# Internet Protocols
# Fall 2006

Lectures 11-12

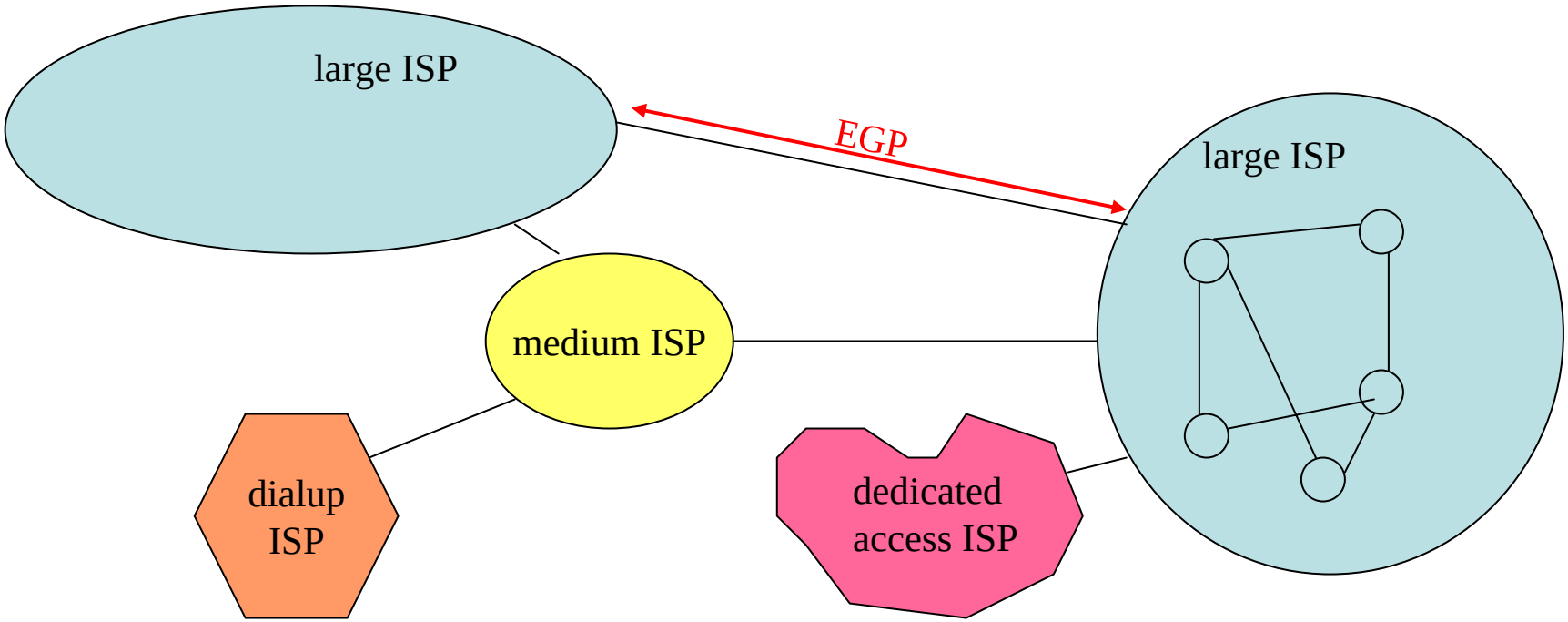
Inter-domain routing, mobility support, multicast routing

Andreas Terzis

# Outline

- Inter-domain Internet Routing
  - BGP
- Routing for mobile nodes
- Multicast routing

