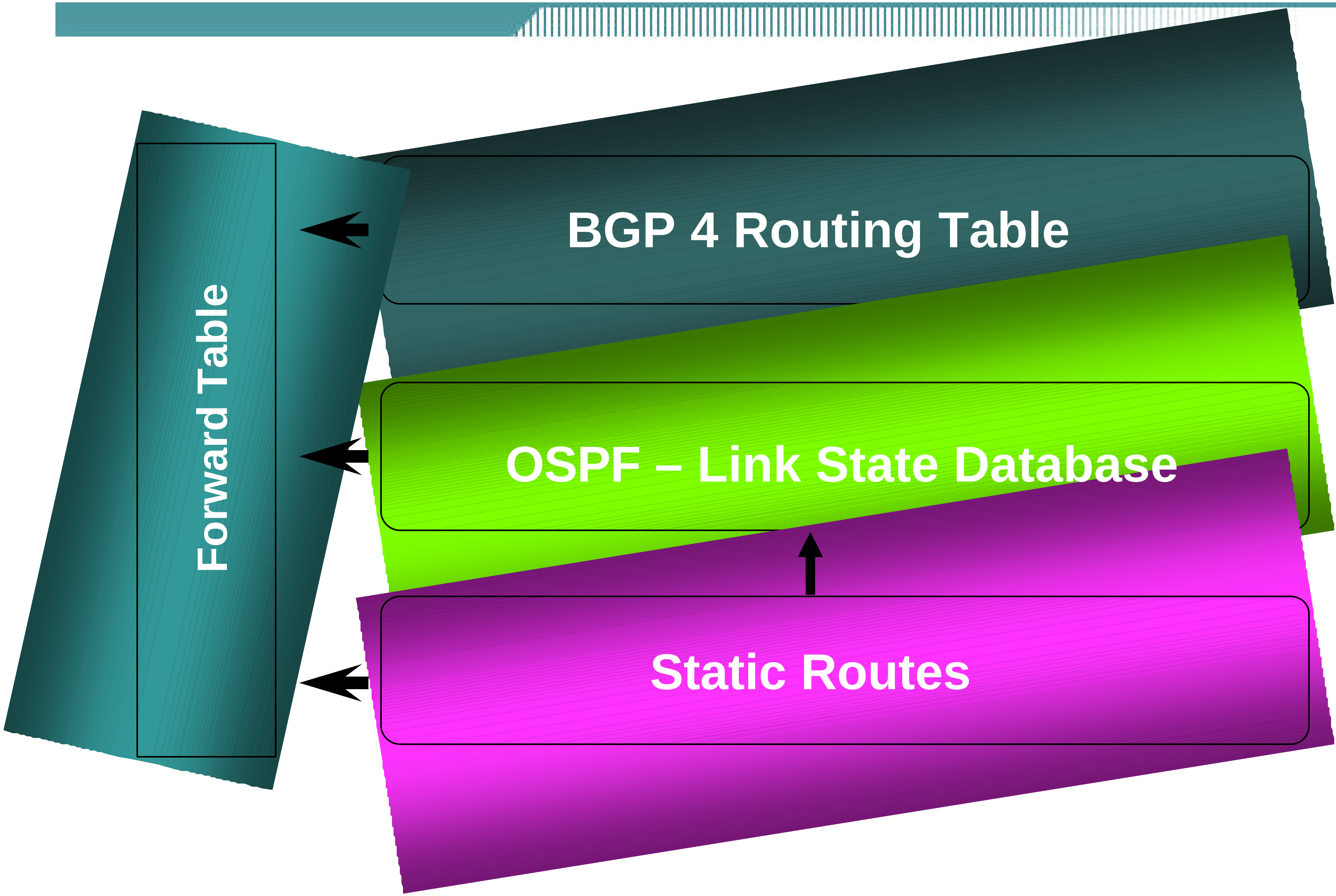
  destination address

  class of service (fair queuing, precedence, others)

  local requirements (packet filtering)

- **Can be aided by special hardware**

Routing Tables Feed the Forwarding Table



Explicit versus Default routing

- **Default:**
  - simple, cheap (cycles, memory, bandwidth)
  - low granularity (metric games)
- **Explicit (default free zone)**
  - high overhead, complex, high cost, high granularity
- **Hybrid**
  - minimise overhead
  - provide useful granularity
  - requires some filtering knowledge

