Routing Basics

Campus Network Design & Operations Workshop

UNIVERSITY OF OREGON

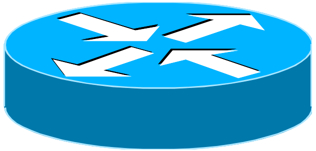
Last updated 7th August 2020

NSRC
Network Startup Resource Center

Routing Concepts

- Routers
- Routing
- Forwarding
- Some definitions
- Routing Protocols

What is a Router?



- A router is a layer 3 device
- Used for interconnecting networks at layer 3
- A router generally has at least two interfaces
  - With VLANs a router can have only one interface (known as "router on a stick")
- A router looks at the destination address in the IP packet, and decides how to forward it

The Routing Table

- Each router/host has a *routing table*, indicating the path or the next hop for a given destination host or a network
- The router/host tries to match the destination address of a packet against entries in the routing table
- If there is a match, the router forwards it to the corresponding gateway router or directly to the destination host
- Default route is taken if no other entry matches the destination address

The Routing Table

Destination	Next-Hop	Interface
10.40.0.0/16	192.248.40.60	Ethernet0
192.248.0.140/30	Directly connected	Serial1
192.248.40.0/26	Directly connected	Ethernet0
192.248.0.0/17	192.248.0.141	Serial1
203.94.73.202/32	192.248.40.3	Ethernet0
203.115.6.132/30	Directly connected	Serial0
Default	203.115.6.133	Serial0

Typical routing table on a simple edge router

IP Routing – finding the path

- Routing table entry (the path) is created by the administrator (static) or received from a routing protocol (dynamic)
- More than one routing protocol may run on a router
  - Each routing protocol builds its own routing table (Local RIB)
- Several alternative paths may exist
  - Best path selected for the router's Global routing table (RIB)
- Decisions are updated periodically or as topology changes (event driven)
- Decisions are based on:
  - Topology, policies and metrics (hop count, filtering, delay, bandwidth, etc.)

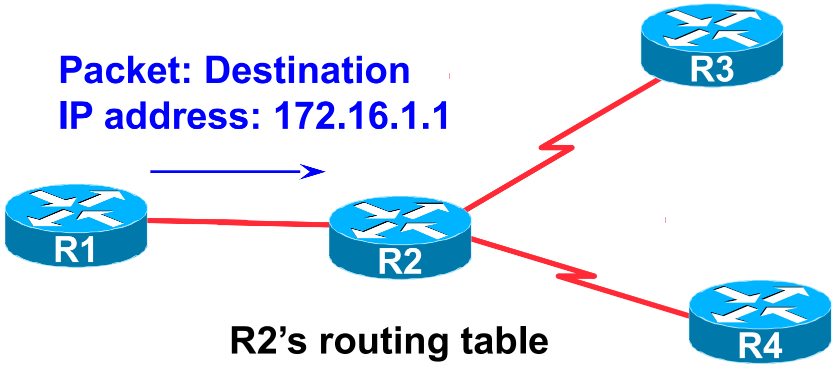
IP route lookup

- Based on destination IP address
- “longest match” routing
  - More specific prefix preferred over less specific prefix
  - **Example**: packet with destination of 172.16.1.1/32 is sent to the router announcing 172.16.1.0/24 rather than the router announcing 172.16.0.0/16.

IP route lookup

- Based on destination IP address

Packet: Destination IP address: 172.16.1.1



172.16.0.0/16 announced from here

172.16.1.0/24 announced from here

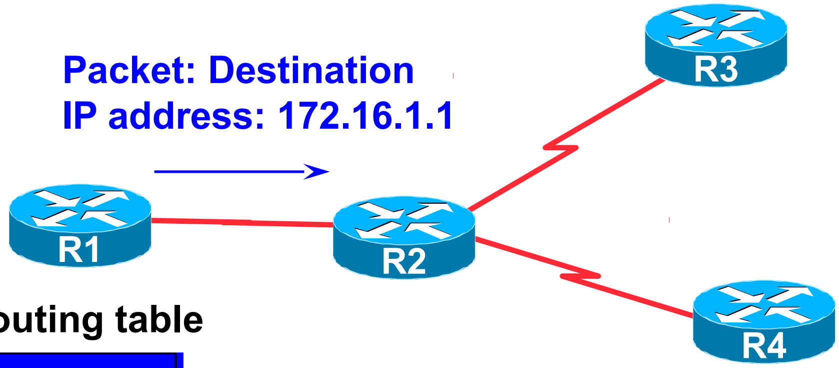
R2's routing table

Destination → NextHop
172.16.0.0/16 → R3
172.16.1.0/24 → R4
172.18.0.0/16 → R5
172.19.0.0/16 → R6
……

