



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

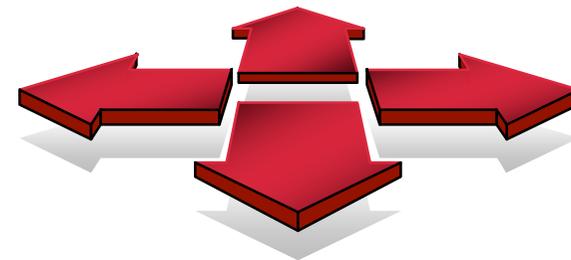
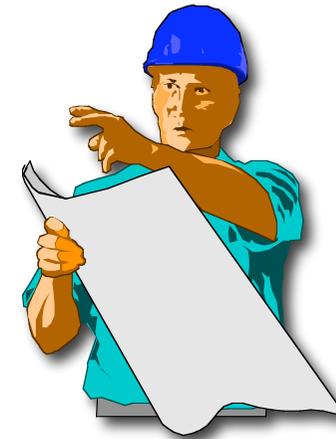
**forward packet, forward packet, forward packet,
forward packet...**

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

- **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

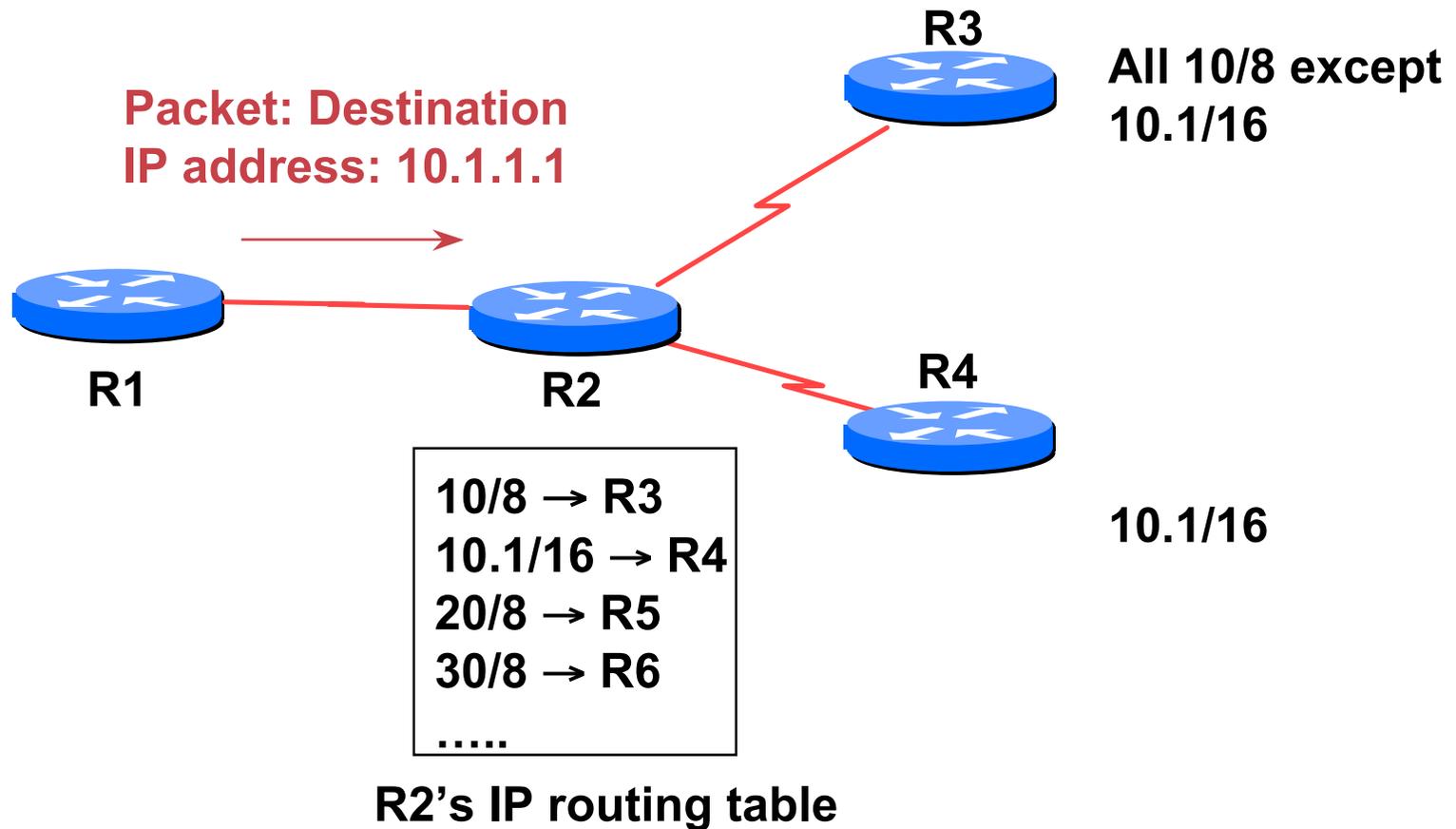
- **Based on destination IP address**
- **“longest match” routing**

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.