Egress Traffic

- How packets leave your network
- Egress traffic depends on:
  - route availability (what others send you)
  - route acceptance (what you accept from others)
  - policy and tuning (what you do with routes from others)
  - Peering and transit agreements

Ingress Traffic

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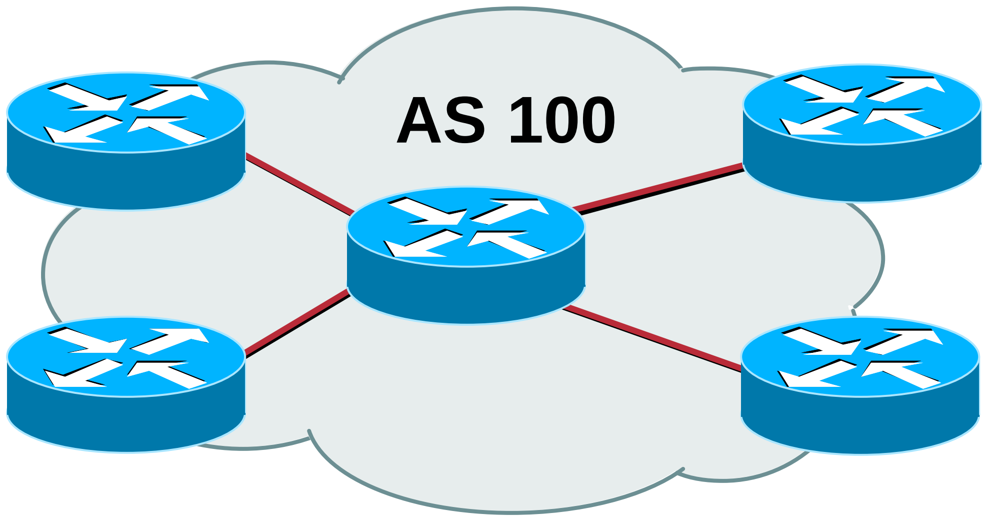
- **How packets get to your network and your customers' networks**
- **Ingress traffic depends on:**

  what information you send and to whom

  based on your addressing and AS's

  based on others' policy (what they accept from you and what they do with it)

Autonomous System (AS)



- **Collection of networks with same routing policy**
- **Single routing protocol**
- **Usually under single ownership, trust and administrative control**

Definition of terms

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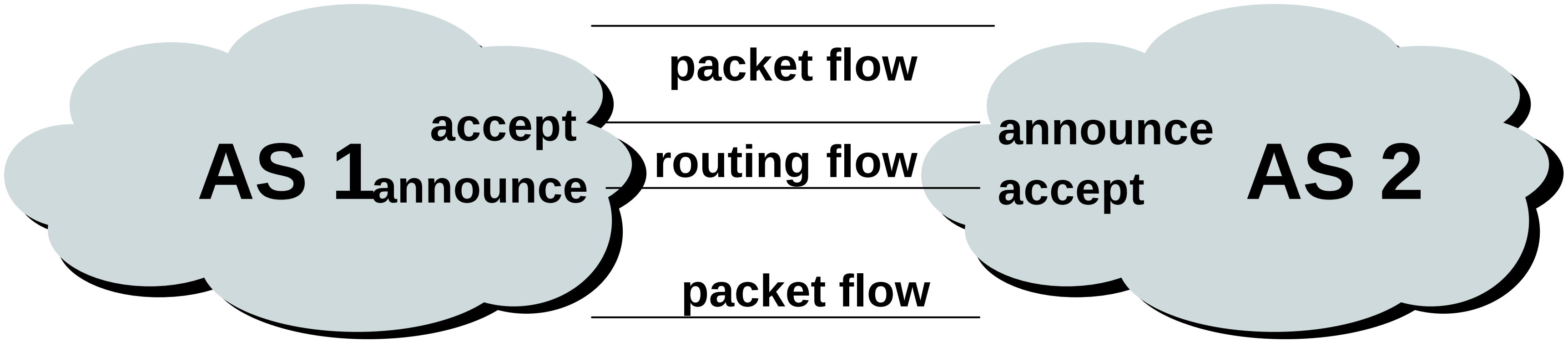
- **Neighbours – AS's which directly exchange routing information**
- **Announce – send routing information to a neighbour**
- **Accept – receive and use routing information sent by a neighbour**
- **Originate – insert routing information into external announcements (usually as a result of the IGP)**
- **Peers – routers in neighbouring AS's or within one AS which exchange routing and policy information**

