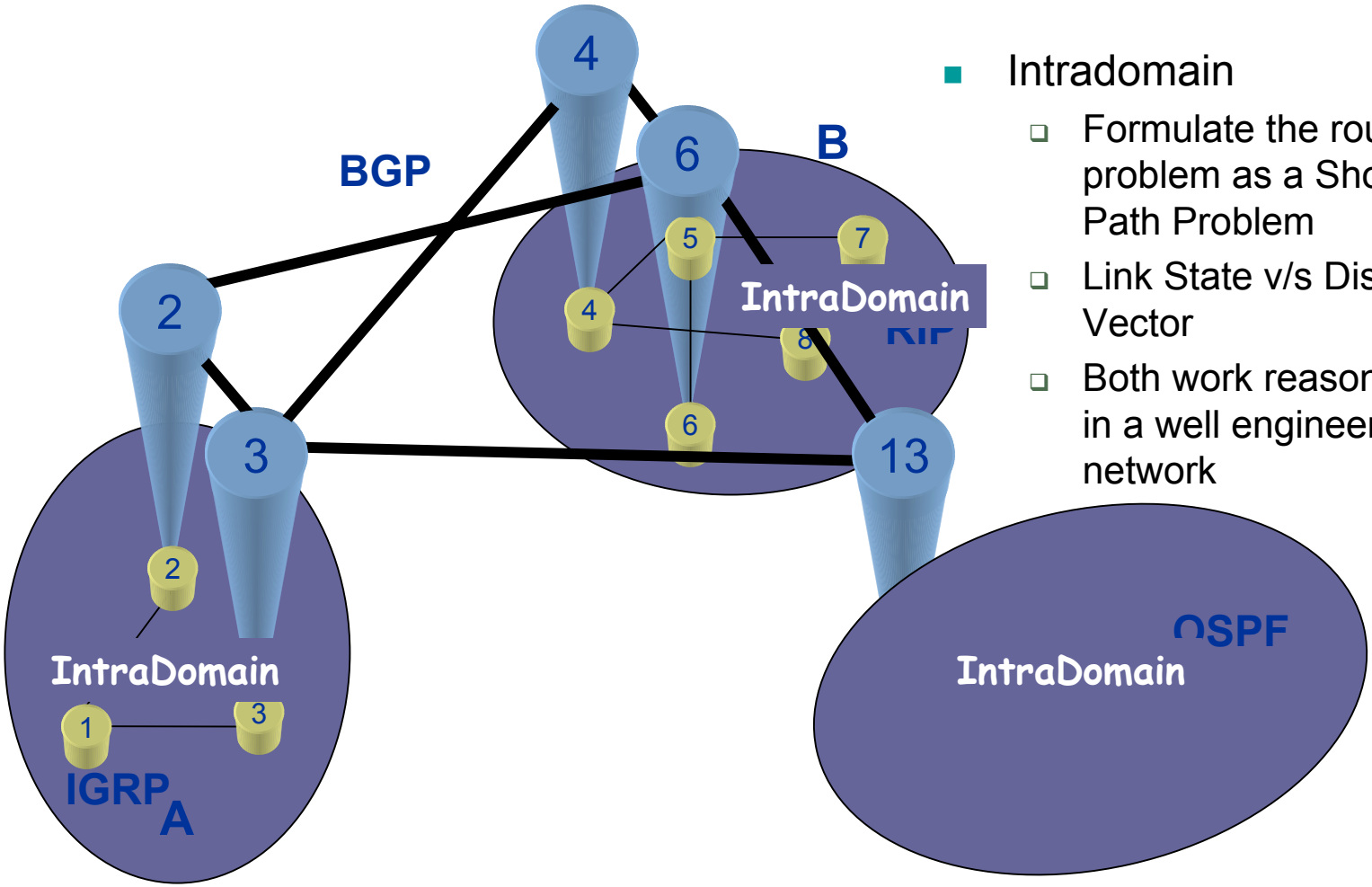
TOC – Interdomain Routing

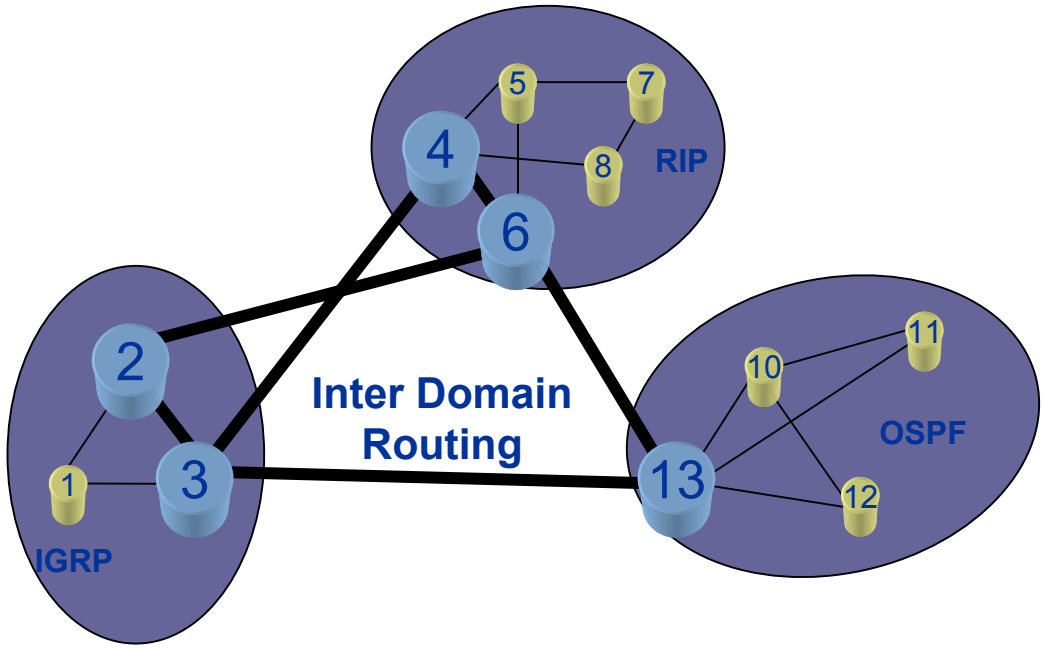
Review



- Intradomain
  - Formulate the routing problem as a Shortest Path Problem
  - Link State v/s Distance Vector
  - Both work reasonably well in a well engineered network

Why Hierarchical Routing?

- Is a natural way for routing to scale
  - Size
  - Network Administration
  - Governance
- Allows multiple metrics at different levels of the hierarchy
- Exploits address aggregation and allocation