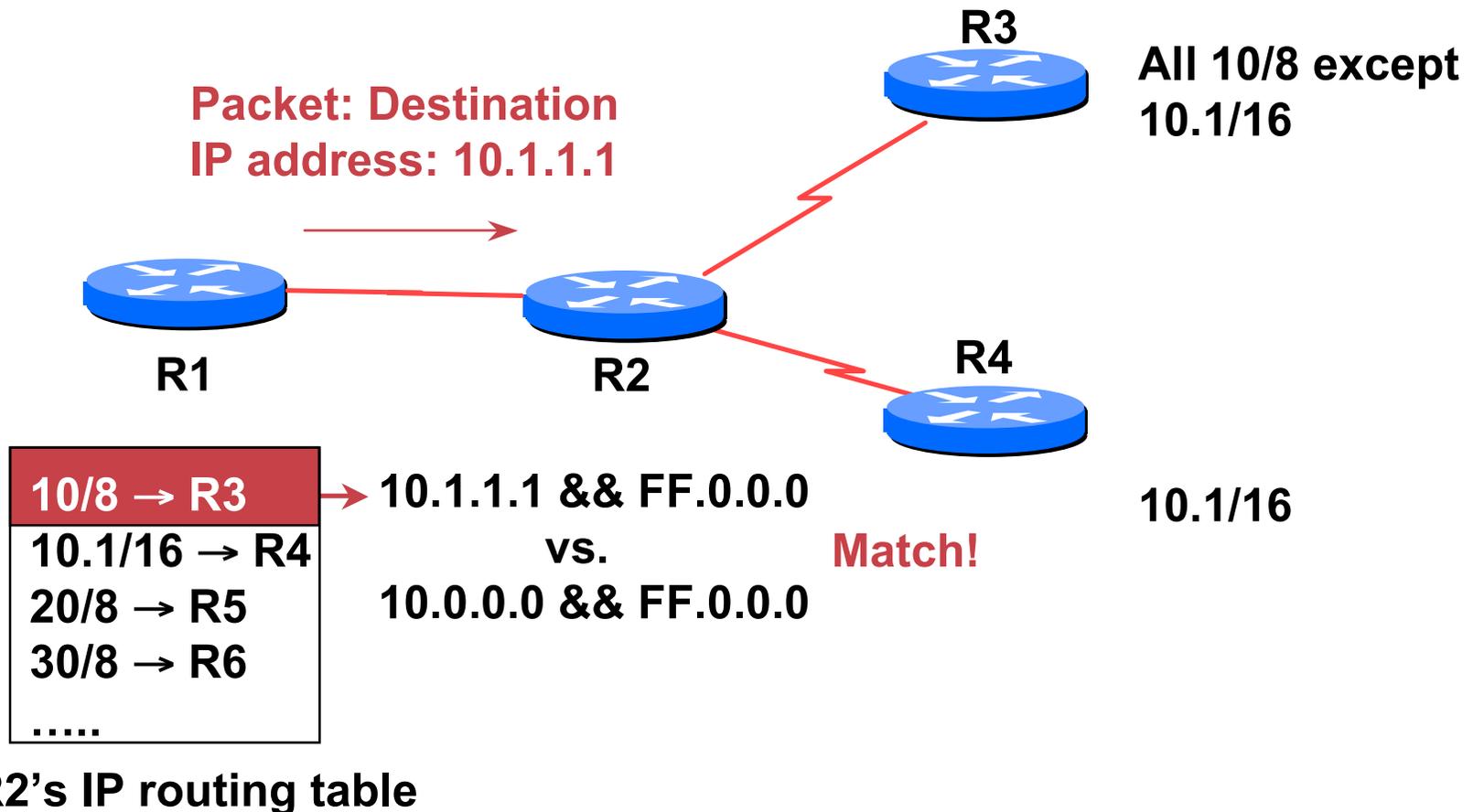
IP route lookup

- Based on destination IP address



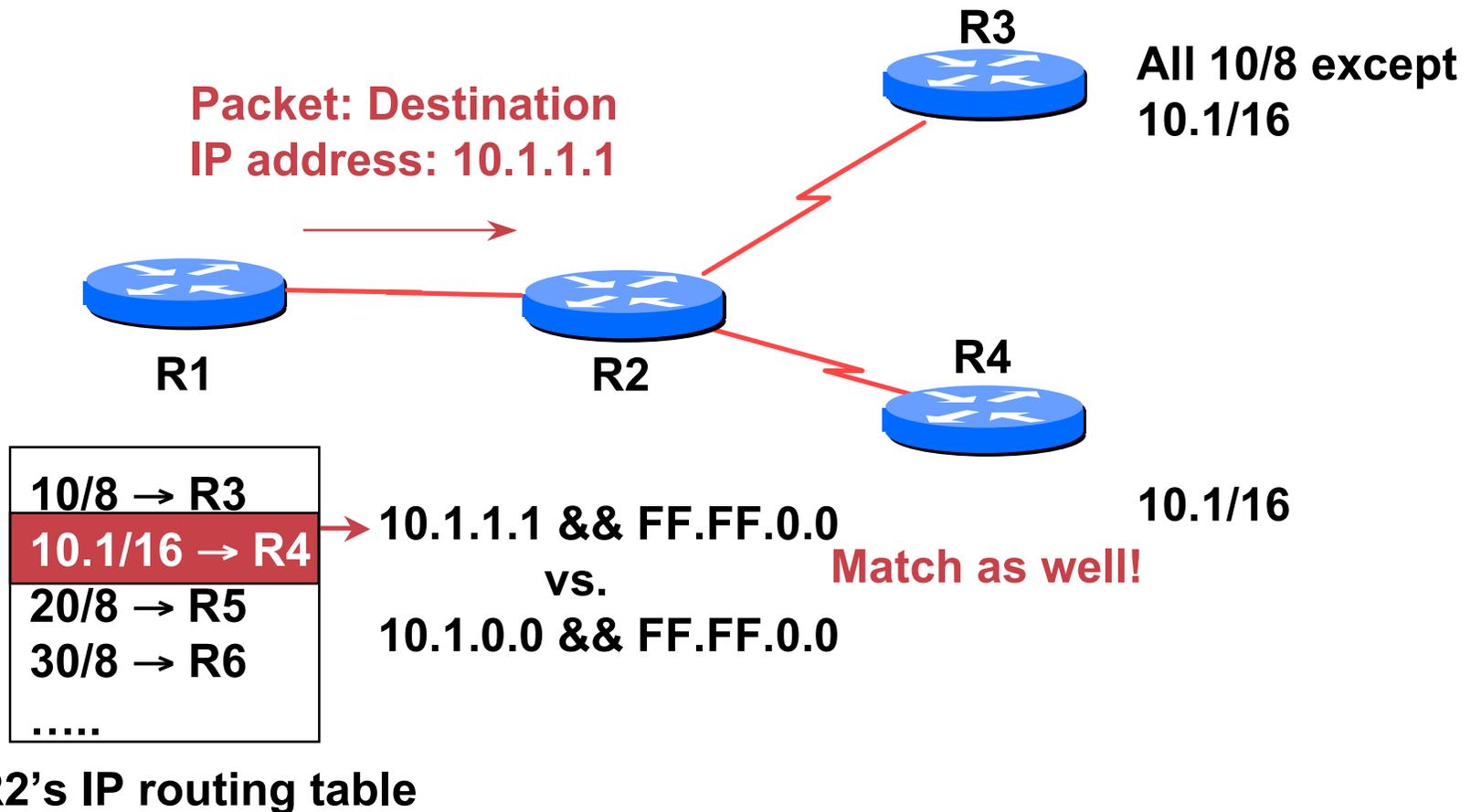
IP route lookup: Longest match routing