# Internet Routing Hierarchy

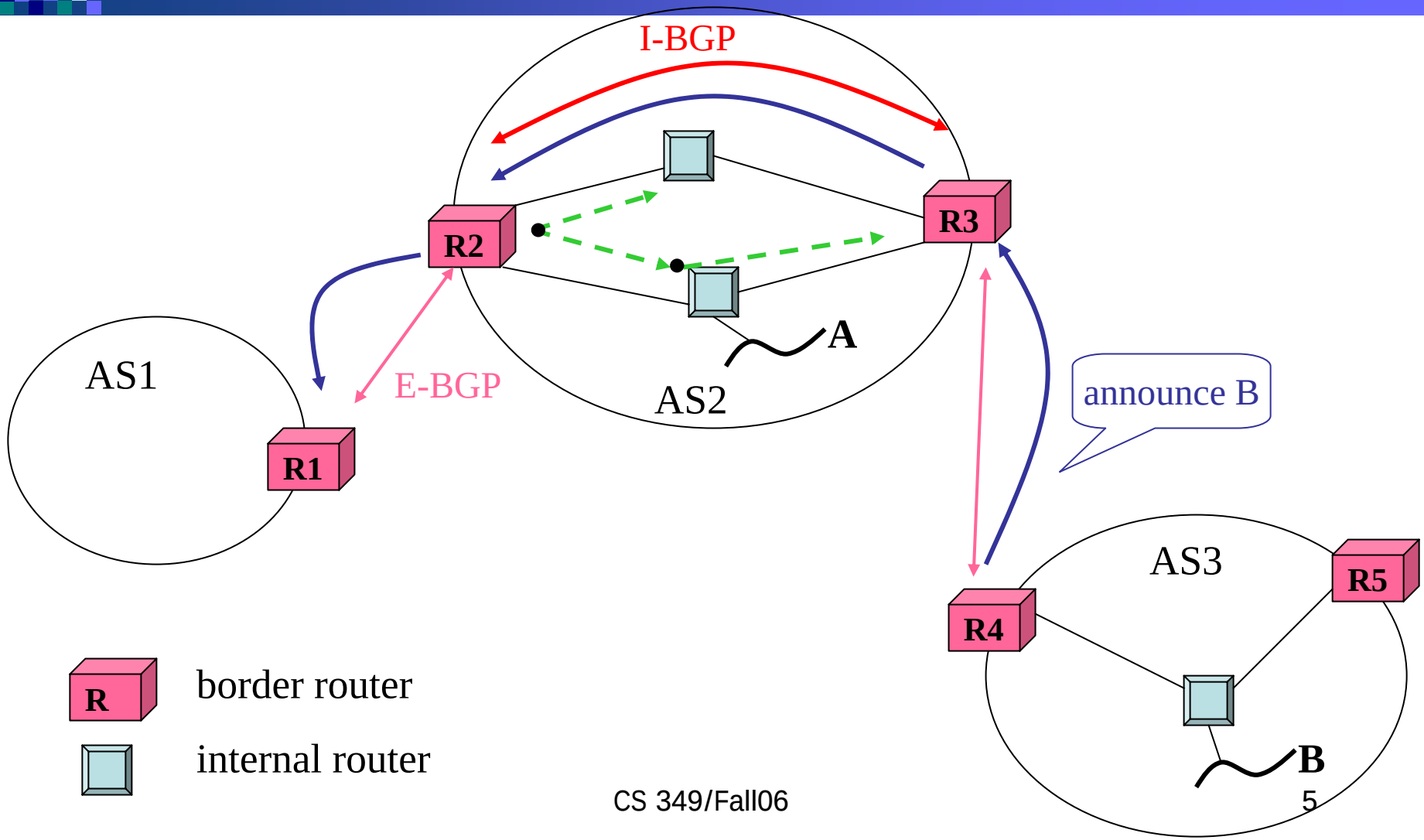



- AS (Autonomous System) - a collection of routers under the same technical and administrative domain.
- EGP (External Gateway Protocol) - used between two AS's to allow them to exchange routing information so that traffic can be forwarded across AS borders. Example: BGP