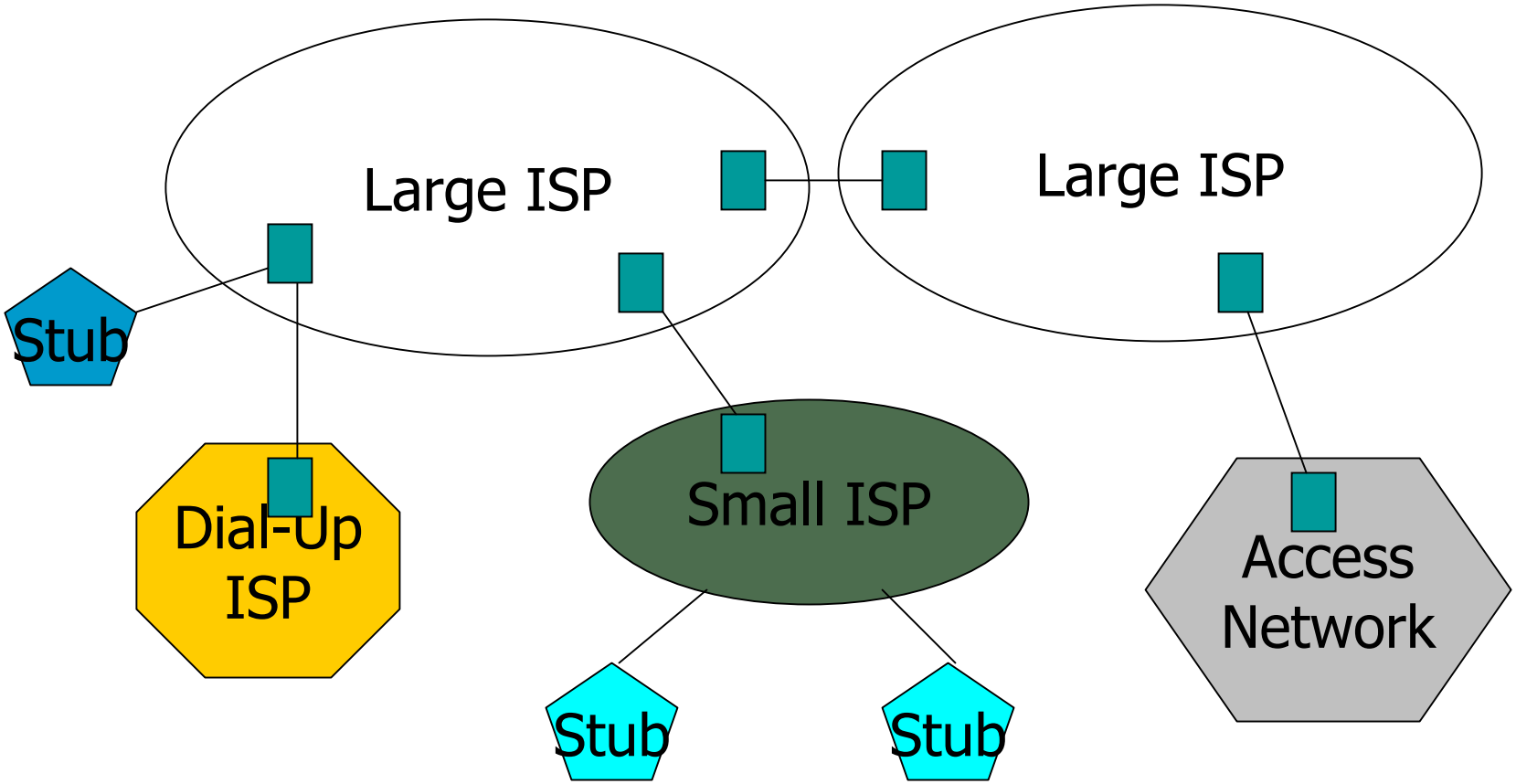
Interconnections

- The internet is an interconnection of unequal networks
- Interconnection arrangements drive
  - the competitive landscape
  - the robustness of the network
  - End-to-end performance
- Interconnection is central to all large networks
  - Voice
  - Data
  - Wireless
  - Cable

Interconnections

- www.thelist.com
  - How many ISP's in the 415 area code?
    - That start with A-C: about 200…
    - Just DSL that start with A-C: about 80
- In the telephone network
  - How many independent telephone companies in 1894-1902 in the US?
    - 3039 commercial companies, 979 co-operatives
  - By controlling interconnection Bell got rid of them
  - Interconnection is now regulated (CLECs)

Big Picture



The Internet contains a large number of diverse networks

Peering & Transit

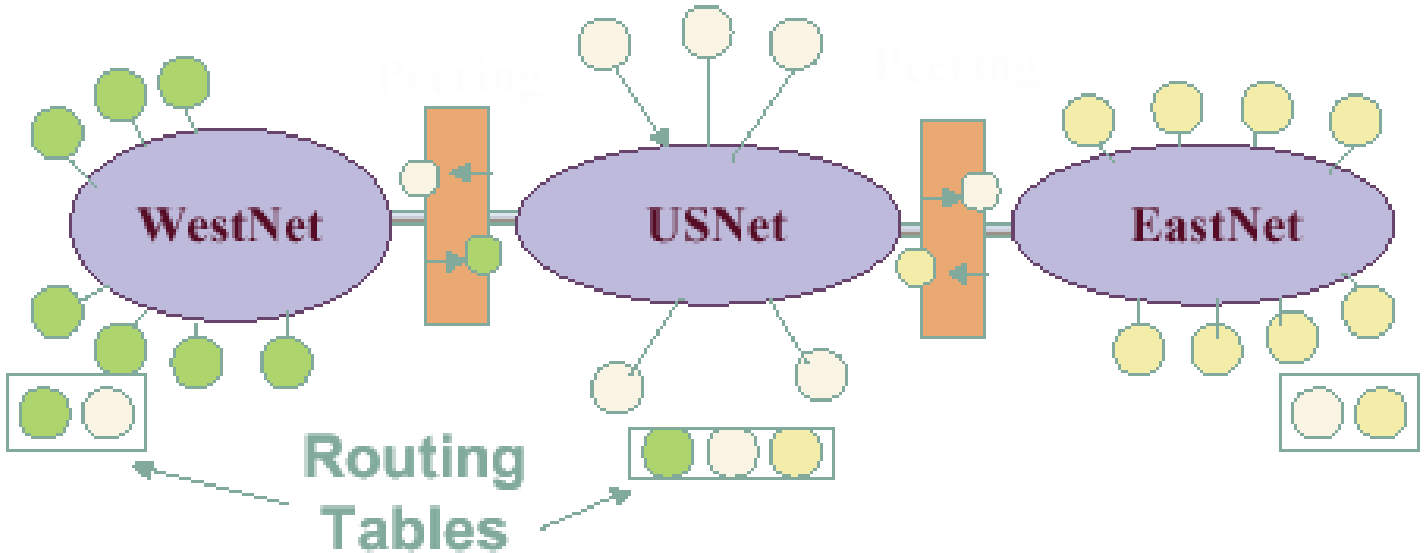
- Peering
  - The business relationship whereby ISPs reciprocally provide to each other connectivity to each others' transit customers
- Transit
  - The business relationship whereby one ISP provides (usually sells) access to all destinations in it's routing table

William B. Norton, "Internet Service Providers and Peering"