- Based on destination IP address



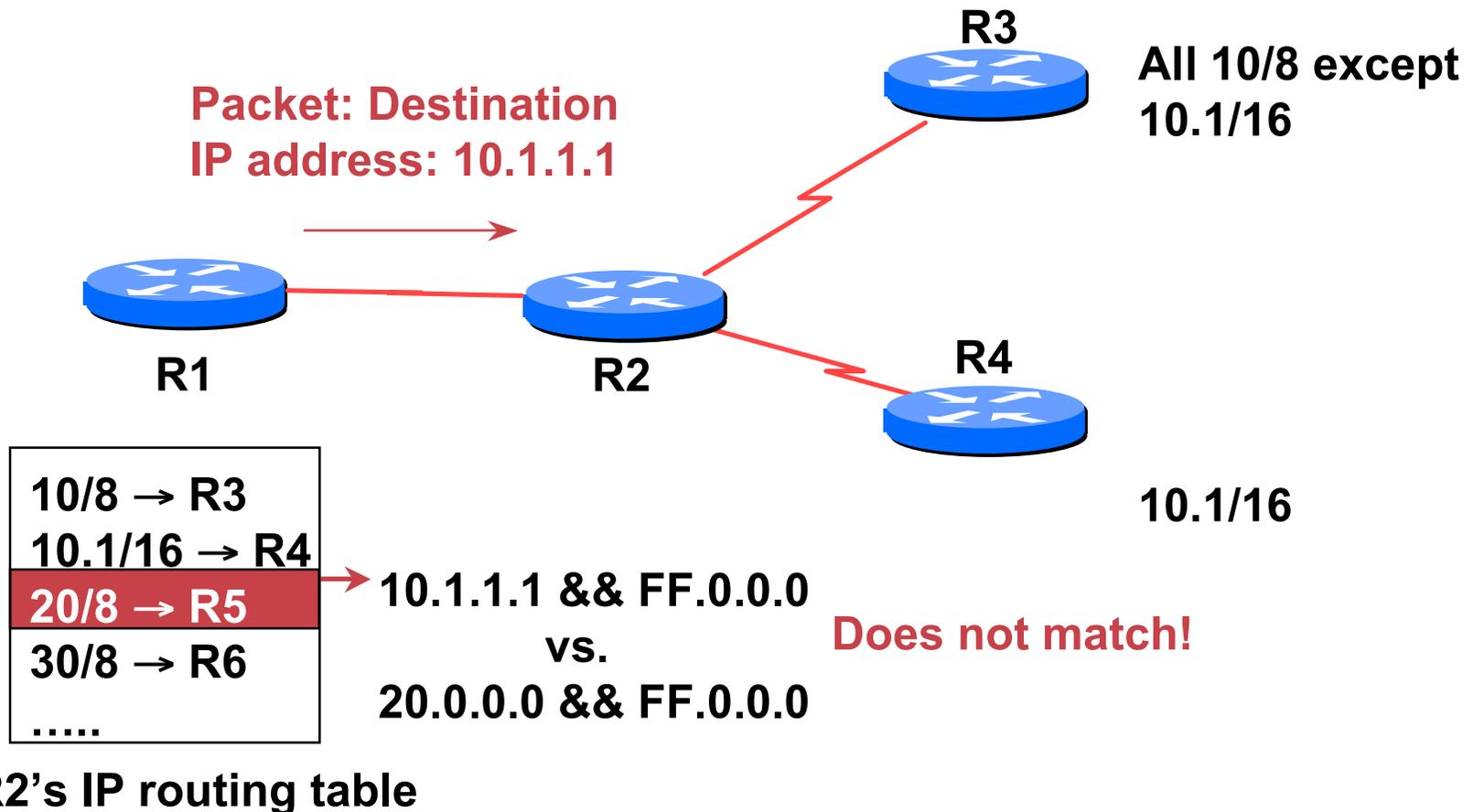
IP route lookup: Longest match routing

- Based on destination IP address



