

# Routing Basics



ISP Training Workshops

# Routing Concepts

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

# IPv4

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- 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

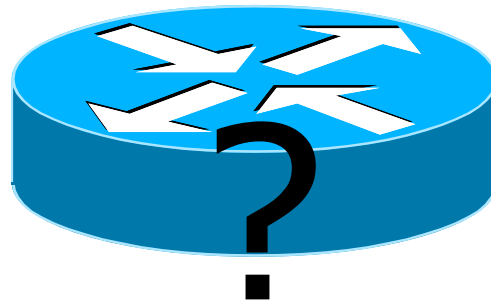
# IPv4 address format

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- 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?

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# A day in a life of a router

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find path

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

find alternate path

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

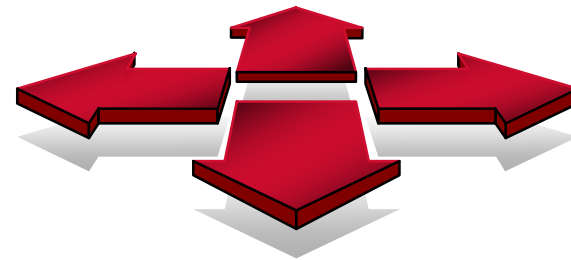
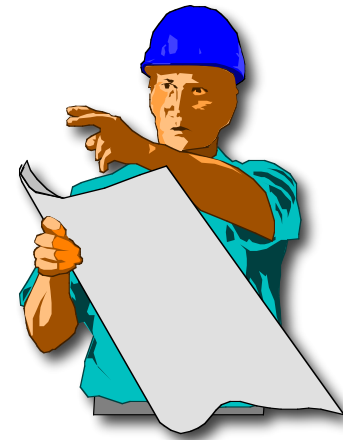
repeat until powered off



# Routing versus Forwarding

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- ❑ 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 path 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.)



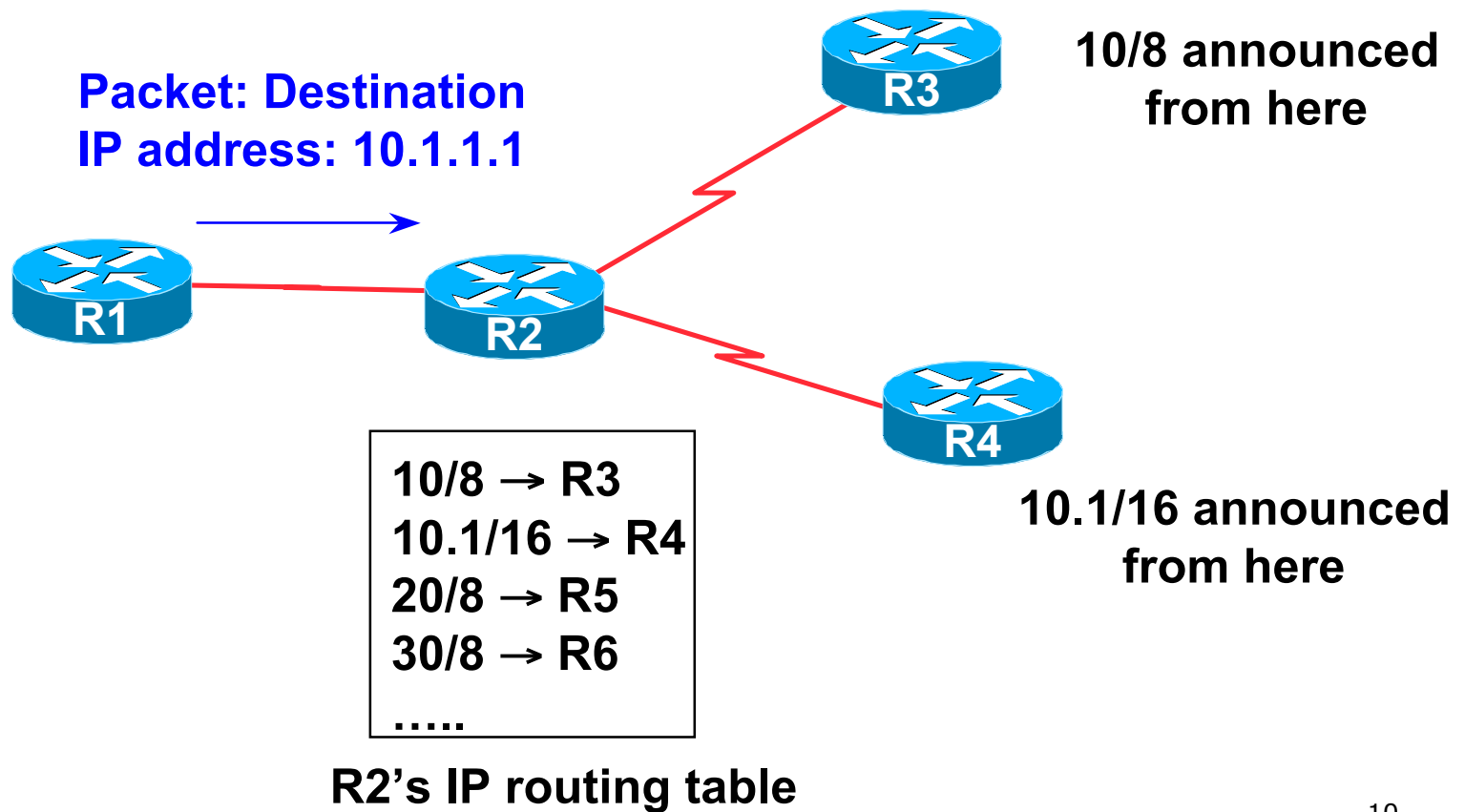
# IP route lookup

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- ❑ 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.