IP route lookup: Longest match routing

- Based on destination IP address

Packet: Destination IP address: 172.16.1.1



172.16.0.0/16 announced from here

172.16.1.0/24 announced from here

R2's IP routing table

172.16.0.0/16 → R3
172.16.1.0/24 → R4
172.18.0.0/16 → R5
172.19.0.0/16 → R6
……

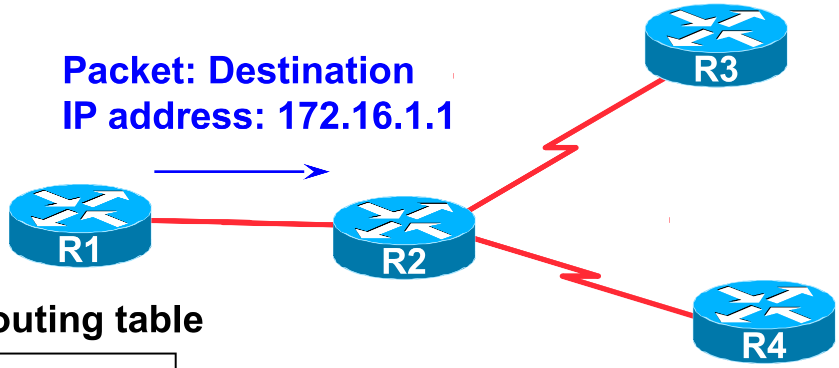
172.16.1.1 exists inside 172.16.1.0/24

Match!

IP route lookup: Longest match routing

- Based on destination IP address

Packet: Destination IP address: 172.16.1.1



172.16.0.0/16 announced from here

172.16.1.0/24 announced from here

R2's IP routing table

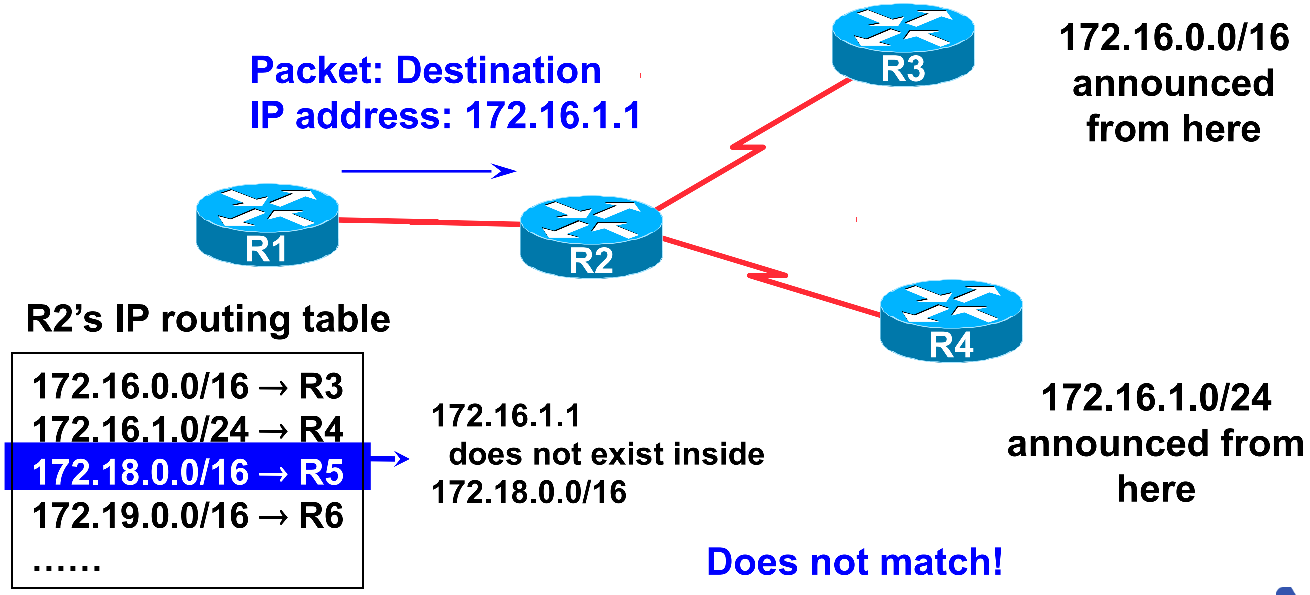
172.16.0.0/16 → R3
172.16.1.0/24 → R4
172.18.0.0/16 → R5
172.19.0.0/16 → R6
……

172.16.1.1 exists inside 172.16.1.0/24

Match as well!