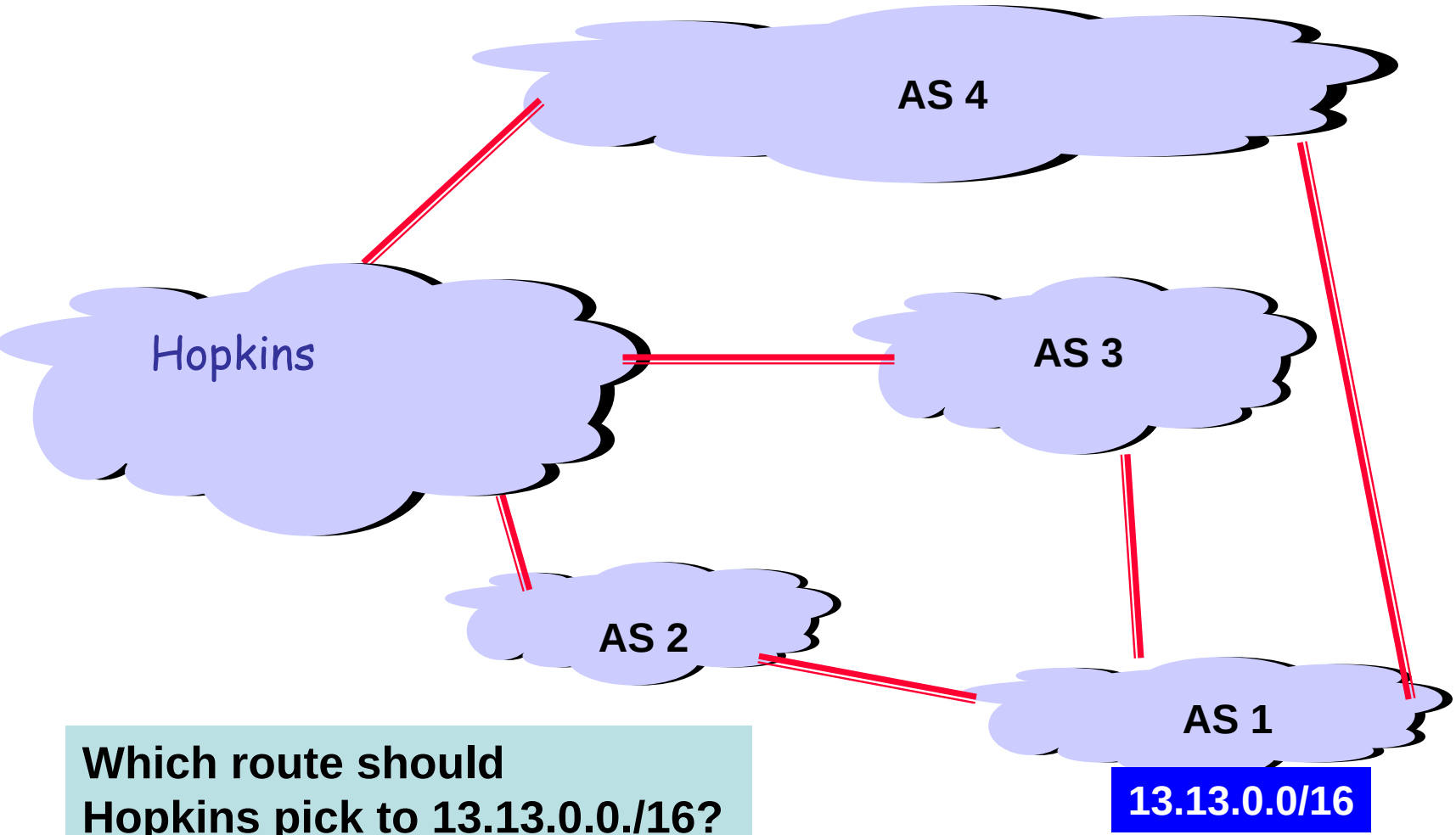
# Questions

- How do we “tie” the two routing levels together?
- What are the special constraints of inter-domain routing?
- What is the routing algorithm used at the inter-domain level?