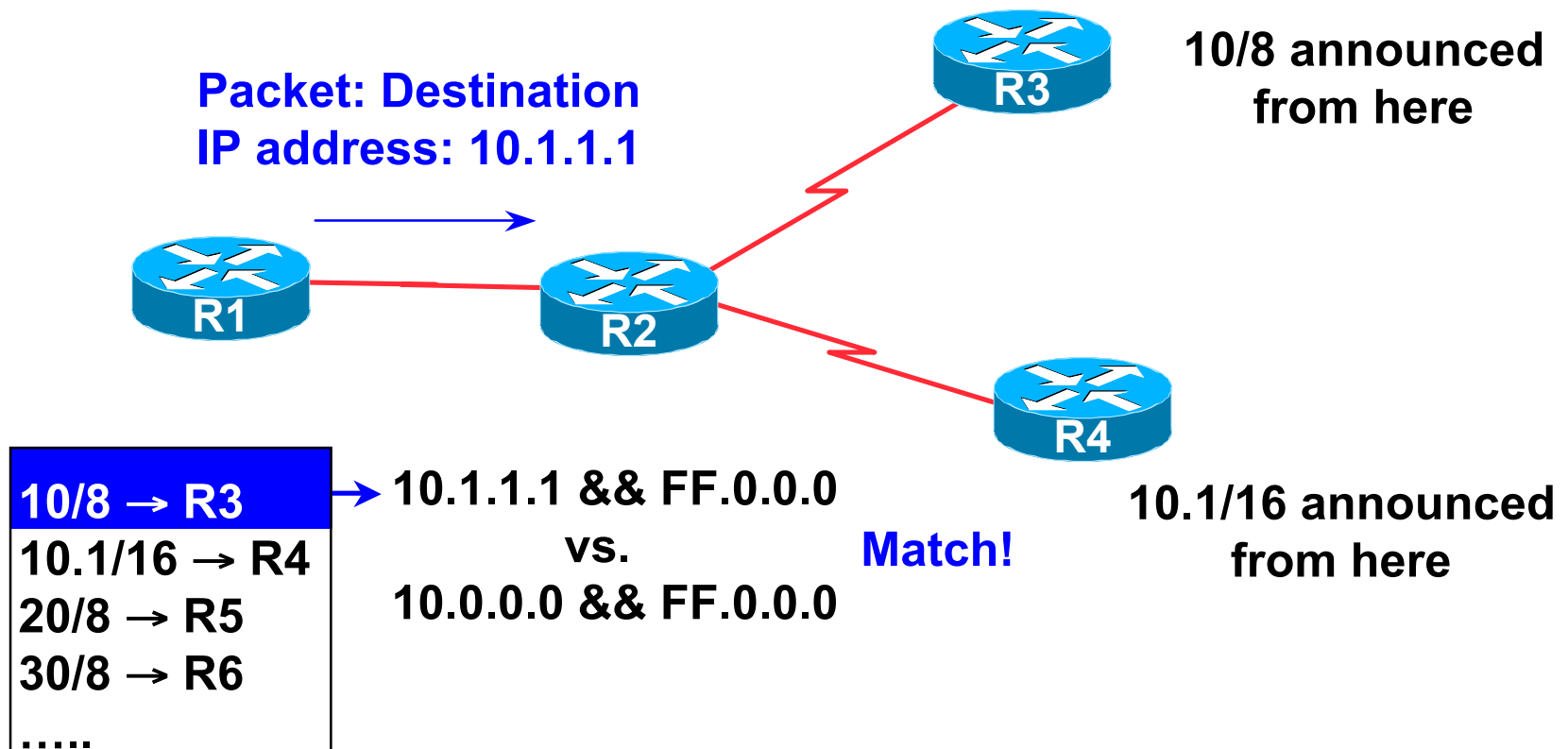
# IP route lookup

- Based on destination IP address



# IP route lookup: Longest match routing

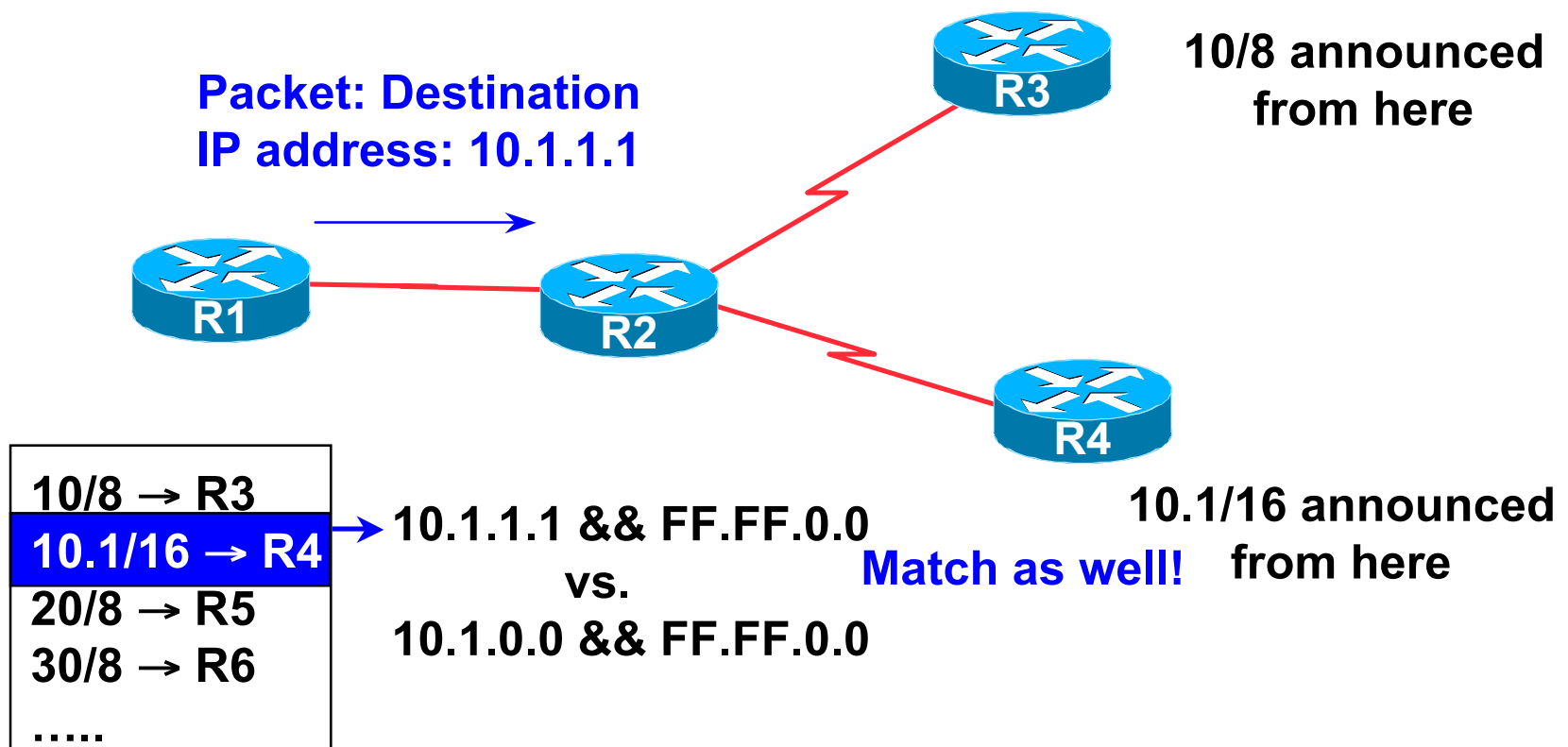
- Based on destination IP address