IP route lookup: Longest match routing

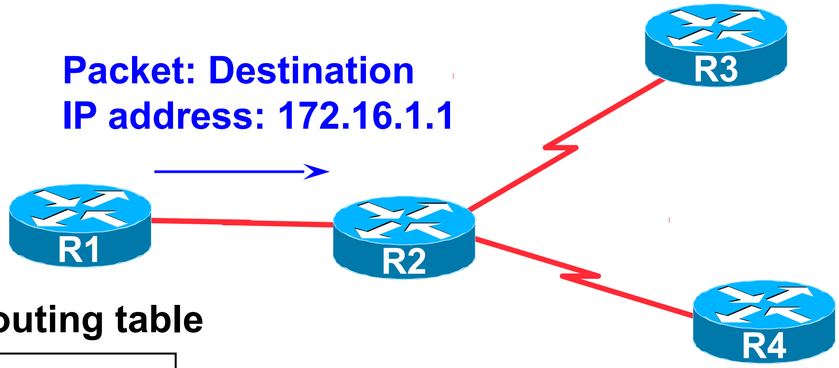
- Based on destination IP address



IP route lookup: Longest match routing

- Based on destination IP address

Packet: Destination
IP address: 172.16.1.1



172.16.0.0/16
announced
from here

172.16.1.0/24
announced from
here

R2's IP routing table

172.16.0.0/16 → R3
172.16.1.0/24 → R4
172.18.0.0/16 → R5
172.19.0.0/16 → R6
……

172.16.1.1
does not exist inside
172.19.0.0/16

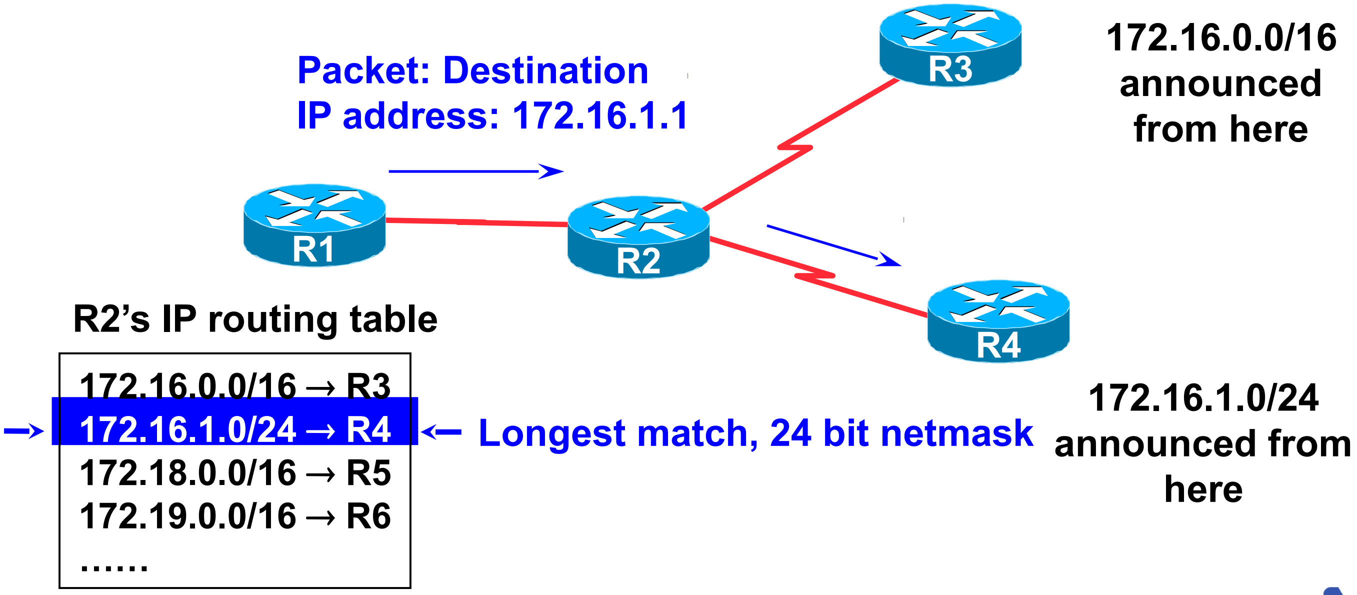
Does not match!