Routing flow and packet flow



For networks in AS1 and AS2 to communicate:

AS1 must announce to AS2

AS2 must accept from AS1

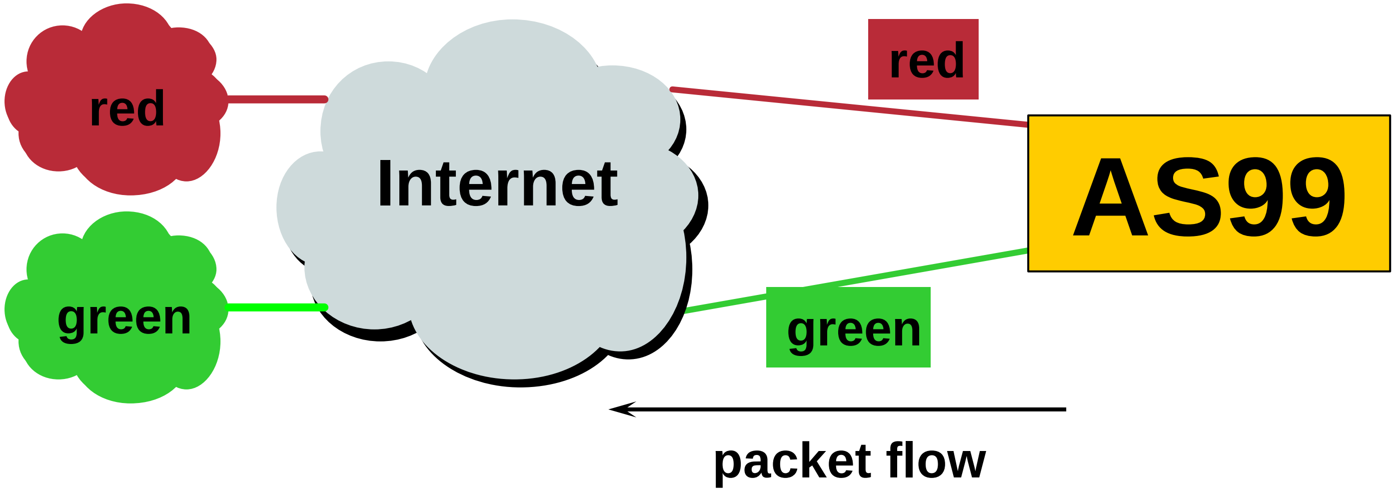
AS2 must announce to AS1

AS1 must accept from AS2

Routing flow and Traffic flow

- **Traffic flow is always in the opposite direction of the flow of routing information**
  - **filtering outgoing routing information inhibits traffic flowing in**
  - **filtering incoming routing information inhibits traffic flowing out**