R2's IP routing table

# IP route lookup: Longest match routing

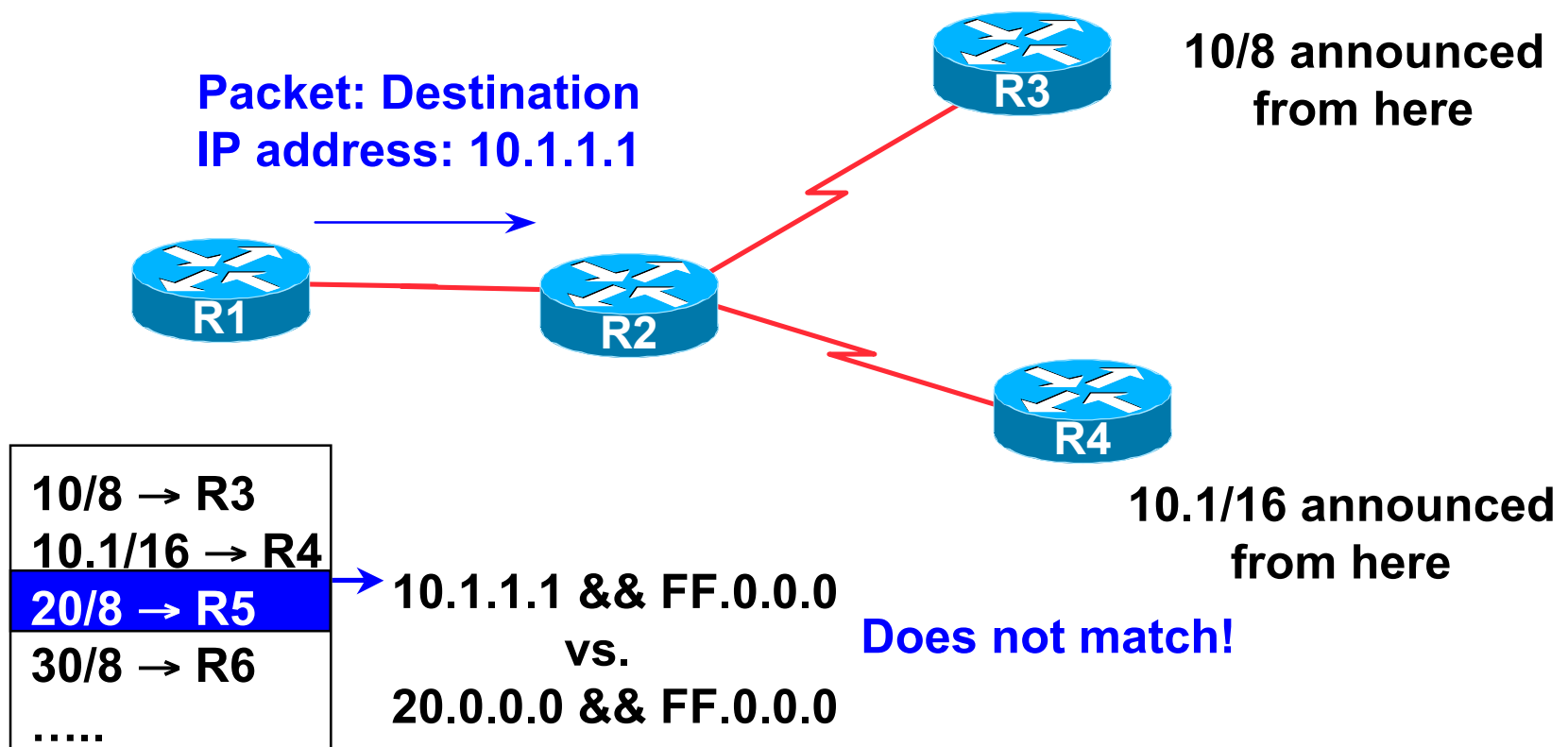
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R2's IP routing table