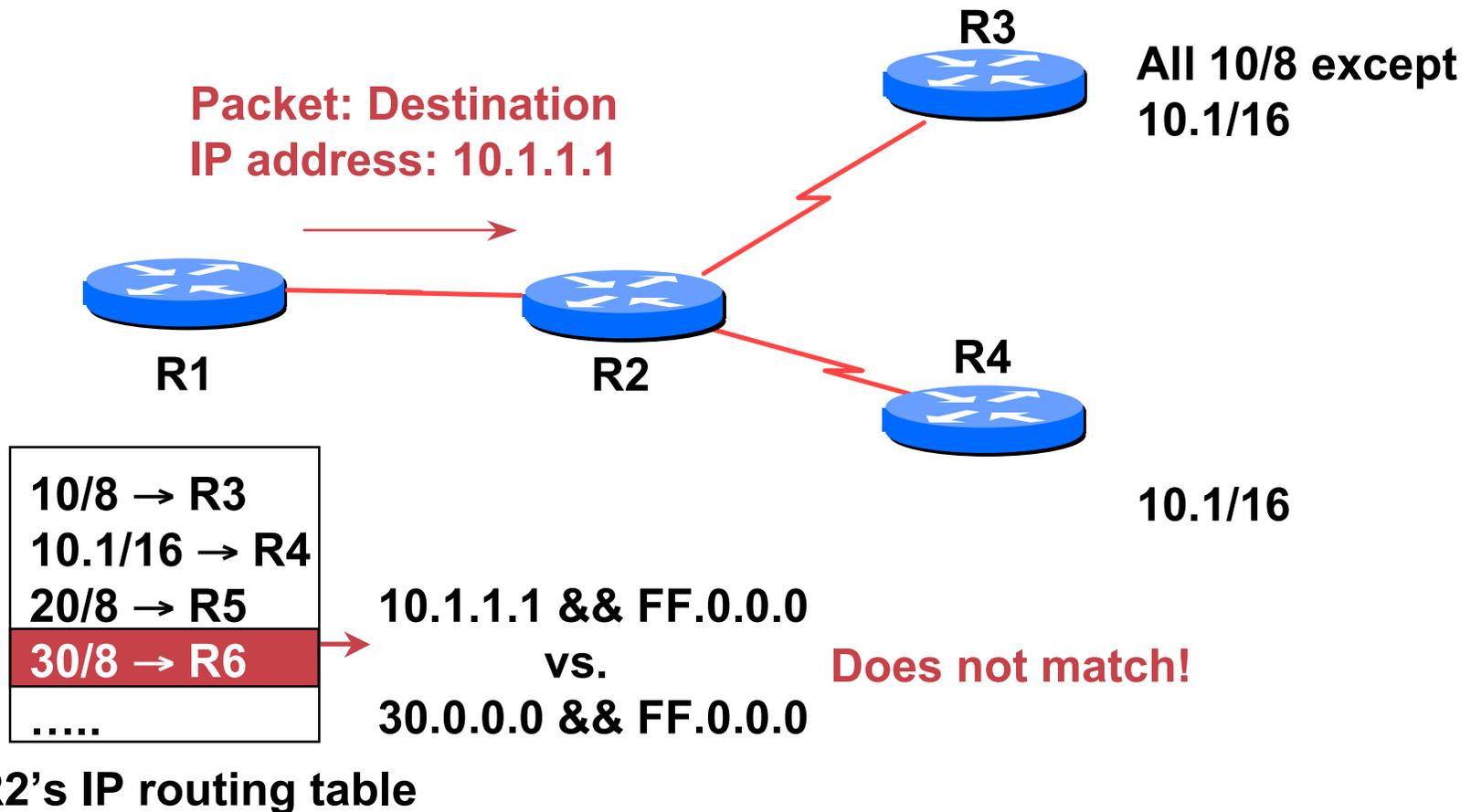
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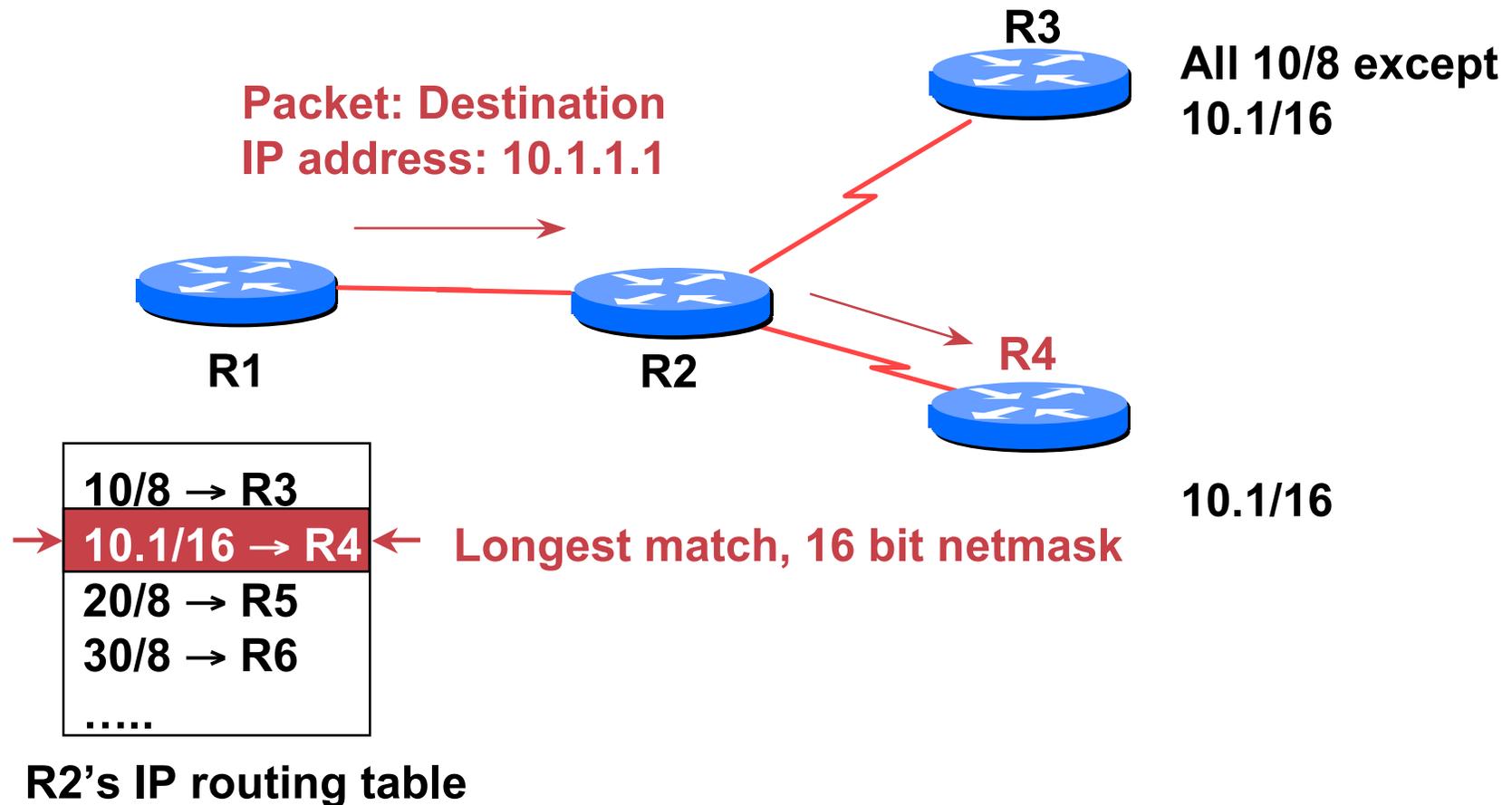
IP route lookup: Longest match routing