Routing policy limitations

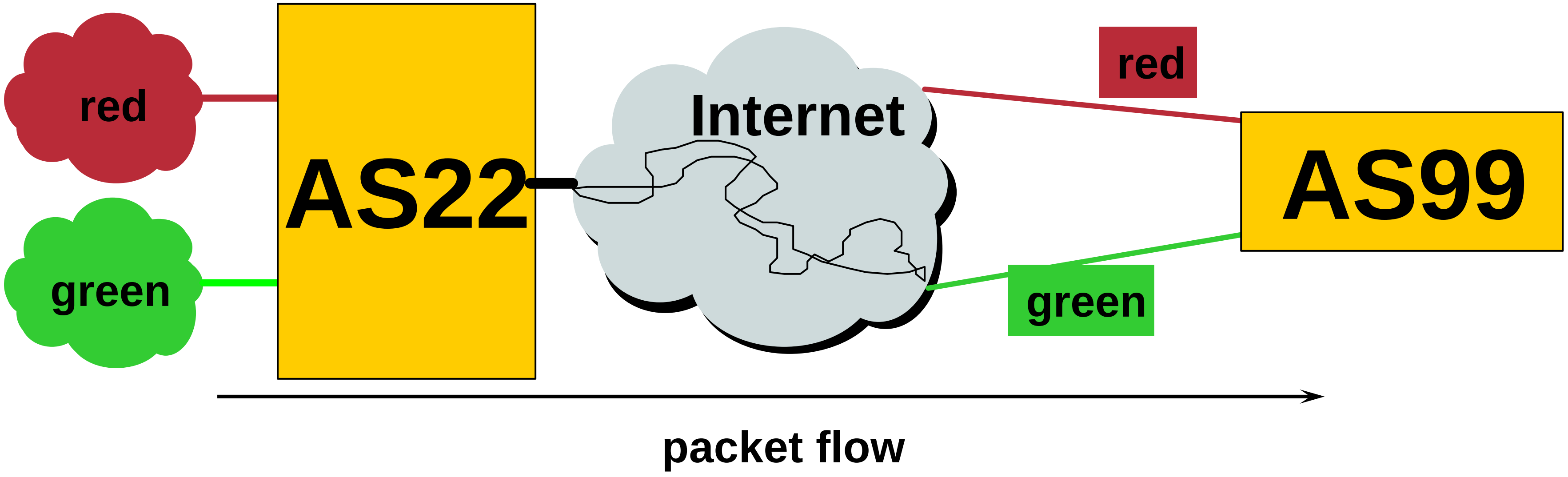


AS99 uses red link for traffic going to the red AS and green link for traffic going to the green AS

To implement this policy for AS99:

- **accept routes originating in the red AS on the red link**
- **accept all other routes on the green link**

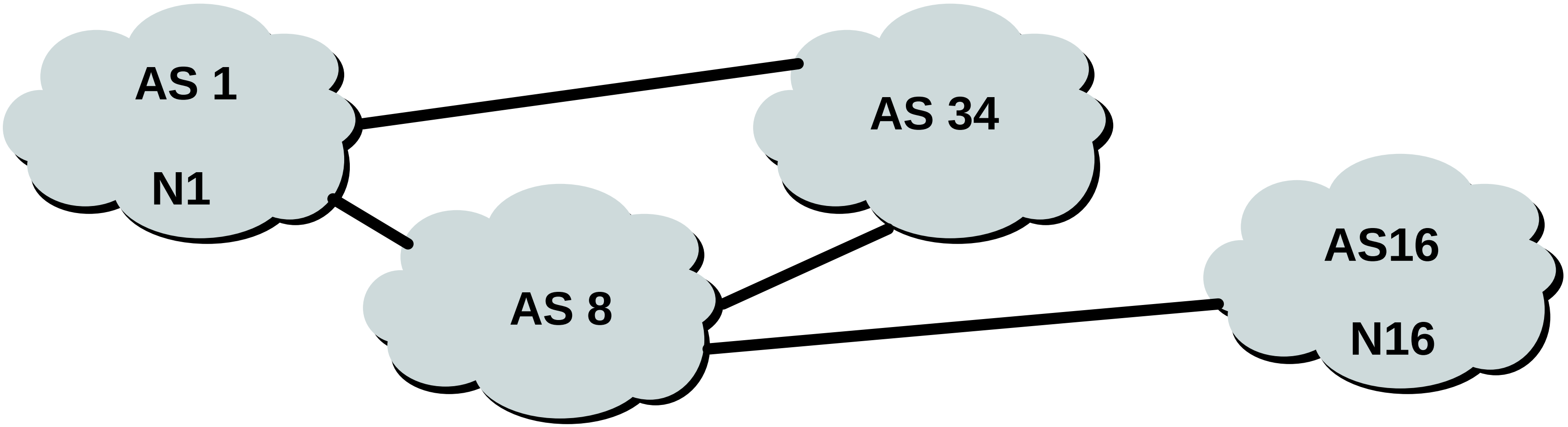
Routing policy limitations



For packets flowing *toward* AS 99:

Unless AS 22 and all other intermediate AS's co-operate in pushing green traffic to the green link then some reasonable policies can not be implemented.