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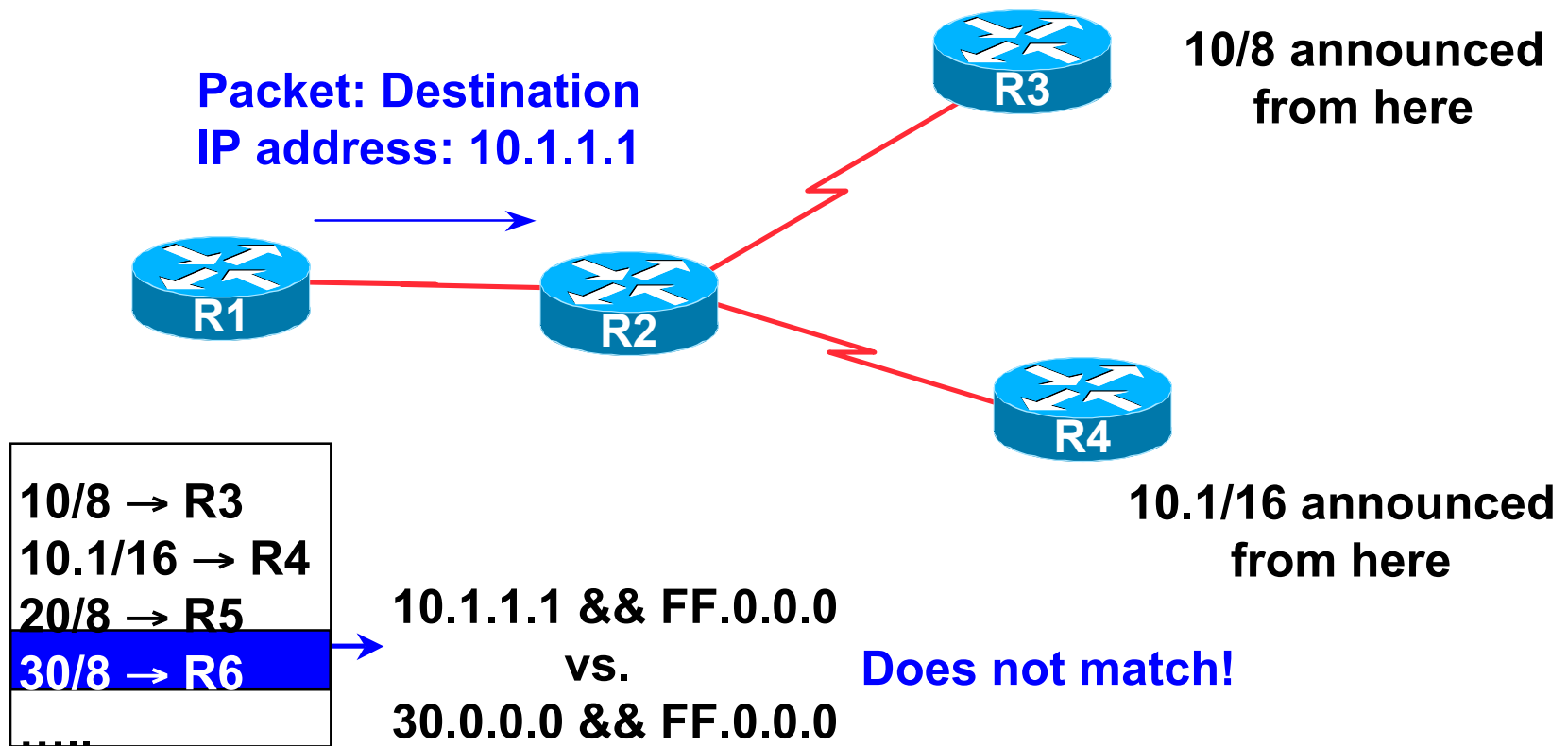
- Based on destination IP address



R2's IP routing table

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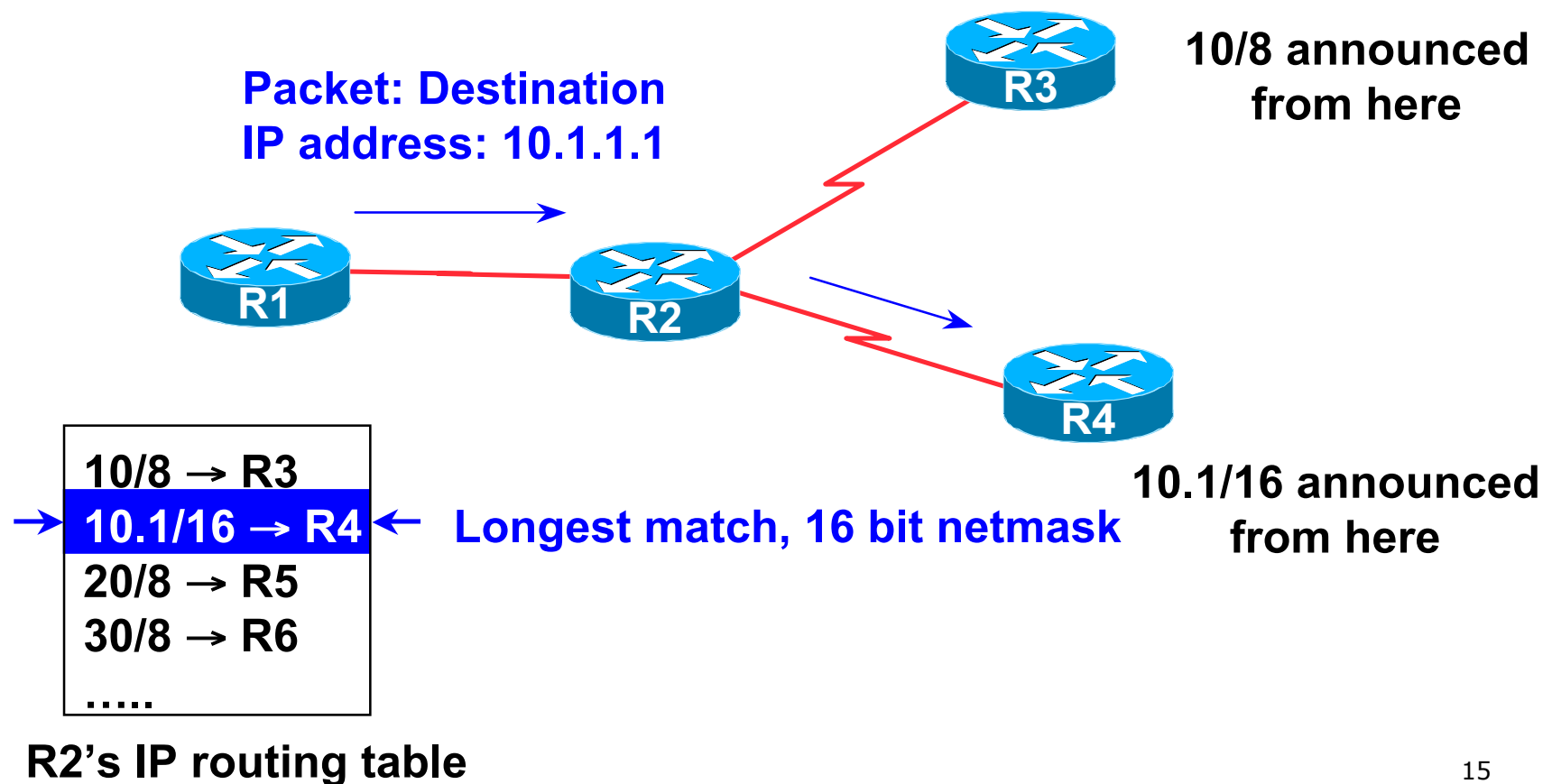
- Based on destination IP address