UNIVERSITY OF OREGON

NSRC
Network Startup Resource Center

IP route lookup: Longest match routing

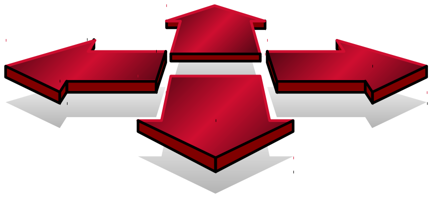
- Based on destination IP address



Routing versus Forwarding

- Routing = building maps and giving directions

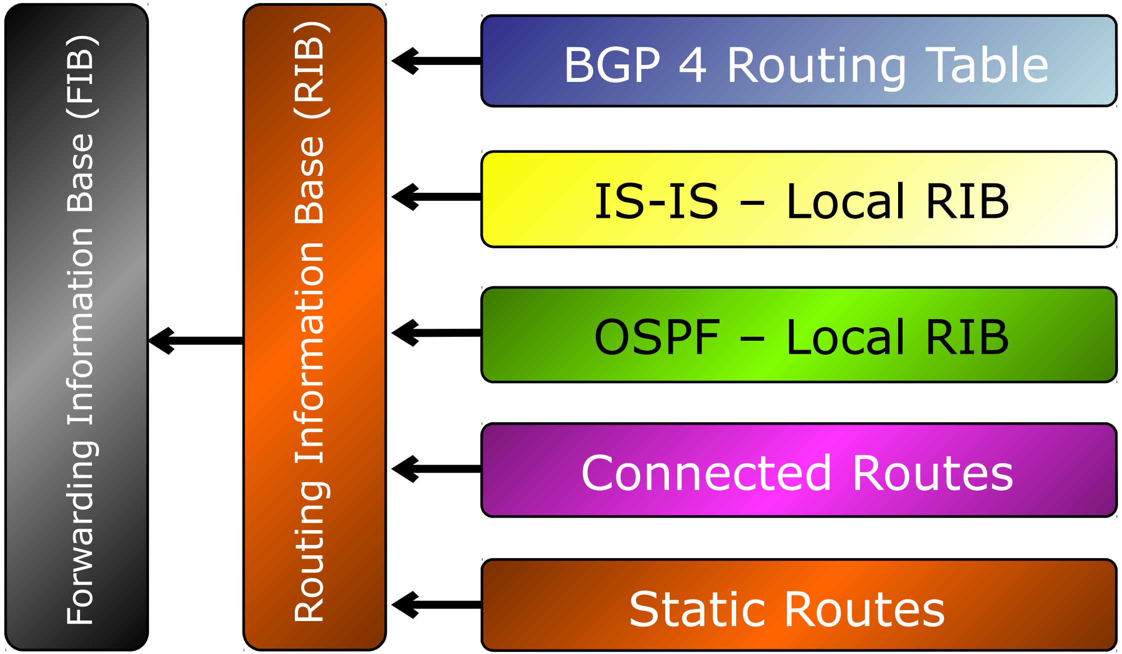
- Forwarding = moving packets between interfaces according to the “directions”



IP Forwarding

- Router decides 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)
- Forwarding is usually aided by special hardware

Routing Tables Feed the Forwarding Table



The FIB

- FIB is the Forwarding Table
  - It contains destinations, the interfaces and the next-hops to get to those destinations
  - It is built from the router’s Global RIB
  - Used by the router to figure out where to send the packet
  - Cisco IOS: “show ip cef”

The Global RIB

- The Global RIB is the Routing Table
  - Built from the routing tables/RIBs of the routing protocols and static routes on the router
    - Routing protocol priority varies per vendor – see addendum
  - It contains all the known destinations and the next-hops used to get to those destinations
  - One destination can have lots of possible next-hops – only the best next-hop goes into the Global RIB
  - The Global RIB is used to build the FIB
  - Cisco IOS: “show ip route”