Routing policy with multiple ASes



For net N1 in AS1 to send traffic to net N16 in AS16:

- **AS16 must originate and announce N16 to AS8.**
- **AS8 must accept N16 from AS16.**
- **AS8 must announce N16 to AS1 or AS34.**
- **AS1 must accept N16 from AS8 or AS34.**

For two-way packet flow, similar policies must exist for N1.

Routing policy with multiple AS's

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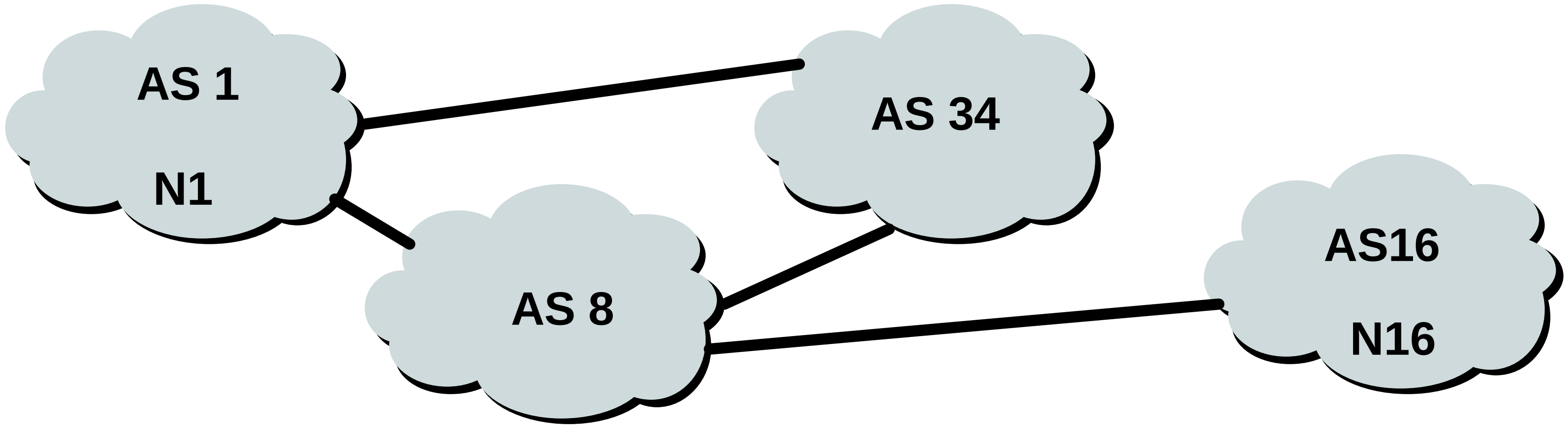

As multiple paths between sites are implemented it is easy to see how policies can become quite complex.

Granularity of routing policy

- **What to announce/accept**
- **Preferences between multiple accepts**

  single route

  routes originated by single AS

  routes originated by a group of AS's

  routes traversing specific path

  routes traversing specific AS

  routes belonging to other groupings (including combinations)

Routing Policy Issues

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- 120000 prefixes (not realistic to set policy on all of them individually)
- 15000 origin AS's (too many)
- routes tied to a specific AS or path may be unstable regardless of connectivity
- groups of AS's are a natural abstraction for filtering purposes

What Is an IGP?

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- **Interior Gateway Protocol**
- **Within an Autonomous System**
- **Carries information about internal infrastructure prefixes**
- **Examples – OSPF, ISIS, EIGRP…**

Why Do We Need an IGP?

- **ISP backbone scaling**

  Hierarchy

  Modular infrastructure construction

  Limiting scope of failure

  Healing of infrastructure faults using dynamic routing with fast convergence

What Is an EGP?

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- Exterior Gateway Protocol
- Used to convey routing information between Autonomous Systems
- De-coupled from the IGP
- Current EGP is BGP

Why Do We Need an EGP?