R2's IP routing table

# IP route lookup: Longest match routing

- Based on destination IP address



# IP Forwarding

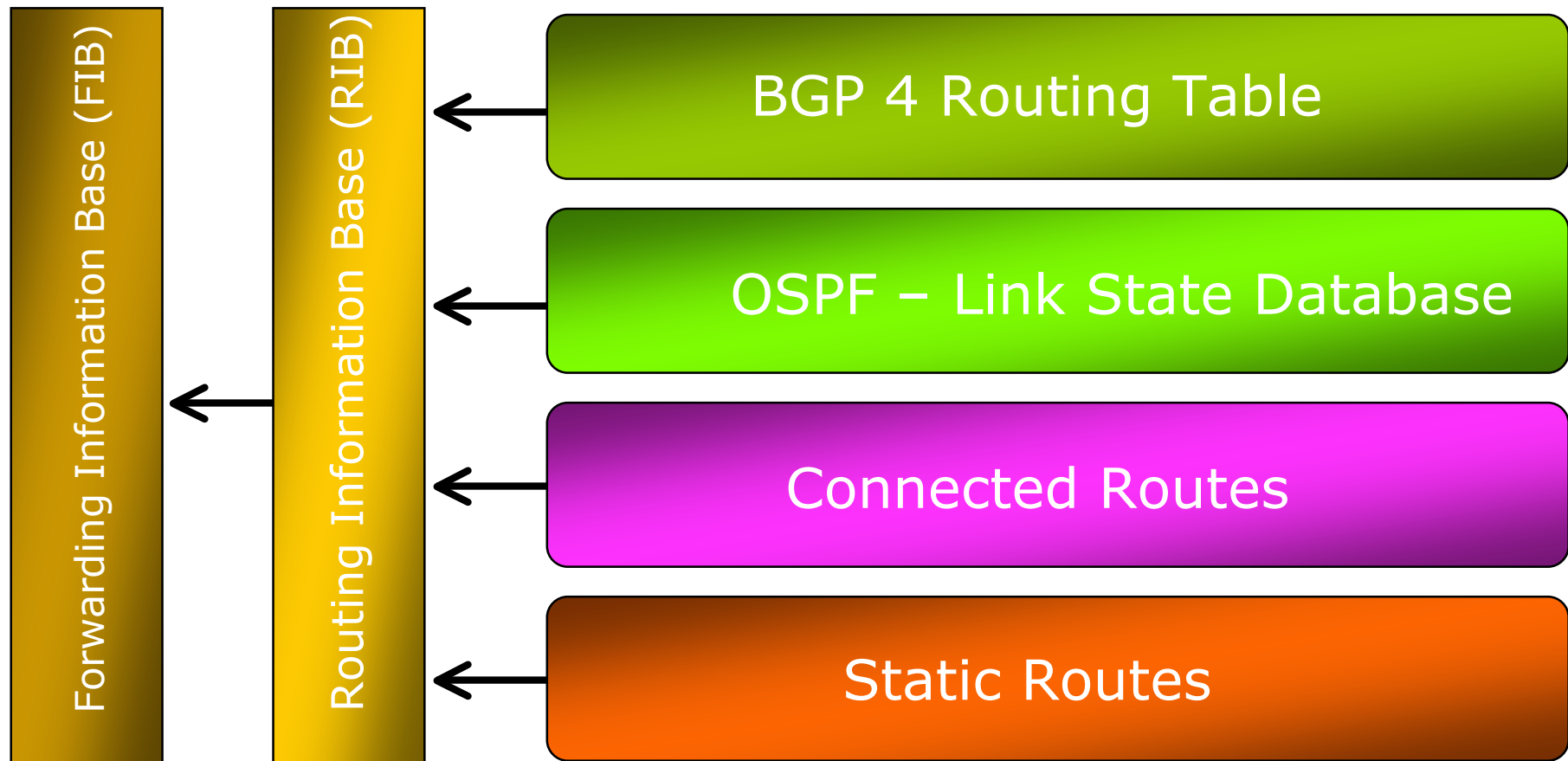
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- ❑ Router makes decision on which interface a packet is sent to
- ❑ Forwarding table populated by routing process
- ❑ Forwarding decisions:
  - destination address
  - class of service (fair queuing, precedence, others)
  - local requirements (packet filtering)
- ❑ Can be aided by special hardware



# Routing Tables Feed the Forwarding Table

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# RIBs and FIBs

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## □ 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

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- 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

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- ❑ 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