Explicit versus Default Routing

- Default: Pointing all destinations to another device
  - Simple, cheap (CPU, memory, bandwidth)
  - No overhead
  - Low granularity (metric games)
- Explicit: Every known destination (default free zone)
  - Complex, expensive (CPU, memory, bandwidth)
  - High overhead
  - High granularity (every destination known)
- Hybrid: Default plus some destinations
  - Minimise overhead
  - Provide useful granularity
  - Requires some filtering knowledge

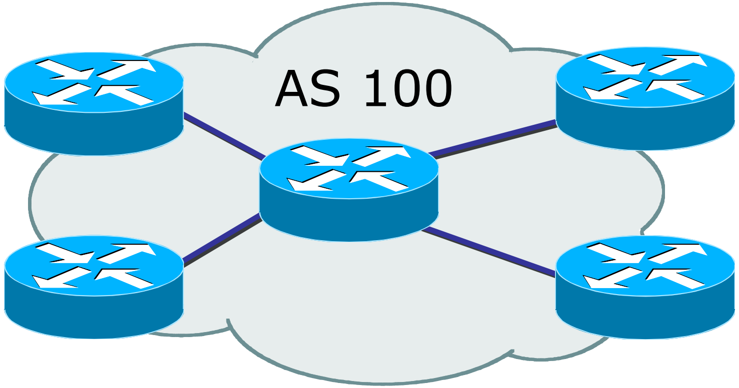
Egress Traffic

- 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 enter your network
- 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)

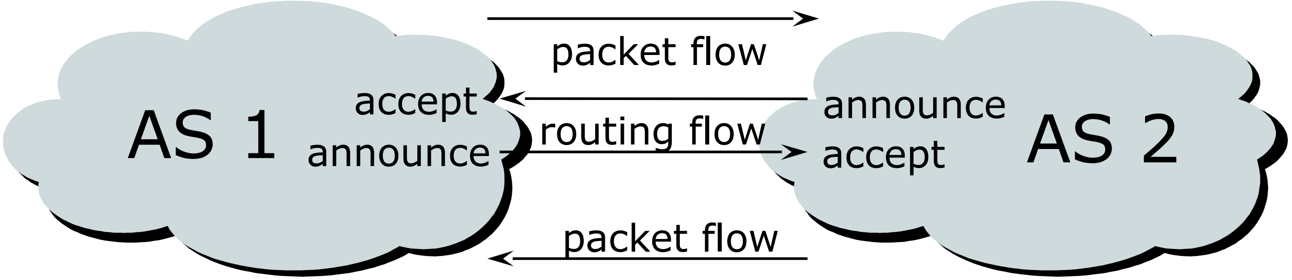


- Collection of networks with same routing policy
- Single routing protocol
- Usually under single ownership, trust and administrative control

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 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 RENs and ISPs who connect to each other's networks
- How does an ISP in Kenya tell an ISP in Japan what end-users it has?
- 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 its neighbouring ISPs what end-users it 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
  - Thousands of ISPs can provide connectivity to each other
  - We have the Internet we see today

4: How Does Routing Work?

- ISP in Kenya doesn't actually tell its neighbouring ISPs the names of the end-users
  - (network equipment does not understand names)
- Instead, the ISP will have received an IP address block as a member of the Regional Internet Registry serving Kenya
  - The end-users will have received address space from this address block as part of their "Internet service"
  - And the ISP announces this address block to its 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 a network
  - **EGP** is used to refer to the process running between routers bordering directly connected networks

What Is an IGP?

- **I**nterior **G**ateway **P**rotocol
- Within an Autonomous System
- Carries information about internal infrastructure prefixes
- Two widely used IGPs:
  - OSPF (Open Shortest Path First)
  - IS-IS (Intermediate System to Intermediate System)

Why Does Internet Need an IGP?

- Backbone scaling in RENs and ISPs
  - Hierarchy
  - Limiting scope of failure
  - Only used for Operator's **infrastructure** addresses, not end user addresses or anything else
  - Design goal is to **minimise** number of prefixes in IGP to aid scalability and rapid convergence
- Scalable internal routing for end user networks

What Is an EGP?

