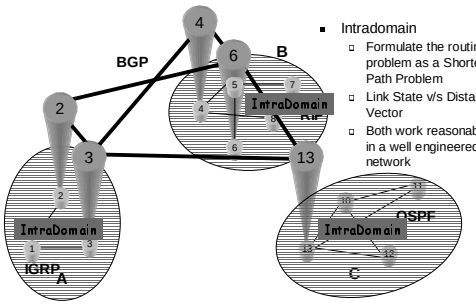
## TOC – Interdomain Routing

- Review
- Why Hierarchical Routing?
- Interconnections
- Big Picture
- Peering and Transit
- Reachability
- BGP



## Review

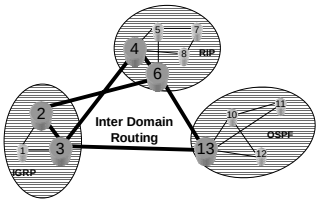



- Intradomain
  - Formulate the routing problem as a Shortest Path Problem
  - Link State v/s Distance Vector
  - Both work reasonably well in a well engineered network



## 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

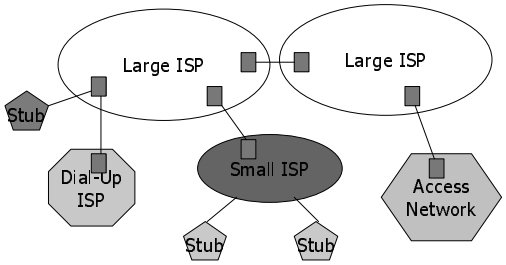


## Interconnections

- 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

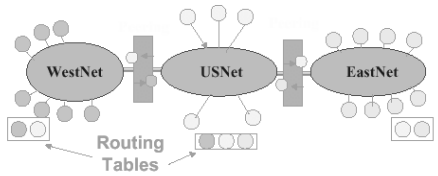
- Peering
  - The business relationship whereby ISPs reciprocally provide to each other connectivity to each others' transit customers
- Transit
  - The business relationship whereby one ISP provides (usually sells) access to all destinations in it's routing table

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



## Peering & Transit
## Peering

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

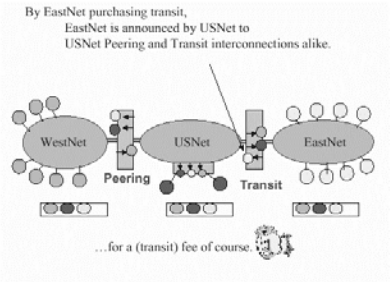



**West and East Peer with USNet but they can't reach each other**



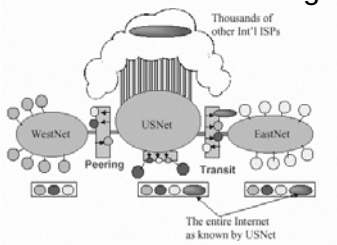
## Peering & Transit
## Transit

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





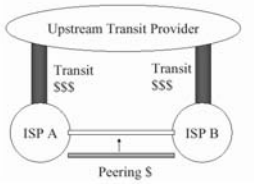

## Peering & Transit
## Benefits of Transit v/s Peering




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



## Peering & Transit
## Moving from Transit to Peering




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



## Reachability

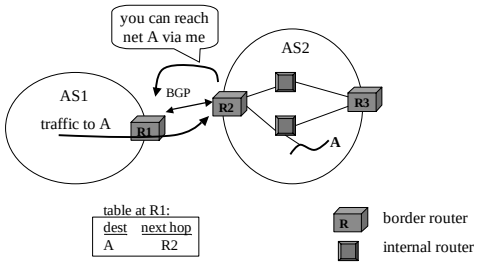
- Interdomain routing is about implementing policies of reachabilty
  - Routing efficiency and performance is important, but not essential
- ISPs could be competitors and do not want to share internal network statistics such as load and topology
- Use Border Gateway Protocol (BGP)
  - Border routers 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
- I-BGP & E-BGP
- Border Routers
- Sharing Routes
- Message Types
- Issues
- BGP - Protocol