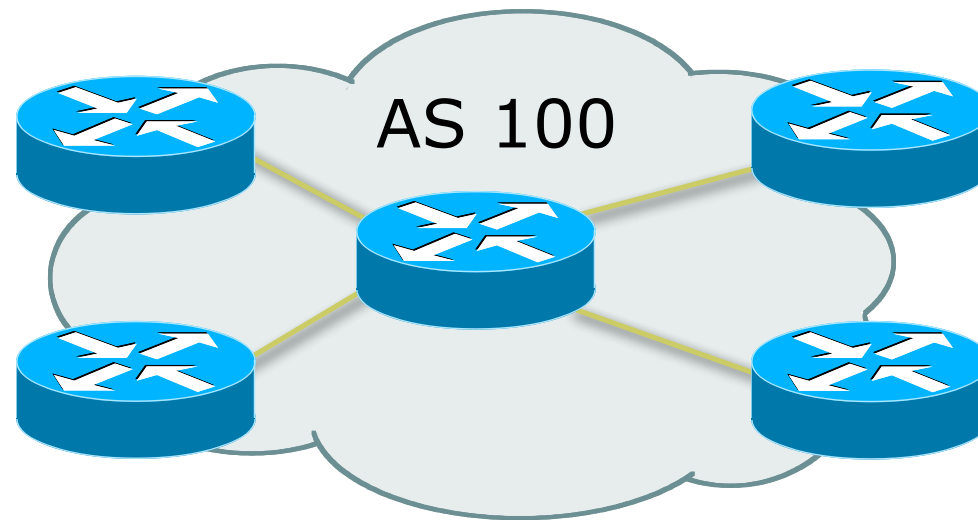
# Ingress Traffic

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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)

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- 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
- Routers which exchange routing information

## □ Announce

- send routing information to a neighbour

## □ Accept

- receive and use routing information sent by a neighbour

## □ Originate

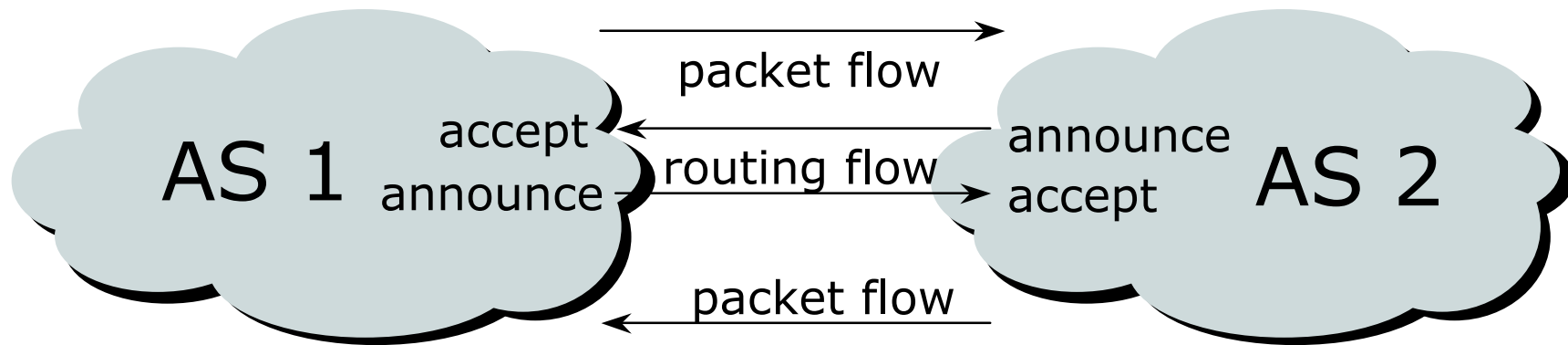
- insert routing information into external announcements (usually as a result of the IGP)

## □ Peers

- routers in neighbouring AS's or within one AS which exchange routing and policy information

# Routing flow and packet flow

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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



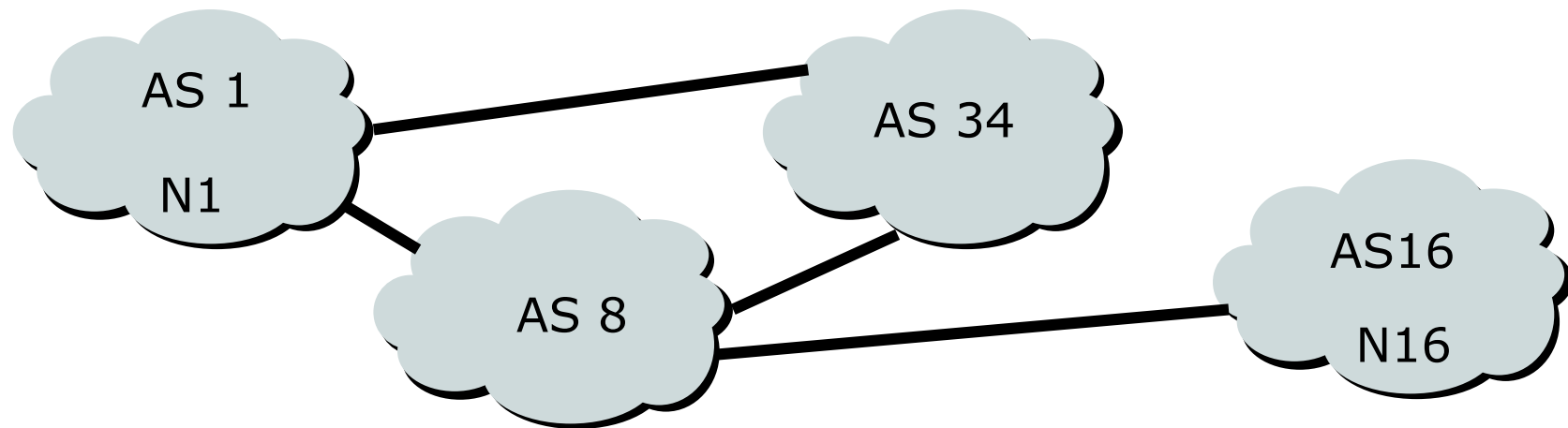
# Routing flow and Traffic flow

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- 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