- Based on destination IP address



IP route lookup: Longest match routing

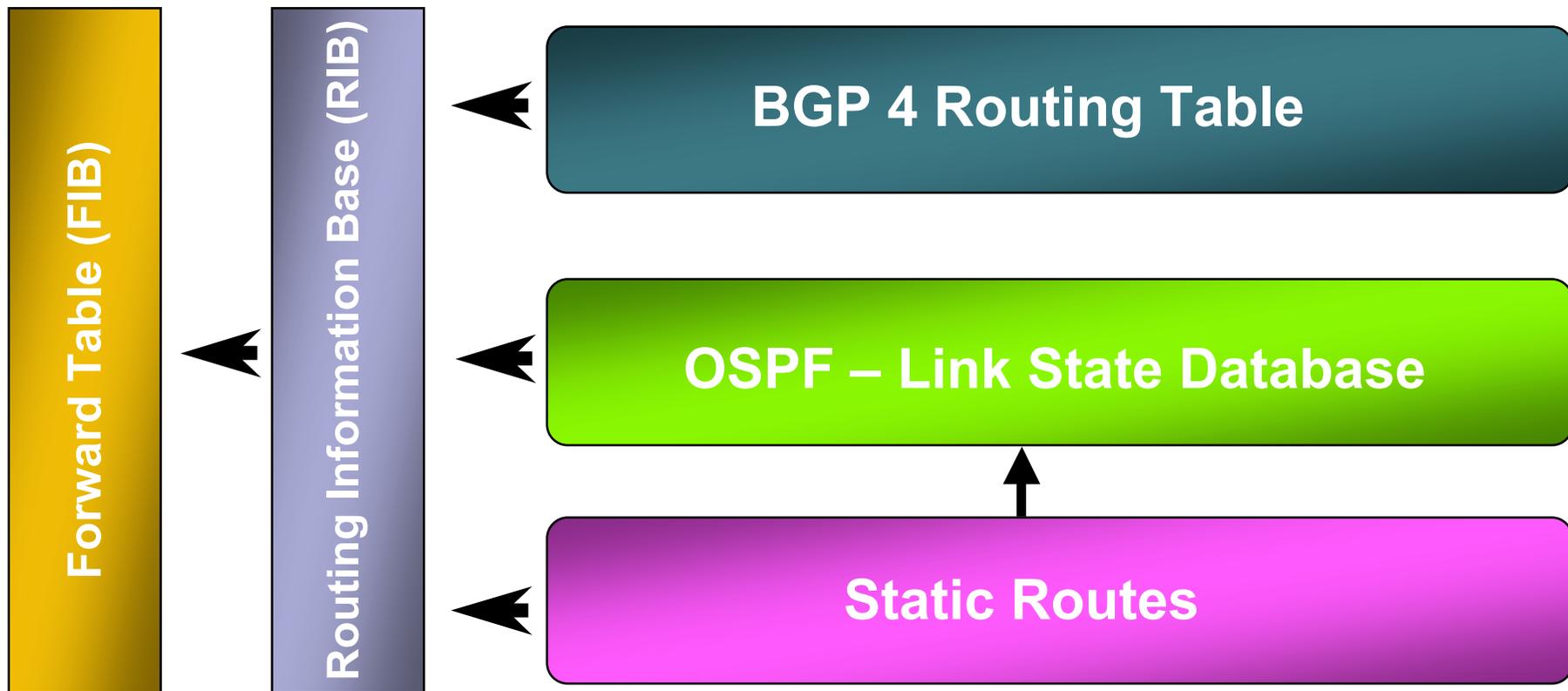
- Based on destination IP address



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



RIBs and FIBs

- **FIB is the Forwarding Table**

It contains destinations and the interfaces to get to those destinations

Used by the router to figure out where to send the packet

Careful! Some people call this a route!

- **RIB is the Routing Table**

It contains a list of all the destinations and the various next hops used to get to those destinations – and lots of other information too!

One destination can have lots of possible next-hops – only the best next-hop goes into the FIB