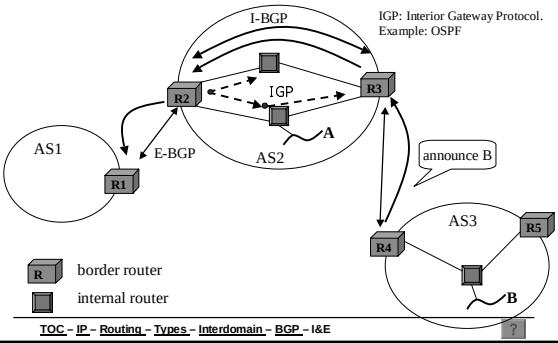
## Concept




**Share connectivity information across ASes**



## I-BGP and E-BGP





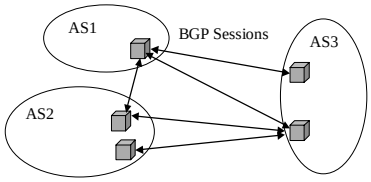

## Border Routers

- 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

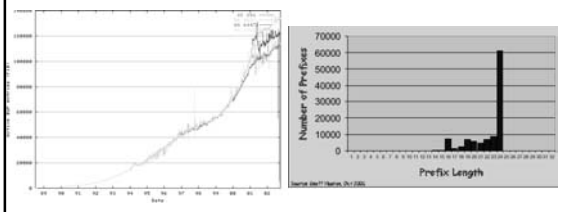


## Advertising a Route

- 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
- Multi-Homing
- Multi-Exit Discriminators
- Routing Process Overview
- Attribute
- Choosing Best Route
- BGP Policies
- Transit vs. Non-Transit AS
- Customer Transit Problem
- BGP and Performance
- Skitter
- Summary

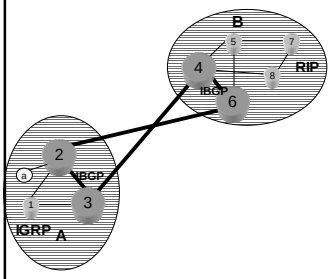


## Path Vector

```
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

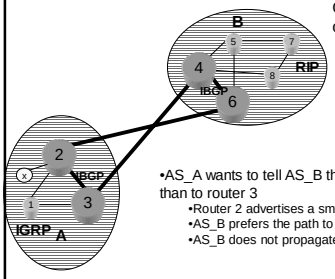



- Two or more interdomain connections between the same AS's
- Two or more interdomain connections between a customer and different ISPs



## Multiexit Discriminators (MEDs)

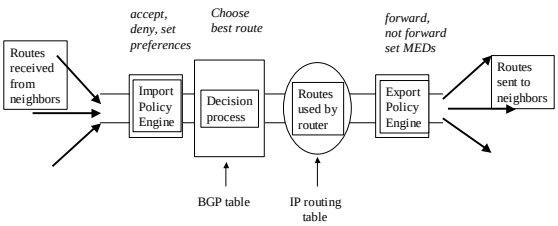
One AS influences the decisions of a neighboring AS




- 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



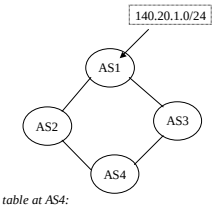
## Routing Process Overview






## 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

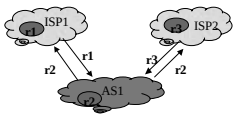
- Multiple ways to implement a "policy"
  - Decide not propagate advertisements
    - I'm not carrying your traffic
  - Decide not to consider MEDs but use shortest hop
    - Hot potato routing
  - Prepend own AS# multiple times to fool BGP into not thinking AS further away
  - Many others…

## Transit vs. Nontransit AS

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

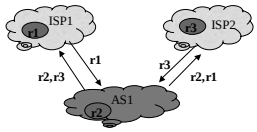
***Nontransit AS***: does not carry transit traffic

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



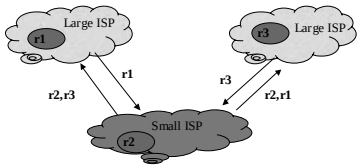

***Transit AS***: does carry transit traffic

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






## Customer-Transit Problem



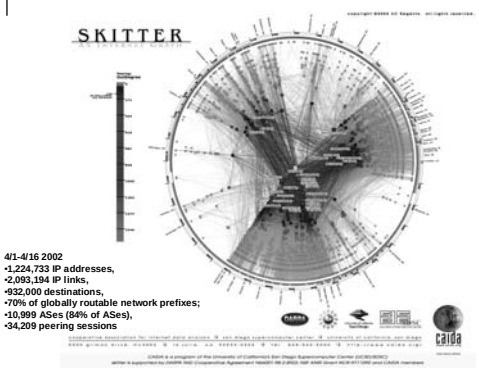

- Assume that the small ISP is a customer of two large ISPs
- If customer ISP does not obey export rules
  - forwards advertisements from one large ISP to another
  - Carries huge volume of transit traffic between two large ISPs



## 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 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

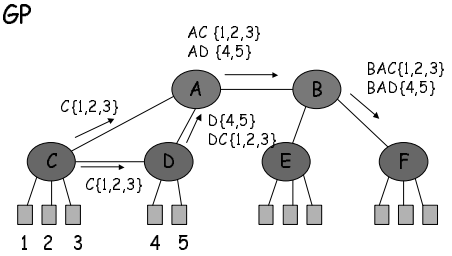


## Summary

- 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

Contents – Index – Review2 – Structure
TOC – IP – Routing – Types – Interdomain – BGP – Protocol – Summary