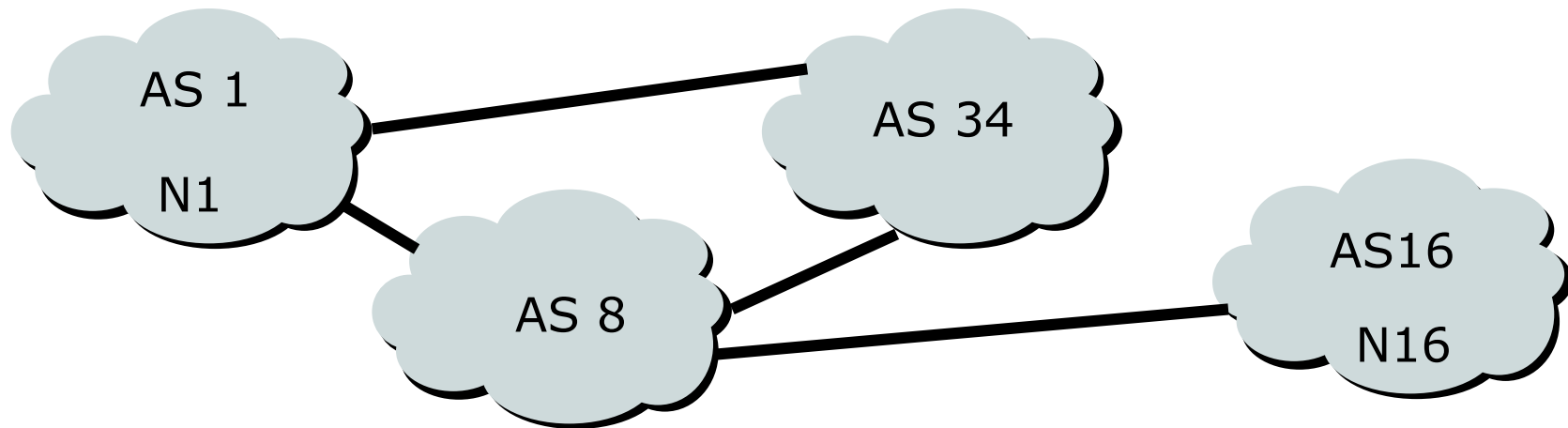
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- ❑ For net N1 in AS1 to send traffic to net N16 in AS16:
  - AS16 must originate and announce N16 to AS8.
  - AS8 must accept N16 from AS16.
  - AS8 must announce N16 to AS1 or AS34.
  - AS1 must accept N16 from AS8 or AS34.
- ❑ For two-way packet flow, similar policies must exist for N1

# Routing Flow/Packet Flow: With multiple ASes

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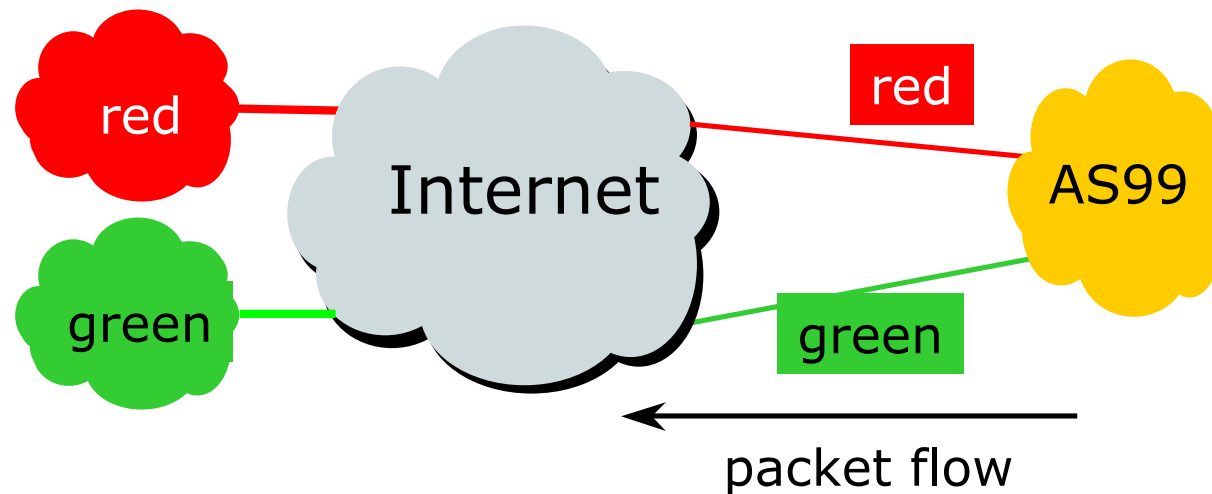
- As multiple paths between sites are implemented it is easy to see how policies can become quite complex.

# Routing Policy

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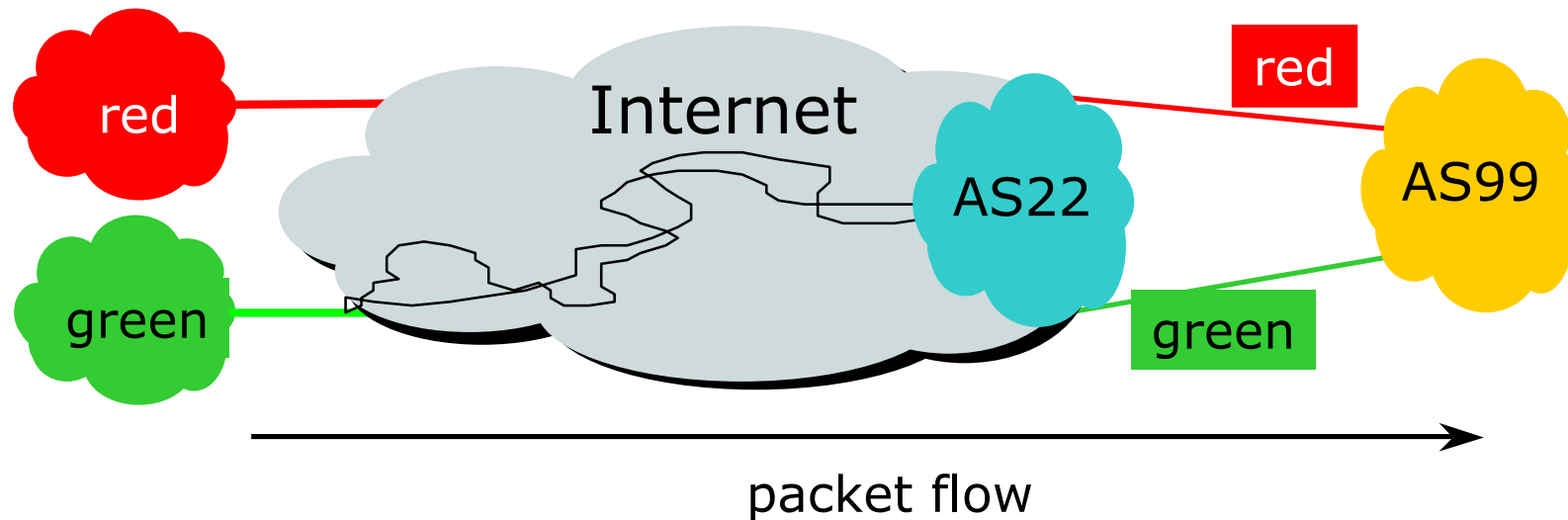
- ❑ Used to control traffic flow in and out of an ISP network
- ❑ ISP makes decisions on what routing information to accept and discard from its neighbours
  - Individual routes
  - Routes originated by specific ASes
  - Routes traversing specific ASes
  - Routes belonging to other groupings
    - ❑ 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