Peering & Transit

Peering

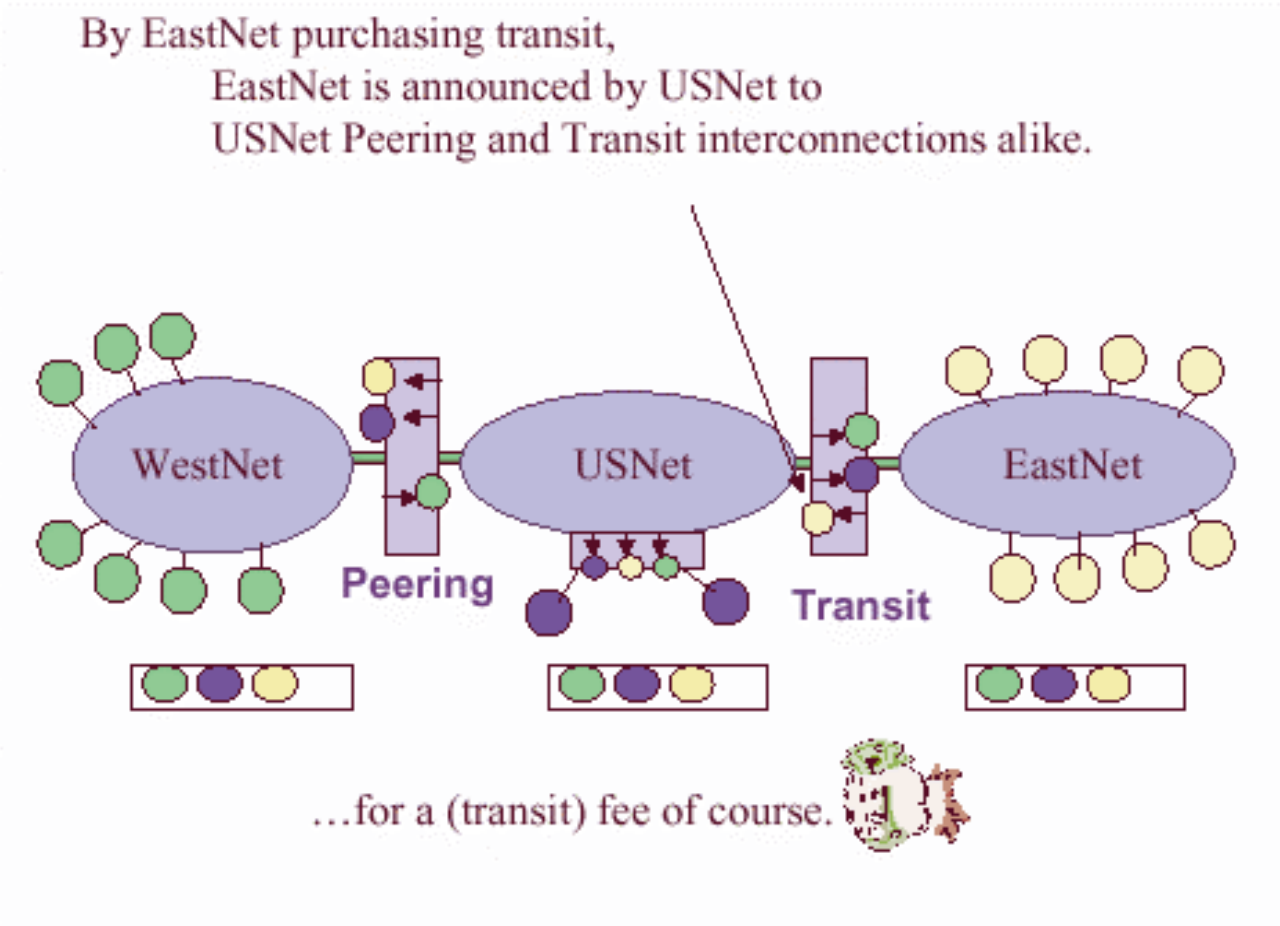
Figure from
William B. Norton, "Internet Service Providers and Peering"



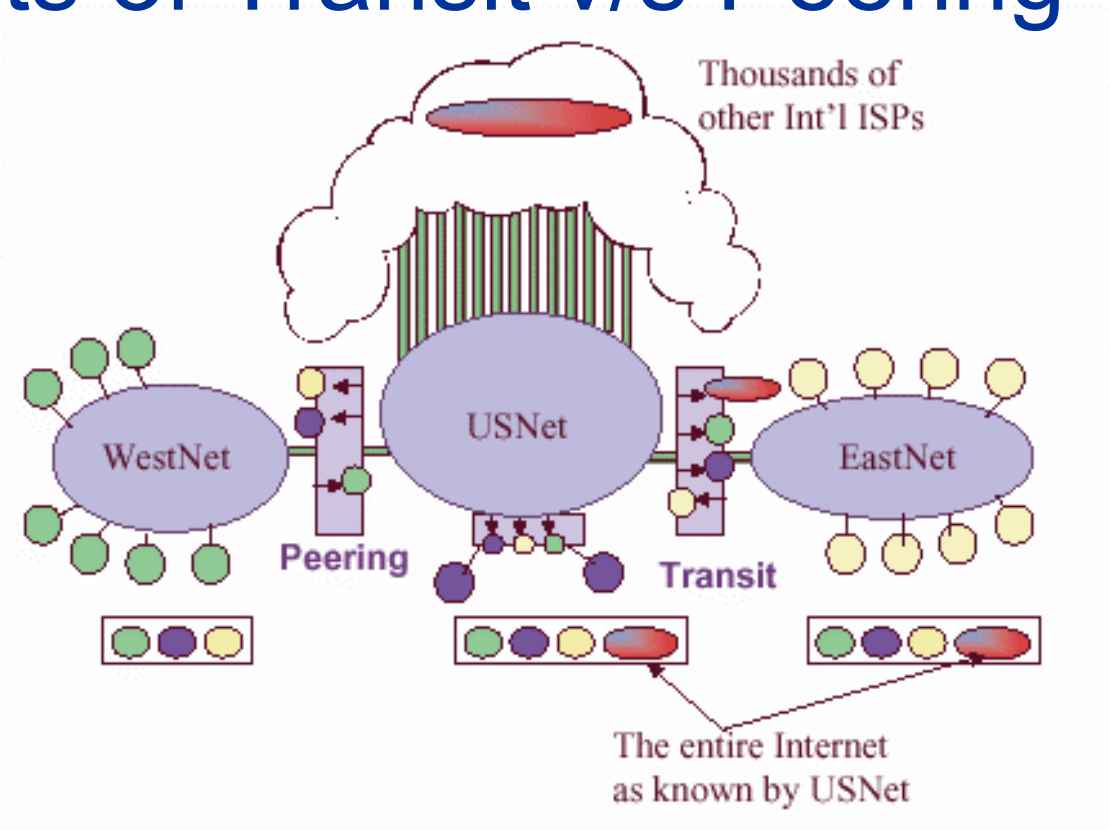
West and East Peer with USNet but they can't reach each other

Peering & Transit
Transit

Figure from
William B. Norton, "Internet Service Providers and Peering"

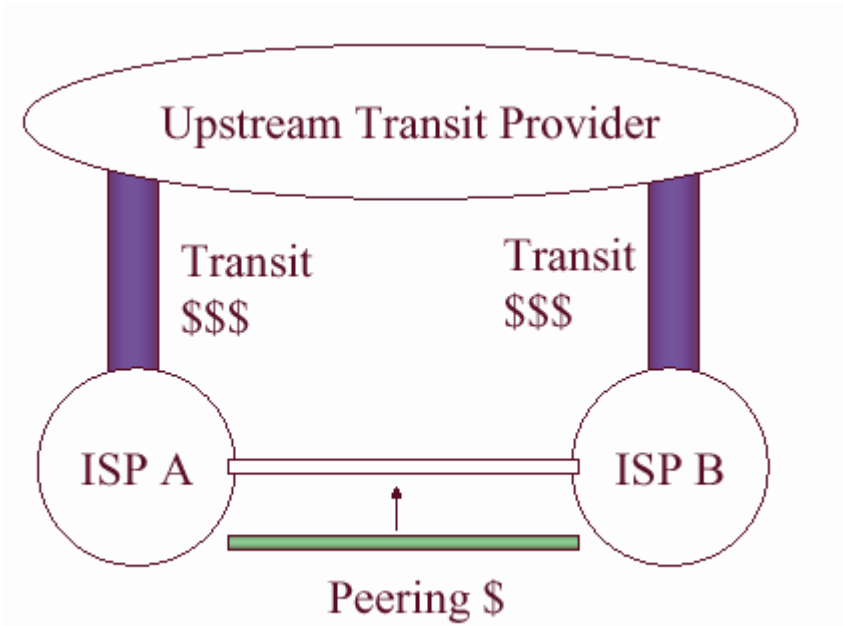


Peering & Transit
Benefits of Transit v/s Peering



William B. Norton, "Internet Service Providers and Peering"

Peering & Transit
Moving from Transit to Peering



William B. Norton, "Internet Service Providers and Peering"

Reachability

- Interdomain routing is about implementing policies of reachabilty
  - Routing efficiency and performance is important, but not essential
- ISPs could be competitors and do not want to share internal network statistics such as load and topology
- Use Border Gateway Protocol (BGP)
  - Border routers communicate over TCP port 179
  - A Path Vector Protocol
    - Communicate entire paths: Route Advertisements
  - A Router Can be involved multiple BGP sessions

