Routing Basics

ISP/IXP Workshops

Routing Concepts

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

IPv4

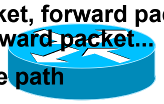
- Internet uses IPv4
  - addresses are 32 bits long
  - range from 1.0.0.0 to 223.255.255.255
  - 0.0.0.0 to 0.255.255.255 and 224.0.0.0 to 255.255.255.255 have "special" uses
- IPv4 address has a network portion and a host portion

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...

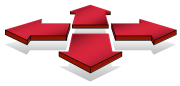
find alternate path

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

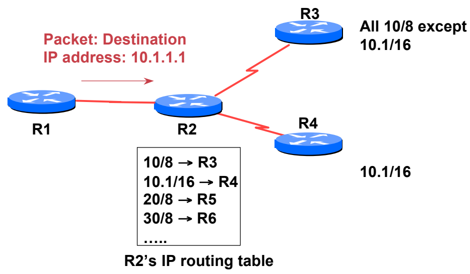
- Based on destination IP packet
- “longest match” routing

  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.

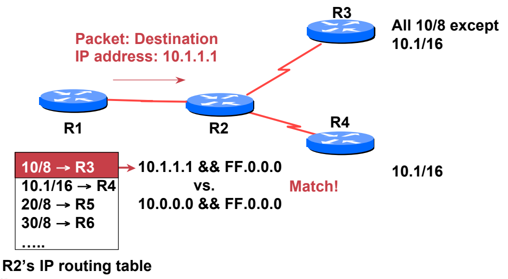
IP route lookup

- Based on destination IP packet



IP route lookup: Longest match routing

- Based on destination IP packet



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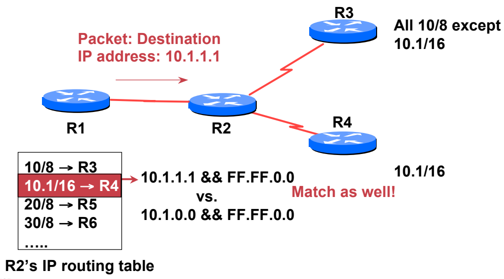

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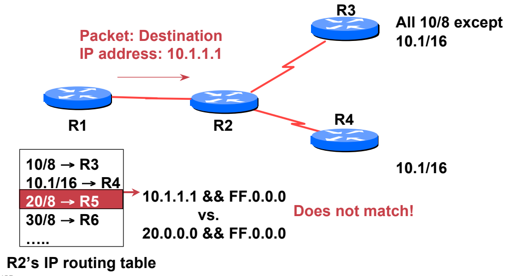

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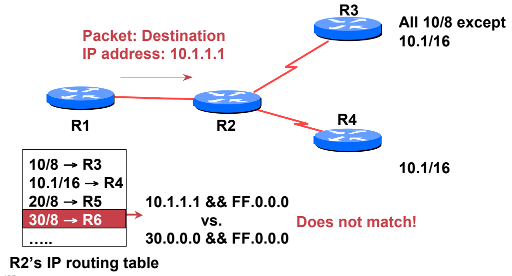

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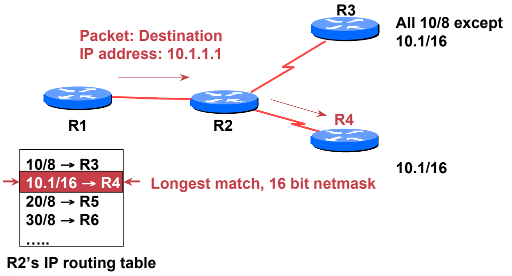
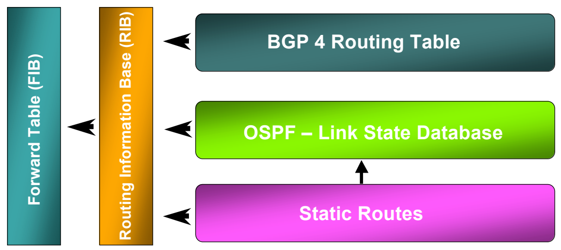


IP Forwarding

- 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

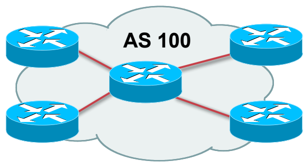
Egress Traffic

- **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)

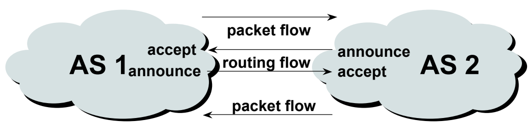


- **Collection of networks with same routing policy**
- **Single routing protocol**
- **Usually under single ownership, trust and administrative control**

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



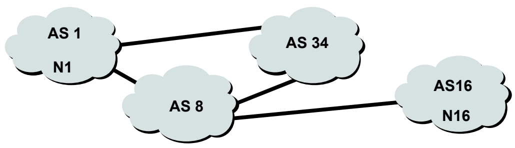
For networks in AS1 and AS2 to communicate:

- 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

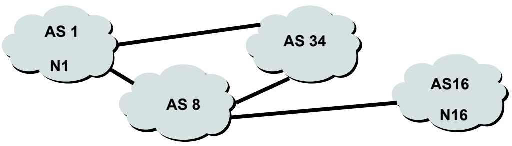


For net N1 in AS1 to send traffic to net N16 in AS16:

- **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

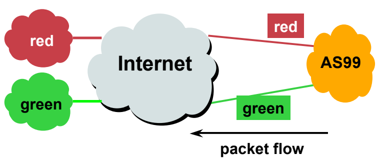


As multiple paths between sites are implemented it is easy to see how policies can become quite complex.

Routing Policy

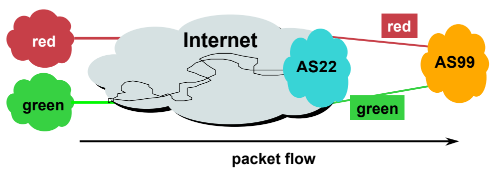
- **Used to control traffic flow in and out of an ISP network**
- **ISP makes decisions on what routing information to accept and discard from its neighbours**
  - **Individual routes**
  - **Routes originated by specific ASes**
  - **Routes traversing specific ASes**
  - **Routes belonging to other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

- 165000 prefixes (not realistic to set policy on all of them individually)
- 20000 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

CISCO SYSTEMS

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

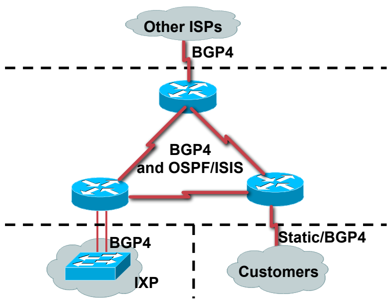
Interior versus Exterior Routing Protocols

- 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

Cisco Systems

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