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- End June 2011:
  - 362000 prefixes
    - Not realistic to set policy on all of them individually
  - 38000 origin AS's
    - Too many to try and create individual policies for
- Routes tied to a specific AS or path may be unstable regardless of connectivity
- Solution: Groups of AS's are a natural abstraction for filtering purposes

# Routing Protocols

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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?

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- ❑ 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?

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- ❑ 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?

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- ❑ 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?

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- ❑ 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

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- 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?

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- Interior Gateway Protocol
- Within an Autonomous System
- Carries information about internal infrastructure prefixes
- Two widely used IGPs:
  - OSPF
  - ISIS

# Why Do We Need an IGP?

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- 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?

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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?

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

# Interior versus Exterior Routing Protocols

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## □ 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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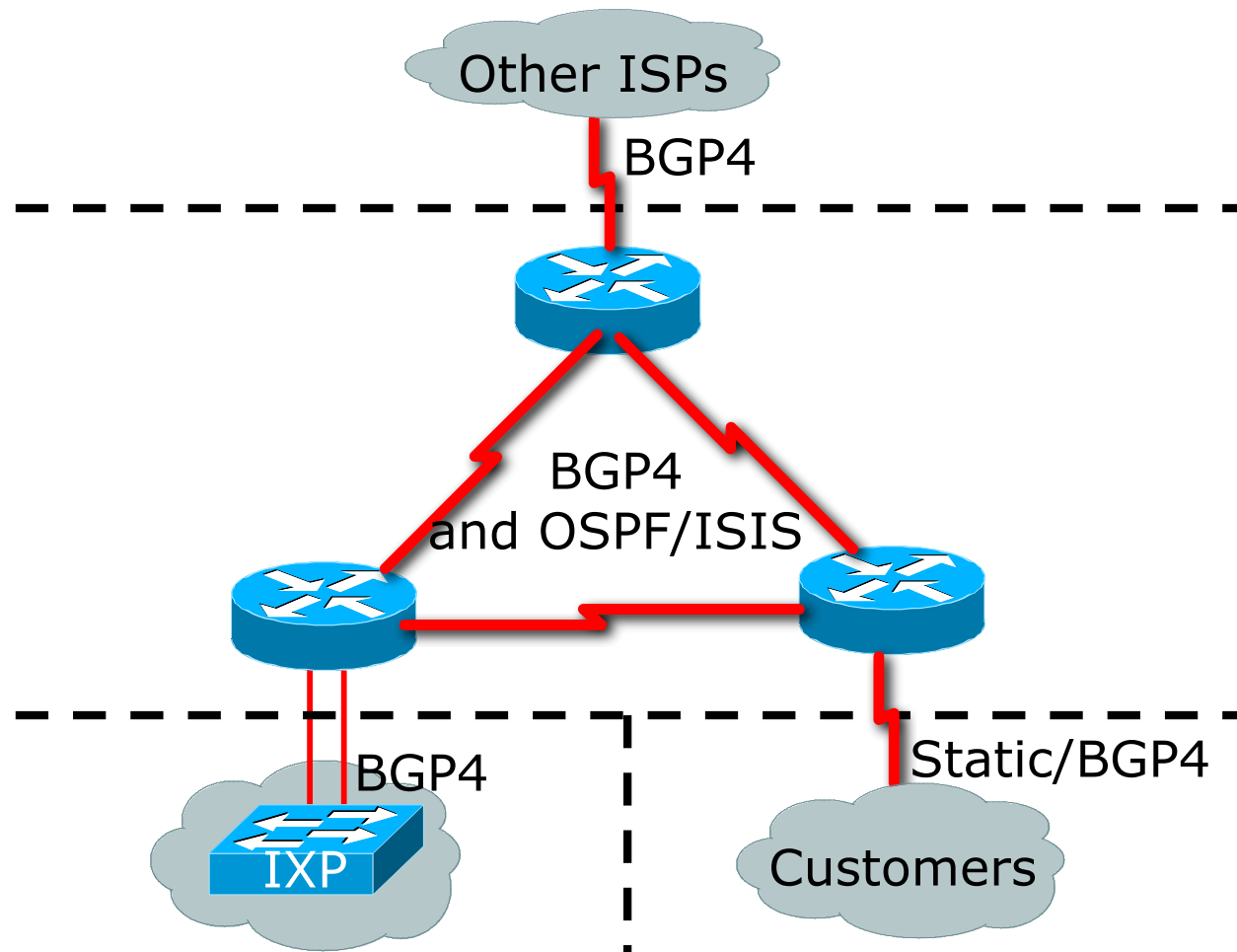
## □ Interior

- 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



# FYI: Cisco 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

# Routing Basics



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