BGP – Border Gateway Protocol

Concept

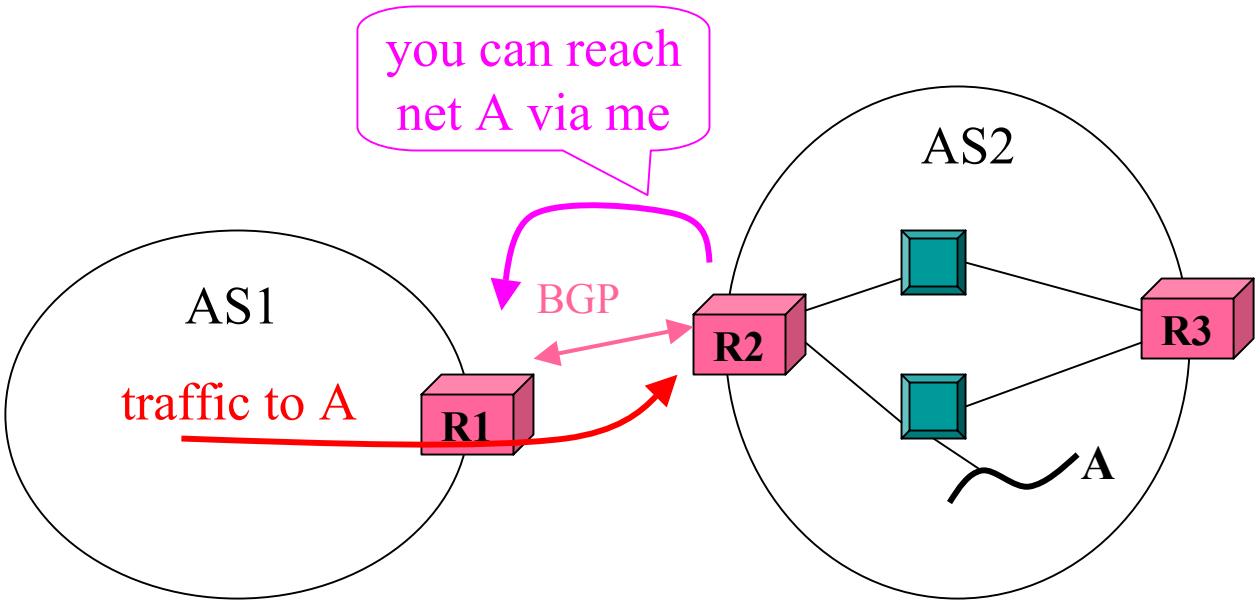
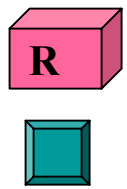


table at R1:

dest	next hop
A	R2

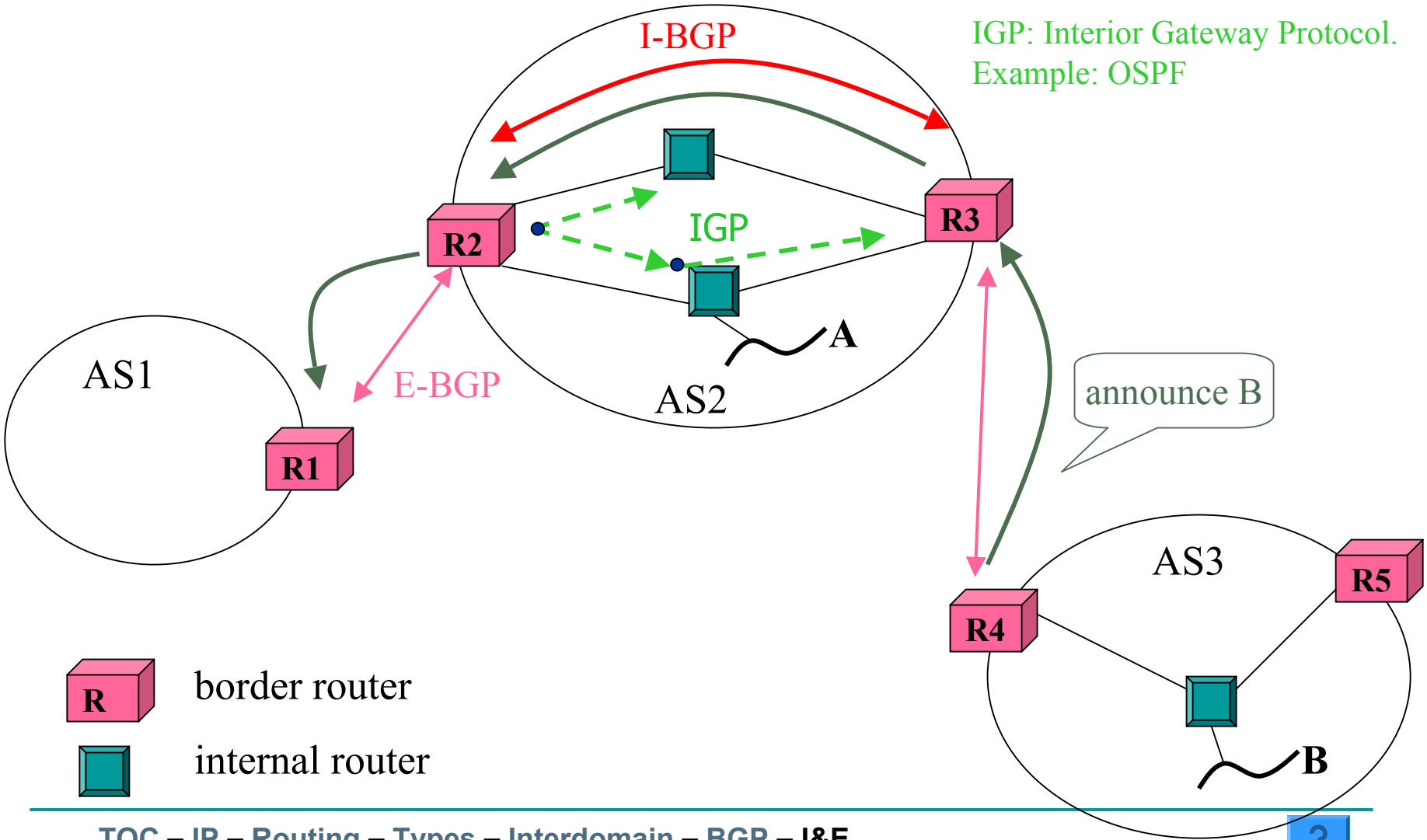


border router

internal router

Share connectivity information across ASes

I-BGP and E-BGP

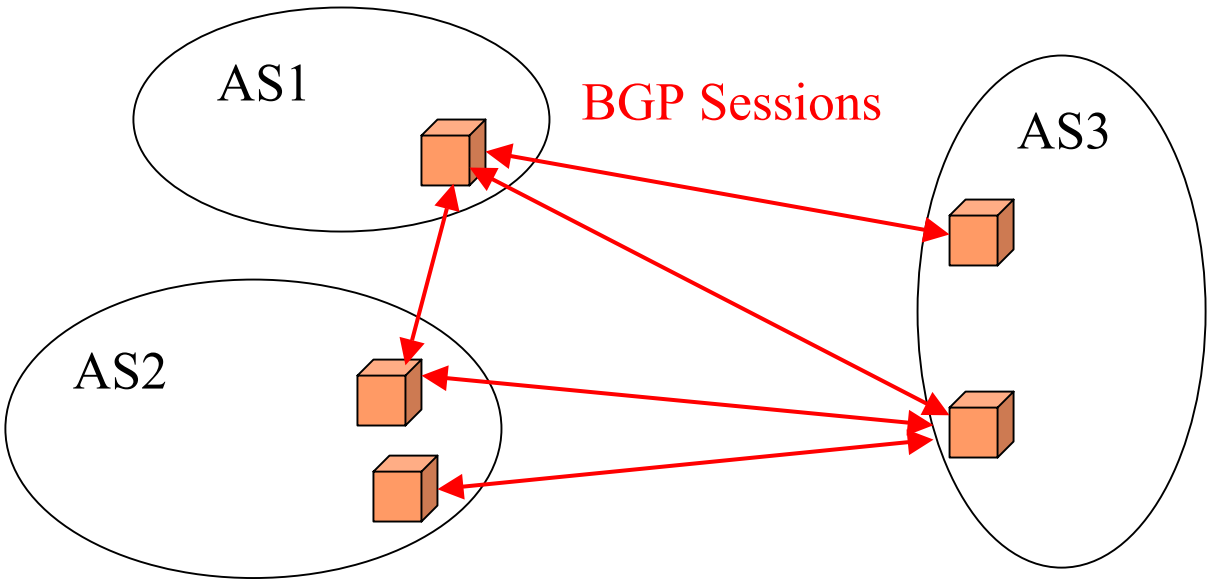


Border Routers

- Border Routers
  - from the same AS speak IBGP
  - from different AS's speak EBGP
- EBGP and IBGP are essentially the same protocol
  - IBGP can only propagate routes it has learned directly from its EBGP neighbors
  - All routers in the same AS form an IBGP mesh
  - Important to keep IBGP and EBGP in sync