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

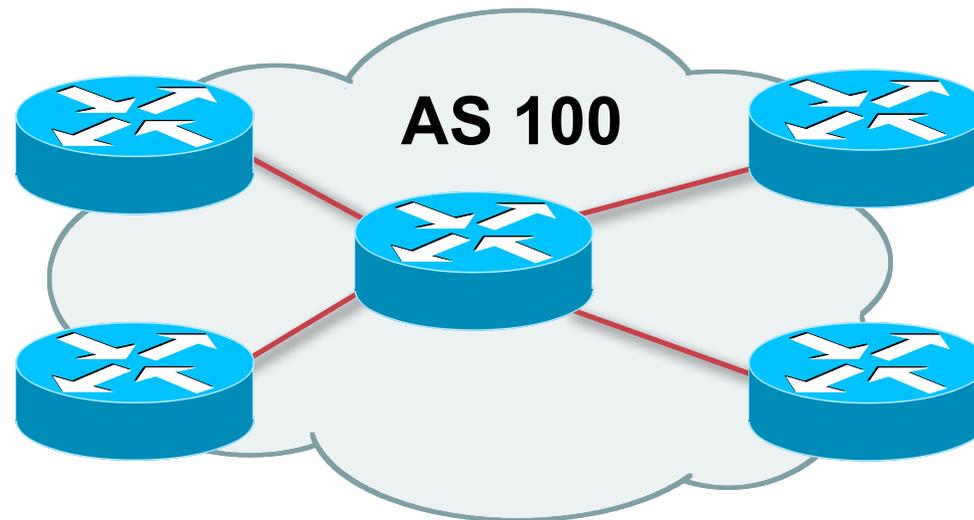
Egress Traffic

- **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

- **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

- **Neighbours**

 - AS's which directly exchange routing information**

 - Routers which exchange routing information**

- **Announce**

 - send routing information to a neighbour**

- **Accept**

 - receive and use routing information sent by a neighbour**

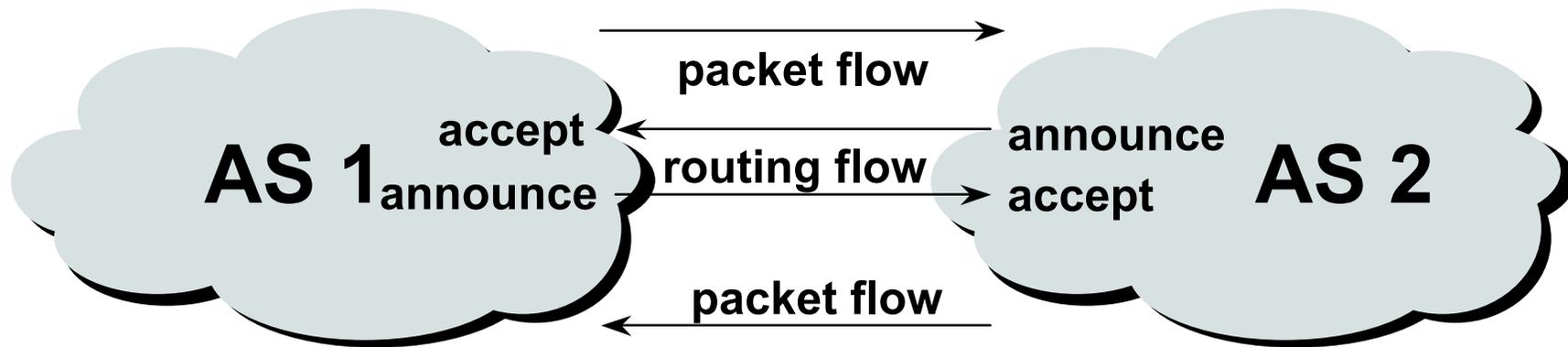
- **Originate**

 - 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

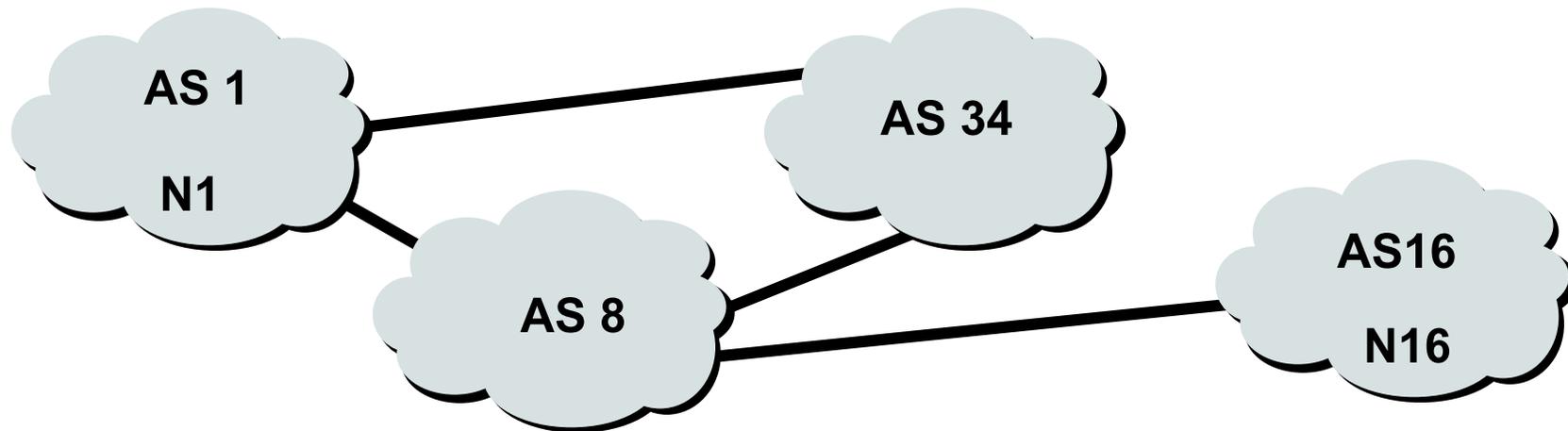
AS2 must announce to AS1

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 flow inbound**
 - Filtering inbound routing information inhibits traffic flow outbound**

Routing Flow/Packet Flow: With multiple ASes

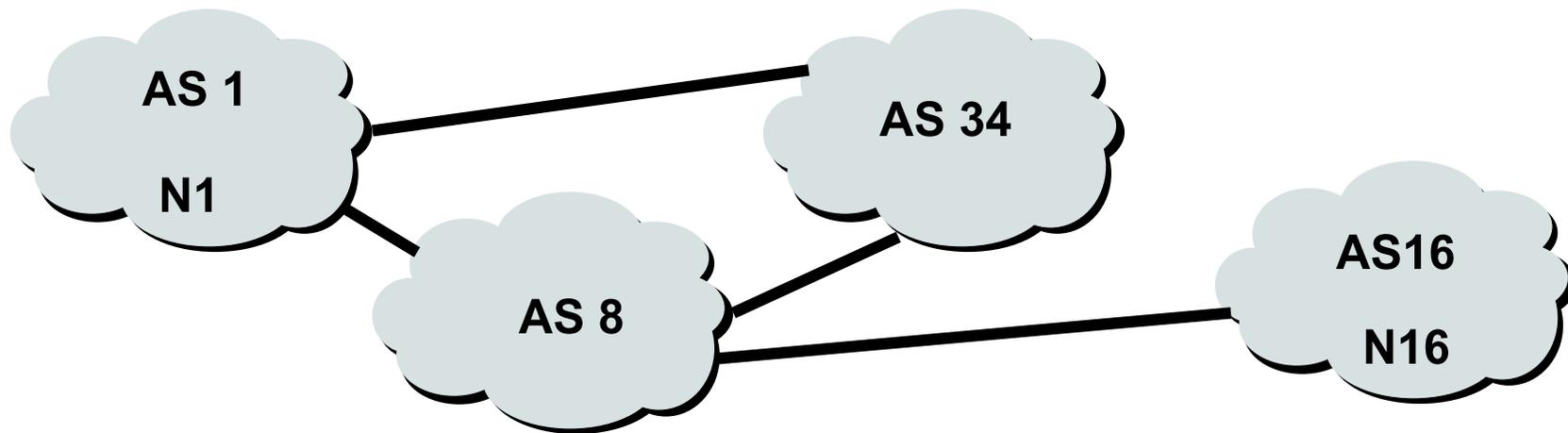


For net N1 in AS1 to send traffic to net N16 in AS16:

- **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 Flow/Packet Flow: With multiple ASes



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

Routing Policy

- **Used to control traffic flow in and out of an ISP network**
- **ISP makes decisions on what routing information to accept and discard from its neighbours**

Individual routes

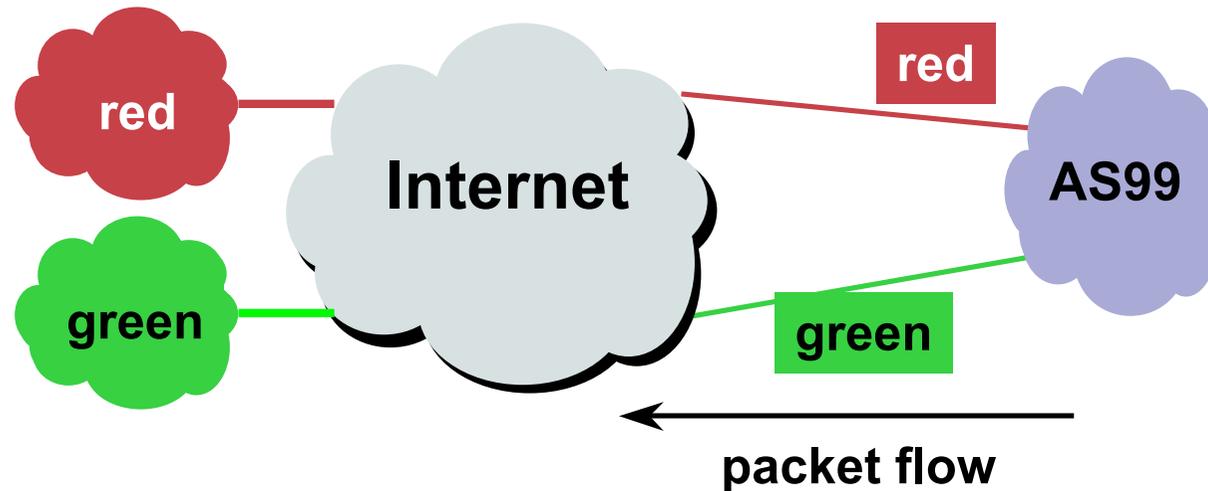
Routes originated by specific ASes

Routes traversing specific ASes

Routes belonging to other groupings

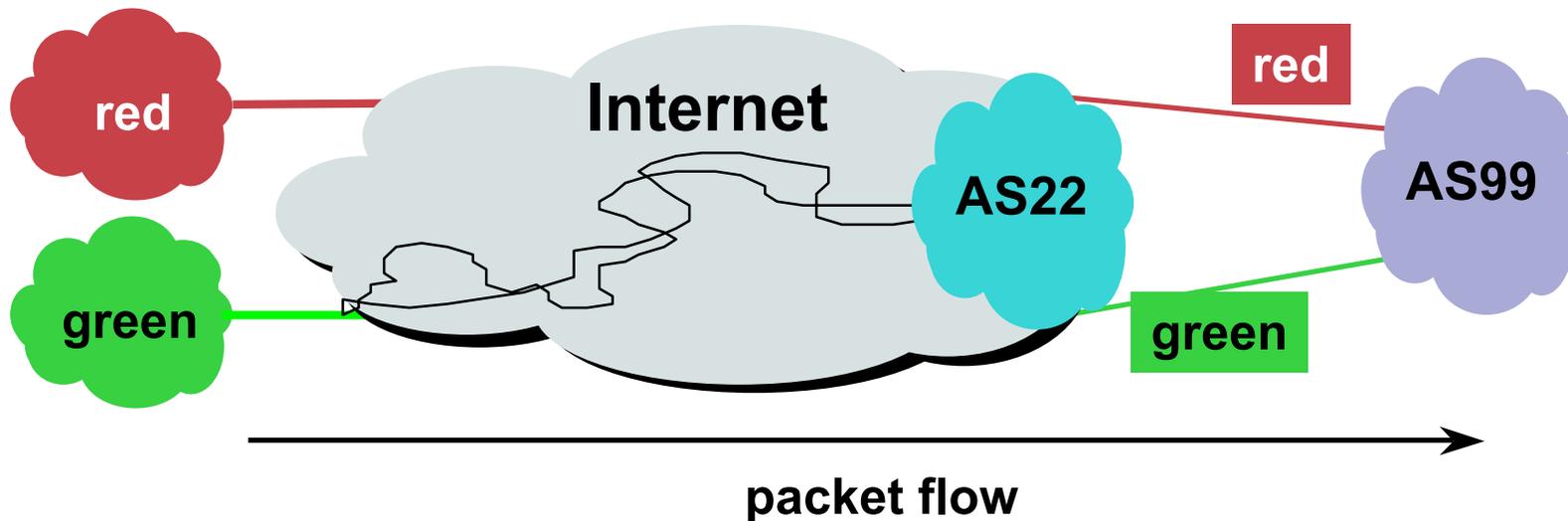
Groupings which you define as you see fit

Routing Policy Limitations



- **AS99 uses red link for traffic to the red AS and the green link for remaining traffic**
- **To implement this policy, AS99 has to:**
 - Accept routes originating from the red AS on the red link**
 - Accept all other routes on the green link**

Routing Policy Limitations



- **AS99 would like packets coming from the green AS to use the green link.**
- **But unless AS22 cooperates in pushing traffic from the green AS down the green link, there is very little that AS99 can do to achieve this aim**

Routing Policy Issues

- **207000 prefixes (not realistic to set policy on all of them individually)**
- **24000 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**



Routing Protocols

**We now know what routing means...
...but what do the routers get up to?
And why are we doing this anyway?**

1: How Does Routing Work?