- **E**xterior **G**ateway **P**rotocol
- Used to convey routing information between Autonomous Systems
- De-coupled from the IGP
- The only EGP is Border Gateway Protocol (BGP)

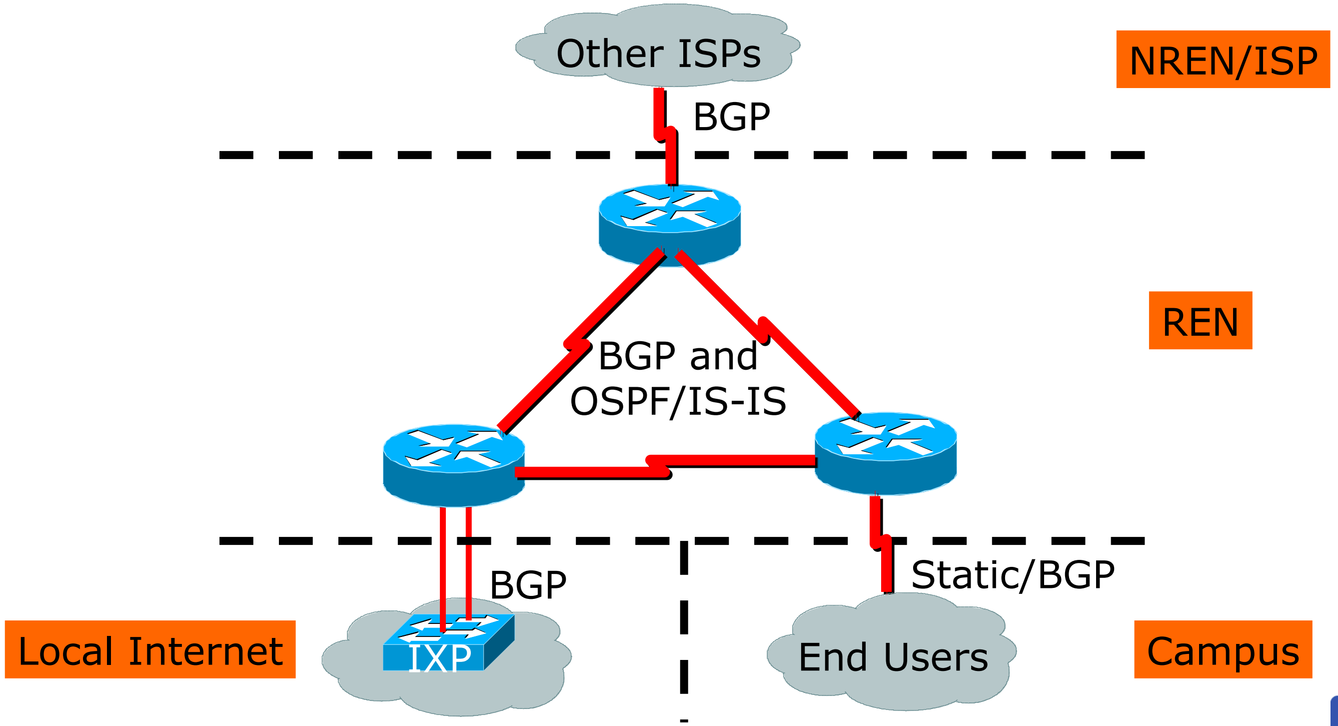
Why Does Internet need an EGP?

- Scaling to large network
  - Hierarchy
  - Limit scope of failure
- Define Administrative Boundary
- Policy
  - Control reachability of prefixes
  - Merge separate organisations
  - Connect multiple IGPs
- Application: RENs, ISPs, Multihomed end-users

Interior versus Exterior Routing Protocols

- Interior
  - Automatic neighbour discovery
  - Generally trust your IGP routers
  - Prefixes go to all IGP routers
- Exterior
  - Specifically configured peers
  - Connecting with outside networks
  - Set administrative boundaries

Hierarchy of Routing Protocols



Questions?

FYI: Default Administrative Distances

Route Source	Cisco	Juniper	Huawei	Brocade	Nokia/ALU	Mikrotik
Connected Interface	0	0	0	0	0	0
Static Route	1	5	60	1	1	1
EIGRP Summary Route	5	N/A	?	N/A	N/A	N/A
External BGP	20	170	255	20	170	20
Internal EIGRP Route	90	N/A	?	N/A	N/A	N/A
IGRP	100	N/A	?	N/A	N/A	N/A
OSPF	110	10	10	110	10	110
IS-IS	115	18	15	115	18	N/A
RIP	120	100	100	120	100	120
EGP	140	N/A	N/A	N/A	N/A	N/A
External EIGRP	170	N/A	?	N/A	N/A	N/A
Internal BGP	200	170	255	200	130	200
Unknown	255	255	?	255	?	

Network Startup Resource Center