- **Scaling to large network**
  - **Hierarchy**
  - **Limit scope of failure**
- **Define Administrative Boundary**
- **Policy**
  - **Control reachability to prefixes**
  - **Merge separate organizations**
  - **Connect multiple IGPs**

Interior versus Exterior Routing Protocols

- **Interior**
  - automatic neighbour discovery
  - generally trust your IGP routers
  - prefixes go to all IGP routers
  - binds routers in one AS together
- **Exterior**
  - specifically configured peers
  - connecting with outside networks
  - set administrative boundaries
  - binds AS's together

Interior versus Exterior Routing Protocols

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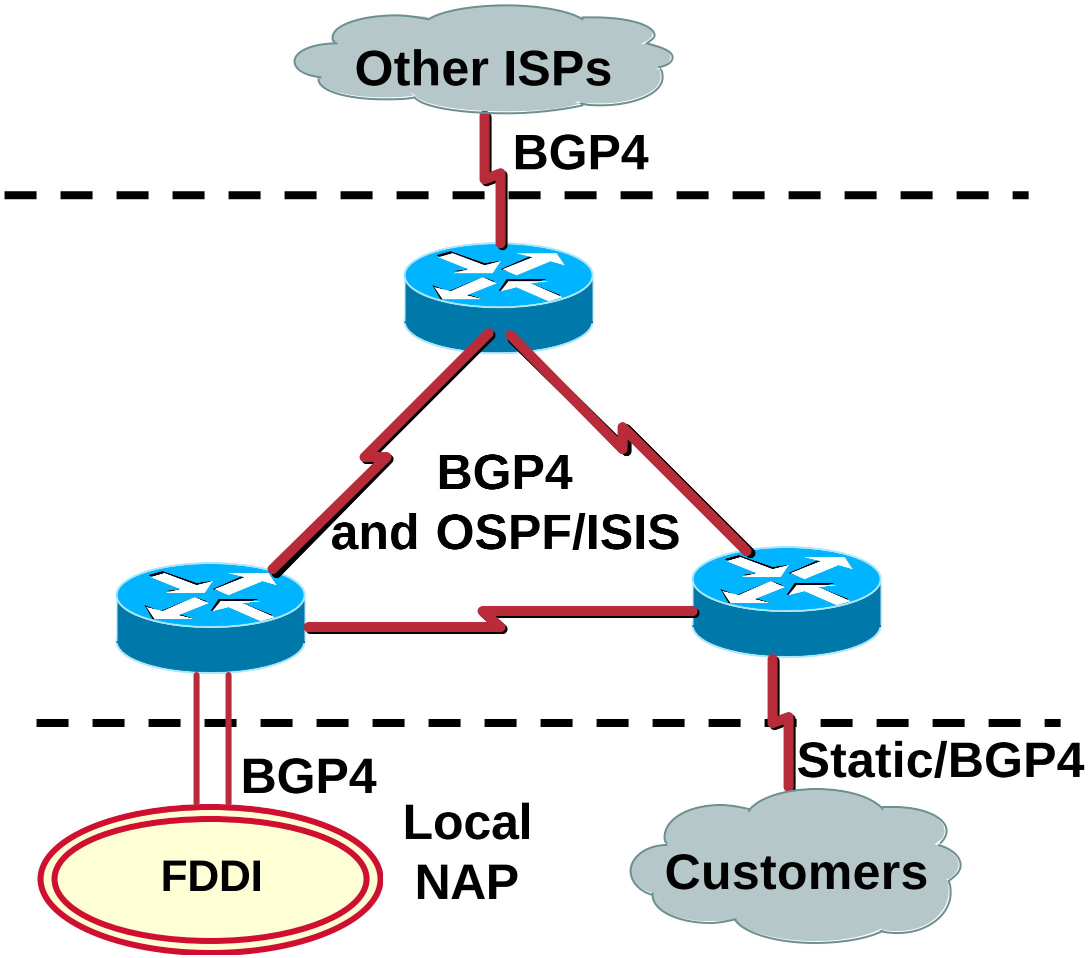
- **Interior**
  - Carries ISP infrastructure addresses only
  - ISPs aim to keep the IGP small for efficiency and scalability
- **Exterior**
  - Carries customer prefixes
  - Carries Internet prefixes
  - EGPs are independent of ISP network topology

Hierarchy of Routing Protocols



Default Administrative Distances

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Route Source	Default Distance
Connected Interface	0
Static Route	1
Enhanced IGRP Summary Route	5
External BGP	20
Internal Enhanced IGRP	90
IGRP	100
OSPF	110
IS-IS	115
RIP	120
EGP	140
External Enhanced IGRP	170
Internal BGP	200
Unknown	255

Routing Basics

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