Sharing routes

- One router can participate in many BGP sessions.
- *Initially* … node advertises ALL routes it wants neighbor to know (could be > 50K routes)
- *Ongoing* … only inform neighbor of changes



Message types: 4

- Open: Session establishment id exchange
- Notification: exception driven information
- Keep Alive: soft state
- **Update: path vector information**

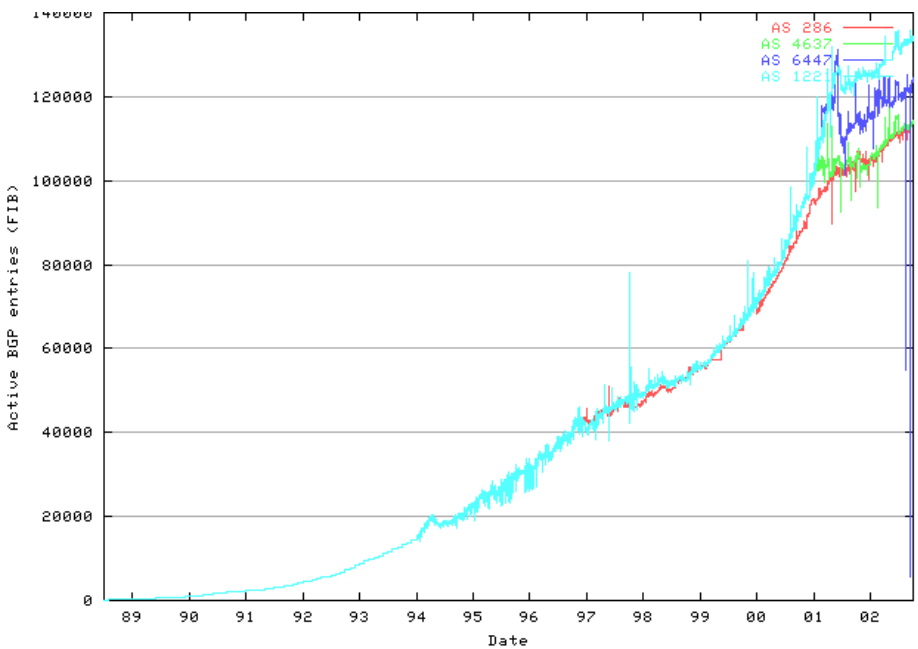
Issues

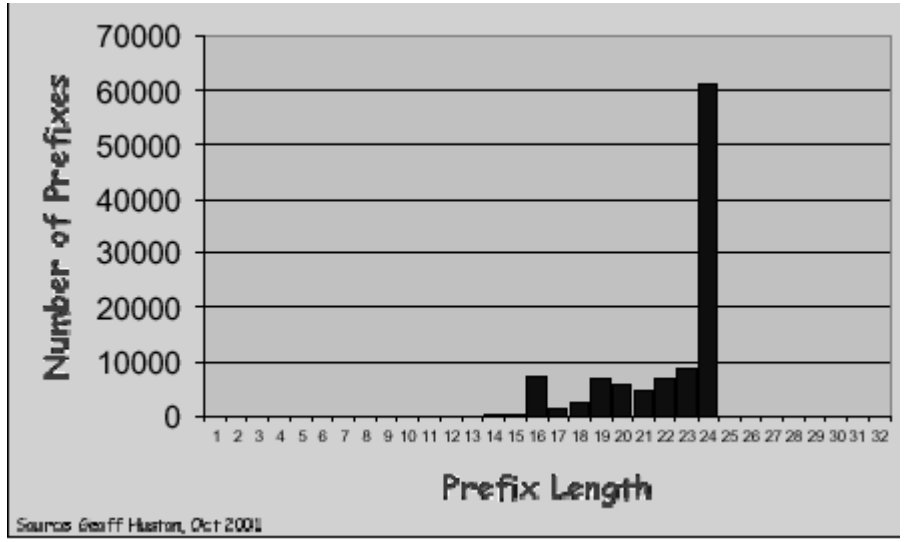
- Advertising a Route
- Routing Table Scaling
- Update Message

Advertising a Route

- One router telling another one
  - The prefix
  - IP address of the next hop
  - Path list of AS's that the announcement has passed through
    - Since announcement propagates from destination, this yields the path
- No refresh messages required
- The announcing router will follow the path itself

BGP Routing Table Scaling





- Many small networks
- Aggregation hides a lot…

BGP Update Message

- Contains information about
  - New Routes
  - Withdrawn Routes: No longer valid
  - Path Attributes:
    - Path Weights
    - Multple Exit Discriminators
    - Local Preferences
    - Etc.
- Attribute information allows policies to be implemented