- **Internet is made up of the ISPs who connect to each other's networks**
- **How does an ISP in Kenya tell an ISP in Japan what customers they have?**
- **And how does that ISP send data packets to the customers of the ISP in Japan, and get responses back**

After all, as on a local ethernet, two way packet flow is needed for communication between two devices

2: How Does Routing Work?

- **ISP in Kenya could buy a direct connection to the ISP in Japan**

But this doesn't scale – thousands of ISPs, would need thousands of connections, and cost would be astronomical

- **Instead, ISP in Kenya tells his neighbouring ISPs what customers he has**

And the neighbouring ISPs pass this information on to their neighbours, and so on

This process repeats until the information reaches the ISP in Japan

3: How Does Routing Work?

- **This process is called “Routing”**
- **The mechanisms used are called “Routing Protocols”**
- **Routing and Routing Protocols ensures that the Internet can scale, that thousands of ISPs can provide connectivity to each other, giving us the Internet we see today**

4: How Does Routing Work?

- **ISP in Kenya doesn't actually tell his neighbouring ISPs the names of the customers**
(network equipment does not understand names)
- **Instead, he has received an IP address block as a member of the Regional Internet Registry serving Kenya**
His customers have received address space from this address block as part of their "Internet service"
And he announces this address block to his neighbouring ISPs – this is called announcing a "route"

Routing Protocols

- **Routers use “routing protocols” to exchange routing information with each other**
 - IGP** is used to refer to the process running on routers inside an ISP’s network
 - EGP** is used to refer to the process running between routers bordering directly connected ISP networks

What Is an IGP?

- **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

Limiting scope of failure

Only used for ISP's **infrastructure addresses, not customers or anything else**

Design goal is to **minimise number of prefixes in IGP to aid scalability and rapid convergence**

What Is an EGP?

- **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 of 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

- **Interior**

Carries ISP infrastructure addresses only

ISPs aim to keep the IGP small for efficiency and scalability

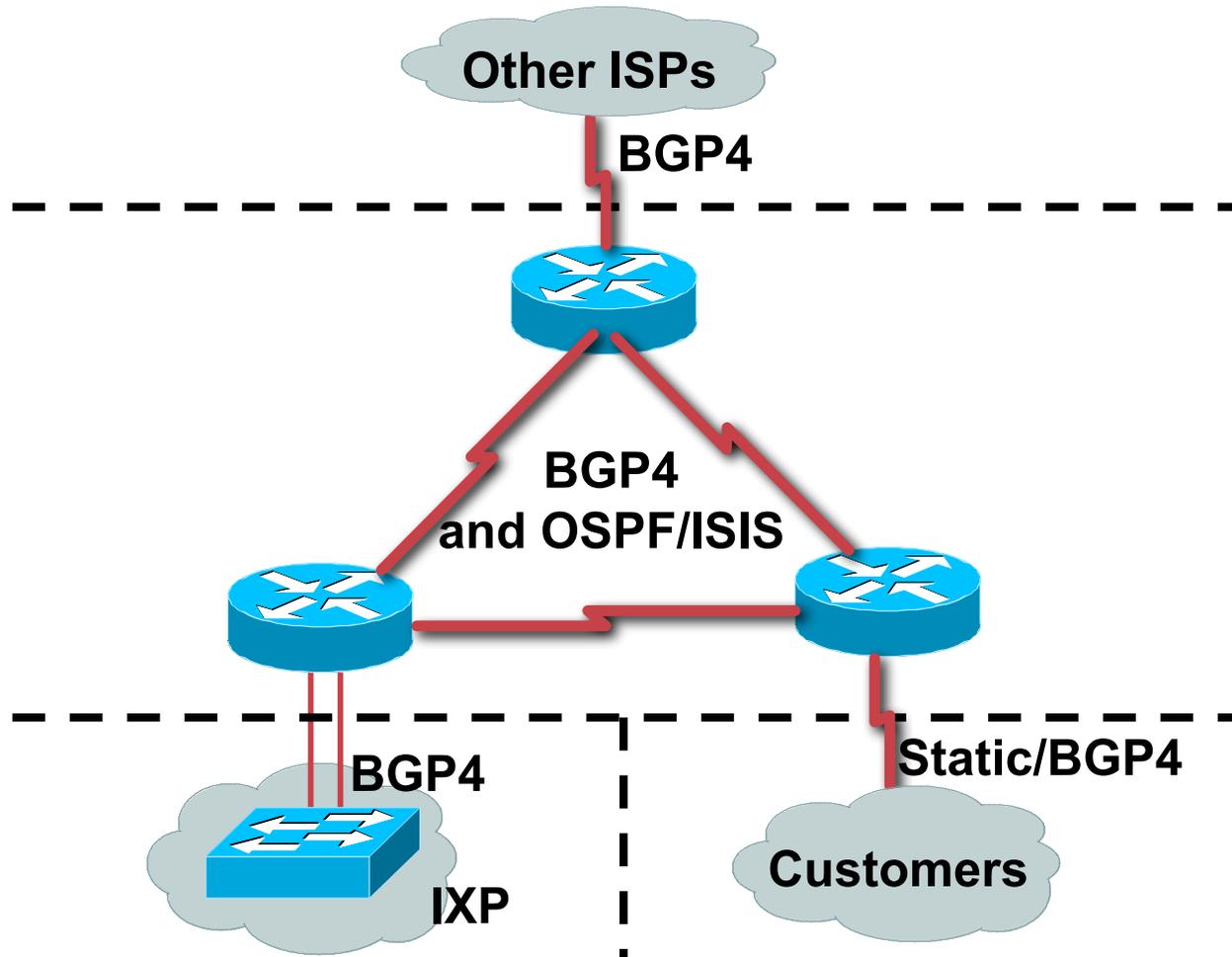
- **Exterior**

Carries customer prefixes

Carries Internet prefixes

EGPs are independent of ISP network topology

Hierarchy of Routing Protocols



FYI: IOS Default Administrative Distances

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



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