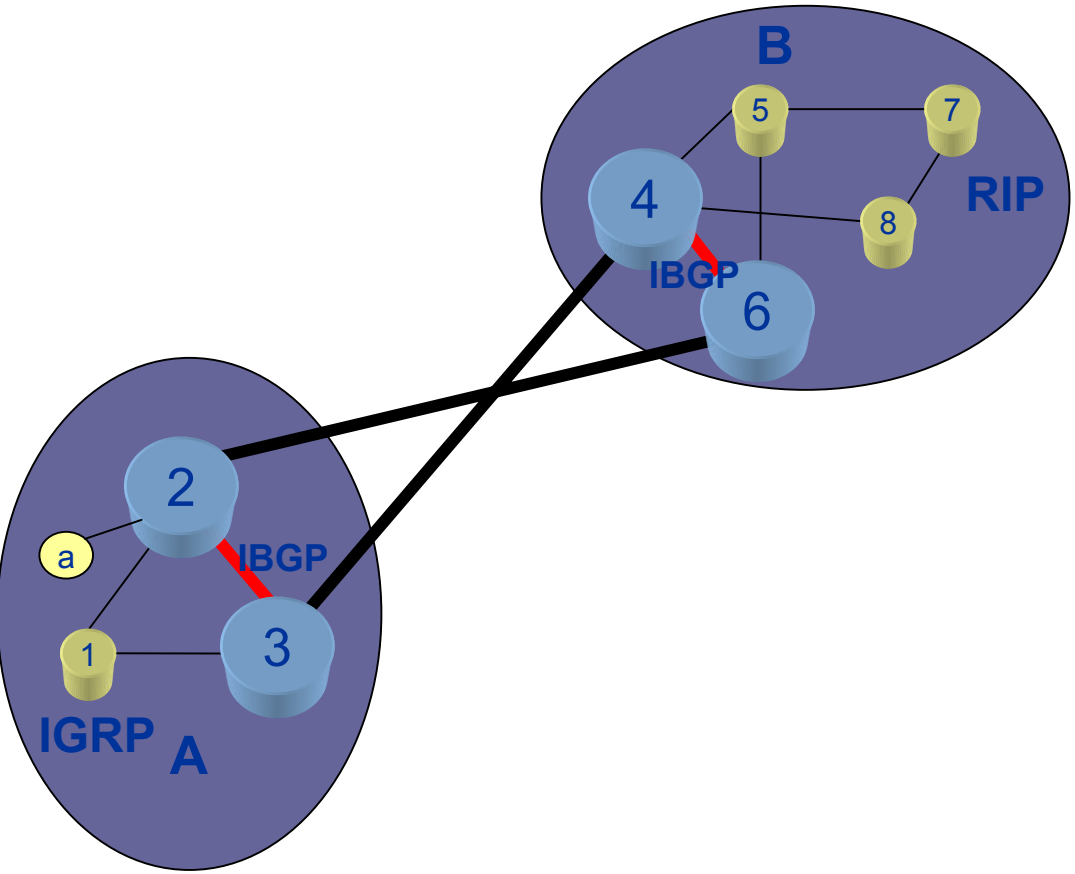
BGP –Protocol

Path Vector

```
ner-routes>show ip bgp
BGP table version is 6128791, local router ID is 4.2.34.165
Status codes: s suppressed, d damped, h history, * valid, > best, i - internal
Origin codes: i - IGP, e - EGP, ? - incomplete
   Network          Next Hop          Metric LocPrf Weight Path
* i3.0.0.0         4.0.6.142           1000     50      0 701 80 i
* i4.0.0.0         4.24.1.35              0    100      0 i
* i12.3.21.0/23    192.205.32.153         0     50      0 7018 4264 6468 ?
* e128.32.0.0/16   192.205.32.153         0     50      0 7018 4264 6468 25 e
```

- Every route advertisement contains the entire AS path
  - Generalization of distance vector
- Can implement policies for choosing best route
- Can detect loops at an AS level

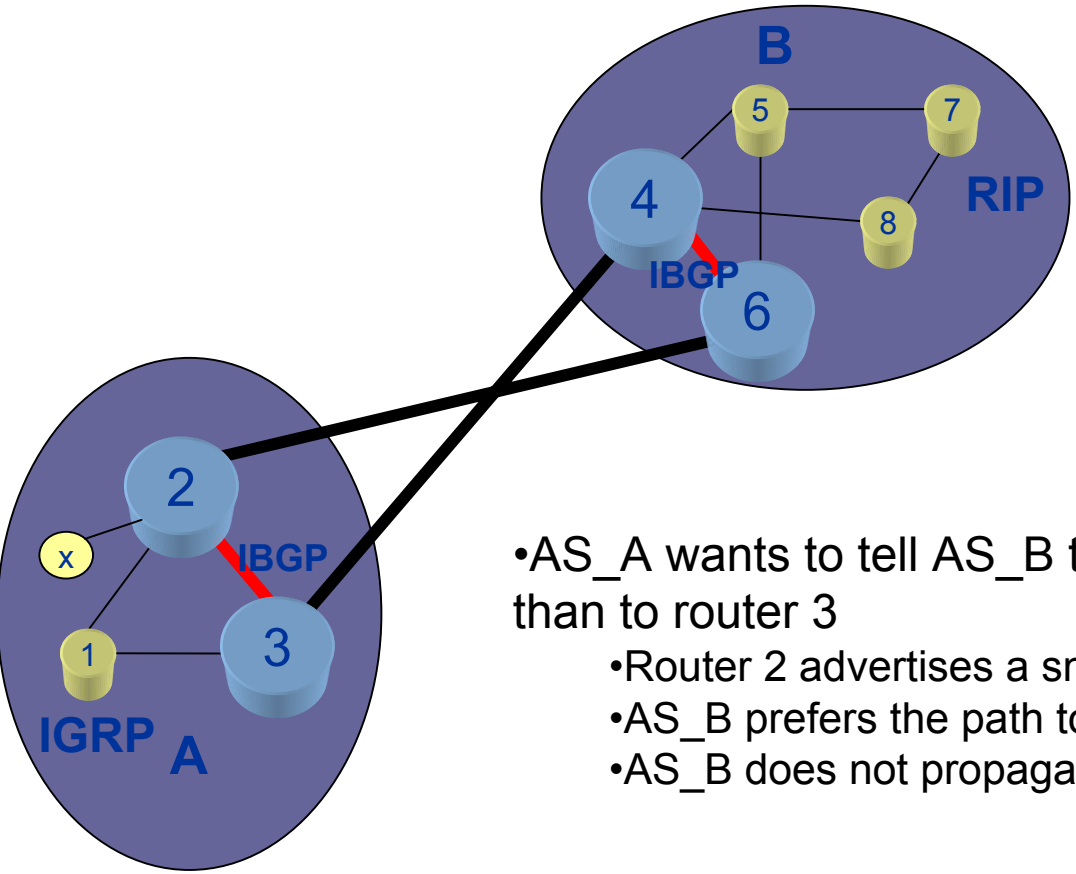
Multihoming



- Two or more interdomain connections between the same AS's
- Two or more interdomain connections between a customer and different ISPs

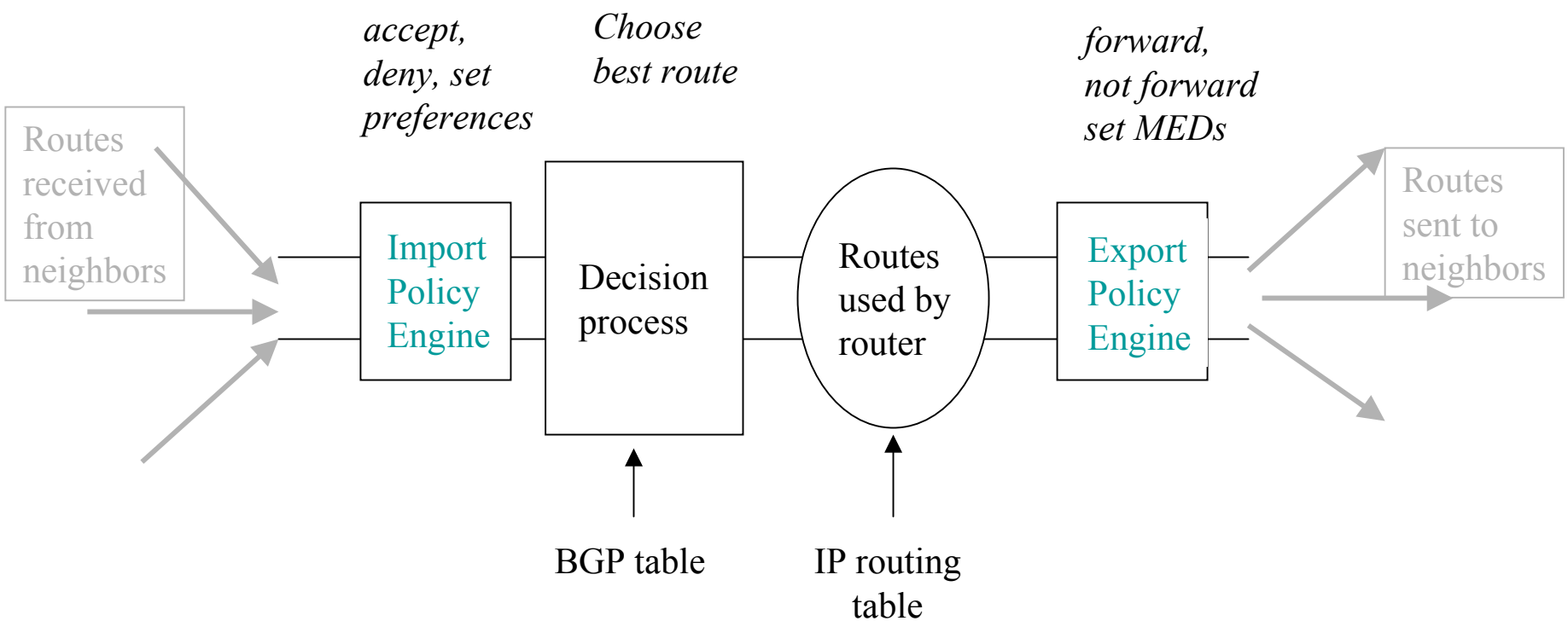
Multiexit Discriminators (MEDs)

One AS influences the decisions of a neighboring AS



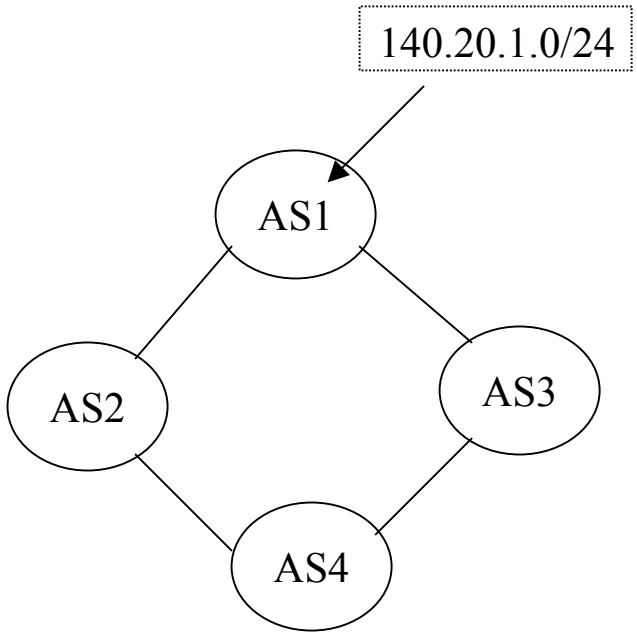
- AS_A wants to tell AS_B that network **x** is closer to router 2 than to router 3
  - Router 2 advertises a smaller MED value for **x** than Router 3
  - AS_B prefers the path to **x** that does not go through 6 and 3
  - AS_B does not propagate MEDS from AS_A any further

Routing Process Overview



Attribute: Local Preference

- Used to indicate preference among multiple paths for the same prefix *anywhere* in the Internet.
- The higher the value the more preferred
- Exchanged between IBGP peers only. Local to the AS.
- Often used to select a specific exit point for a particular destination



BGP table at AS4:

Destination	AS Path	Local Pref
140.20.1.0/24	**AS3 AS1**	**300**
140.20.1.0/24	**AS2 AS1**	**100**

Choosing best route

- Choose route with highest **LOCAL_PREF**
  - Preference-based routing
- If multiple choices, select route with shortest **hop-count**
- If multiple choices for same neighboring AS, choose path with max MED value
- Choose route based on lowest origin type
  - IGP < EGP < INCOMPLETE
- Among IGP paths, choose one with lowest cost
- Finally use router ID to break the tie.

BGP Policies

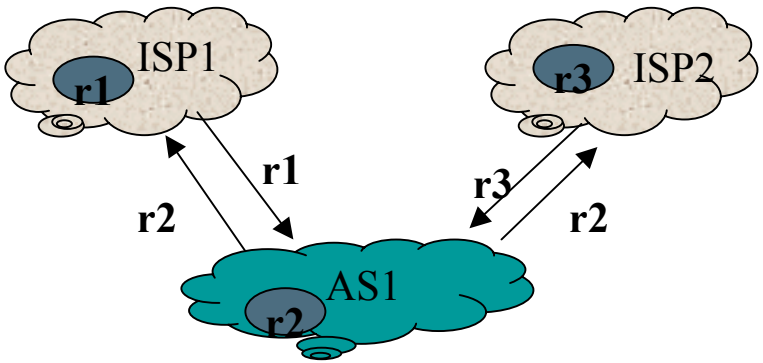
- Multiple ways to implement a “policy”
  - Decide not propagate advertisements
    - I’m not carrying your traffic
  - Decide not to consider MEDs but use shortest hop
    - Hot potato routing
  - Prepend own AS# multiple times to fool BGP into not thinking AS further away
  - Many others…

Transit vs. Nontransit AS

Transit traffic = traffic whose source and destination are outside the AS

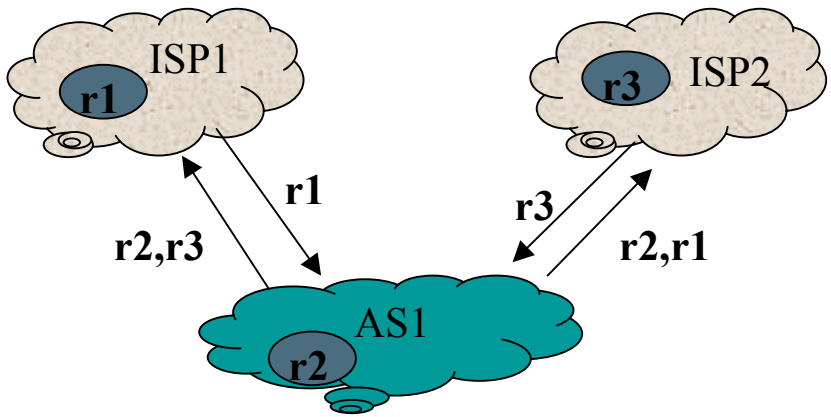
Nontransit AS: does not carry transit traffic

- Advertise own routes only
- Do not propagate routes learned from other AS's

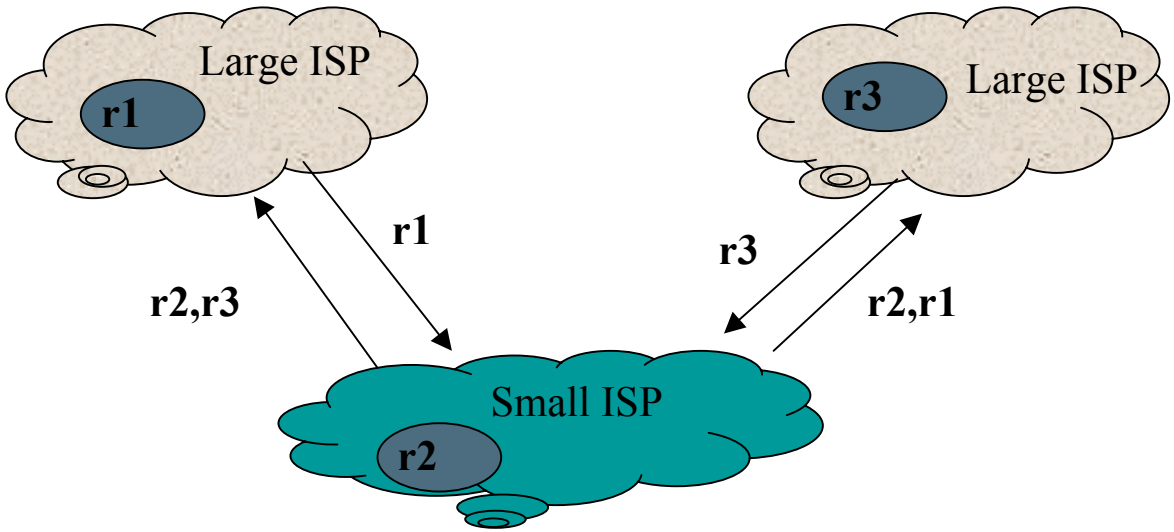


Transit AS: does carry transit traffic

- Advertises its own routes PLUS routes learned from other AS's



Customer-Transit Problem

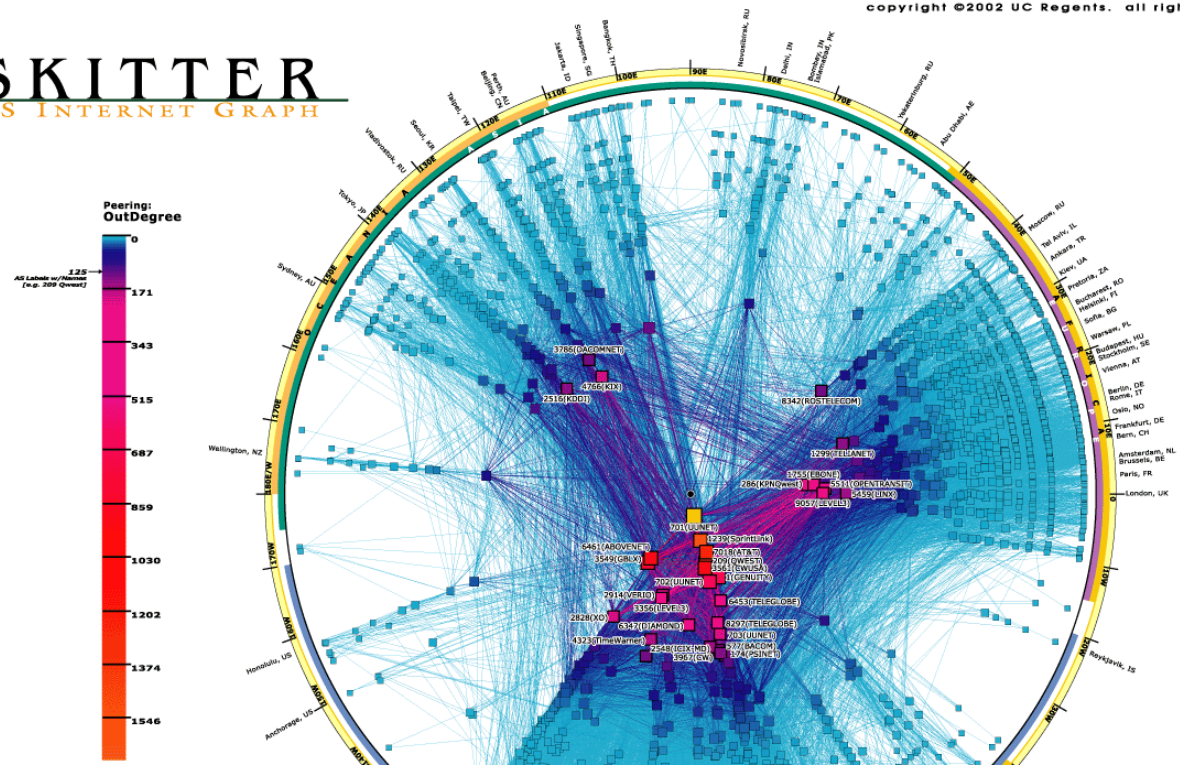


- Assume that the small ISP is a customer of two large ISPs
- If customer ISP does not obey export rules
  - forwards advertisements from one large ISP to another
  - Carries huge volume of transit traffic between two large ISPs

BGP and Performance

- BGP isn't designed for policy routing not performance
  - Hot Potato routing is most common but suboptimal
  - Performance isn't the greatest
- 20% of internet paths inflated by at least 5 router hops
- Very susceptible to router misconfiguration
  - Blackholes: announce a route you cannot reach
    - October 1997 one router brought down the internet for 2 hours
  - Flood update messages (don't store routes, but keep asking your neighbors to clue you in). 3-5 million useless withdrawals!
- In principle, BGP could diverge
  - Various solutions proposed to limit the set of allowable policies
  - Focuses on avoiding "policy cycles"

SKITTER
AS Internet Graph



4/1-4/16 2002
- **1,224,733 IP addresses,**
- **2,093,194 IP links,**
- **932,000 destinations,**
- **70% of globally routable network prefixes;**
- **10,999 ASes (84% of ASes),**
- **34,209 peering sessions**

cooperative association for internet data analysis ○ san diego supercomputer center ○ university of california, san diego
9500 gilman drive, mc0505 ○ la jolla, ca 92093-0505 ○ tel. 858-534-5000 ○ http://www.caida.org/

CAIDA is a program of the University of California's San Diego Supercomputer Center (UCSD/SDSC)
skitter is supported by DARPA NGI Cooperative Agreement N66001-98-2-8922, NSF ANIR Grant NCR-9711092 and CAIDA members

Skitter Legend

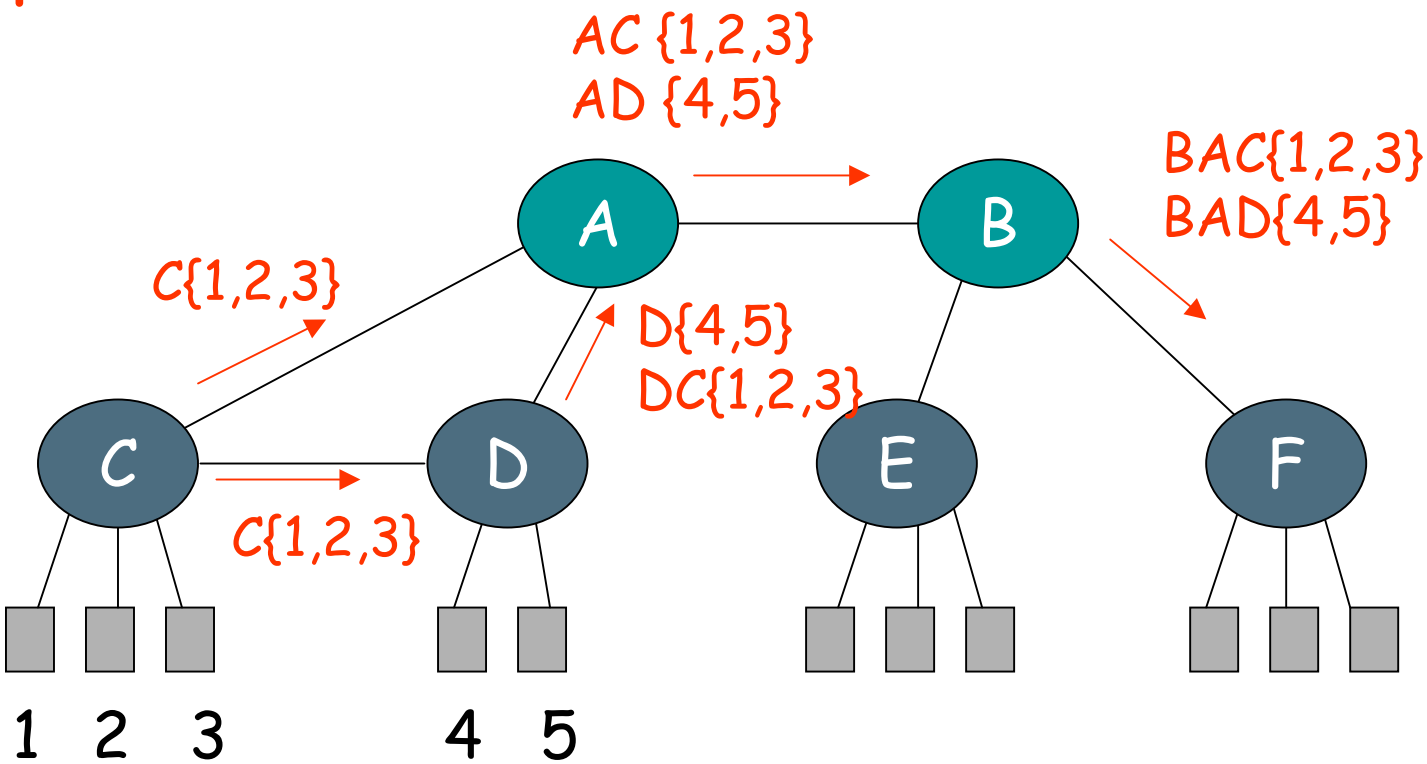
- Plot the AS based on polar co-ordinates (r,θ):
  - r = 1- log (As degree +1 / Max Degree+1)
    - Higher the degree lower the radius
  - Θ = longitude of AS headquarters

Summary

- The Internet is composed of various ASes which use BGP to inter-network themselves
- The Internet uses classless addressing
- BGP as a routing protocol
  - Path-vector based
  - Supports route-aggregation
  - Supports preferential routing
  - Uses Import and Export policies
- BGP is the protocol that “holds” the Internet together

Summary (cont.)

BGP



Transit; Peering Agreements; Customer-Provider