# Two-Tier Routing



# So Many Choices




**Which route should Hopkins pick to 13.13.0.0./16?**

# Choice of Routing Algorithm

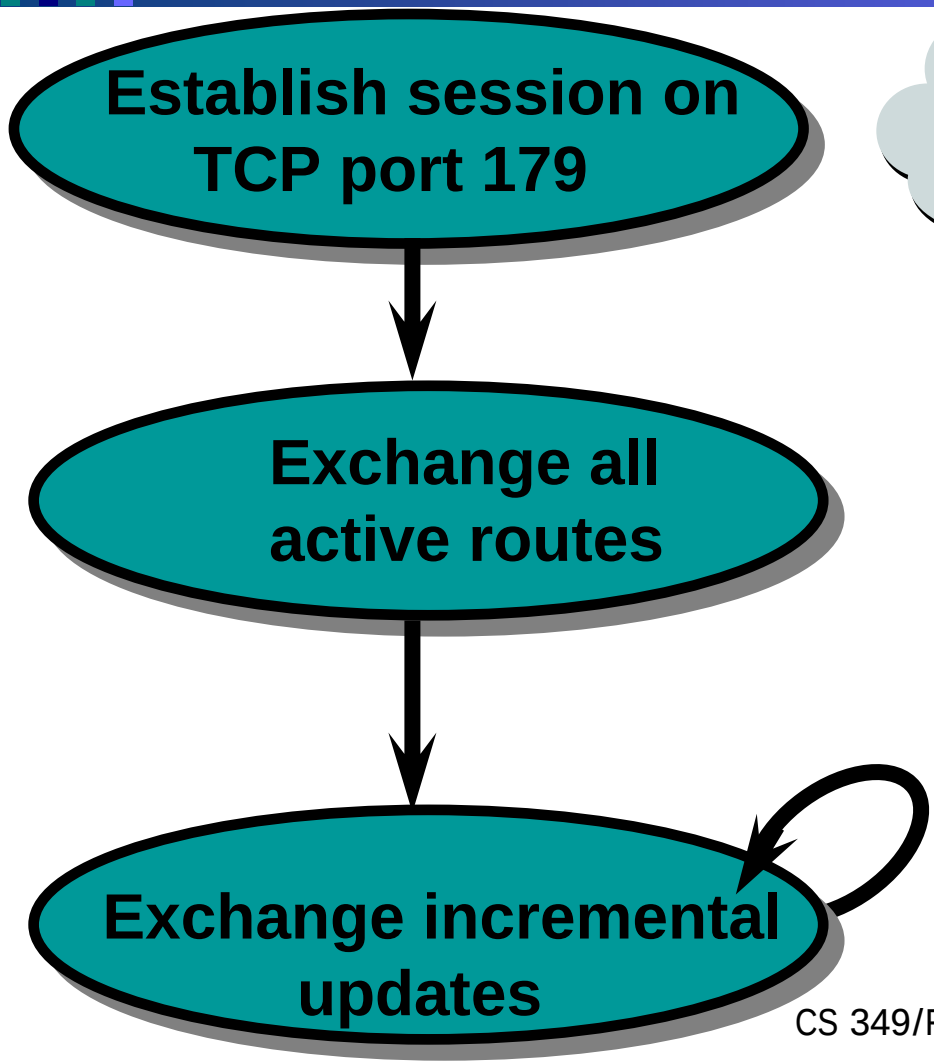
- Constraints:
  - scaling
  - Support policy-based route selection
- Link-state?
  - requires sharing of complete network informatin
  - information exchanges doesn't scale
  - can't express policy
- Distance Vector?
  - scales and retains privacy
  - can't implement policy
  - can't avoid loops if shortest paths not taken

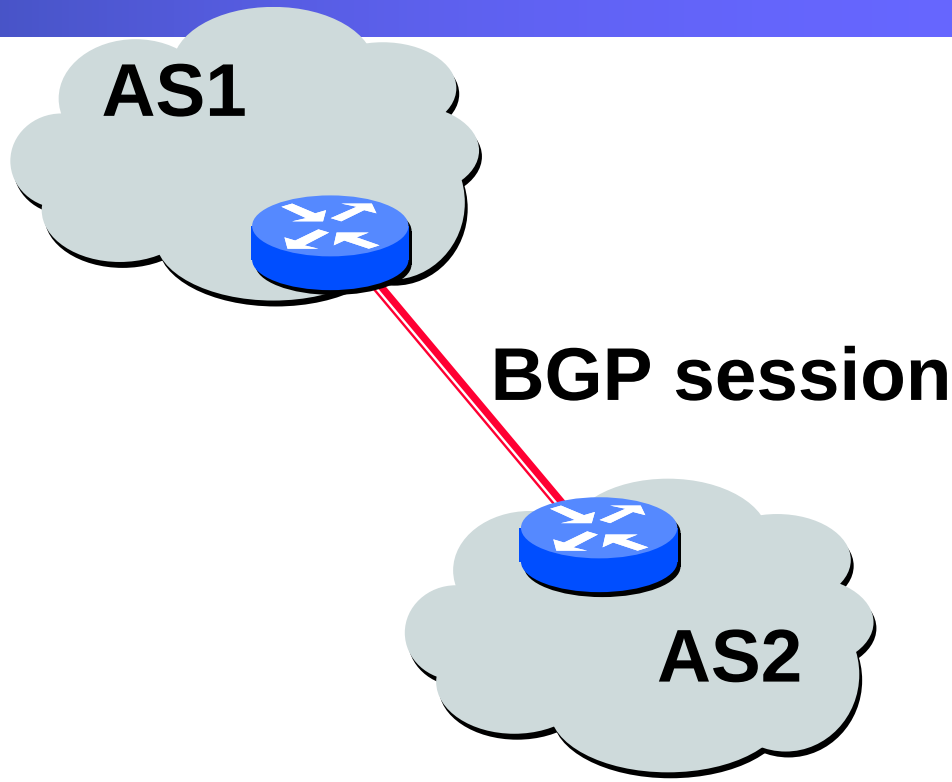
# Path Vector Protocol

- Distance vector algorithm with extra information
  - For each route, store the complete path (ASs)
  - No extra computation, just extra storage

- Advantages:
  - Can make policy choices based on set of ASs in path
  - Can easily avoid loops

# BGP Operations (Simplified)




**While connection is ALIVE exchange route UPDATE messages**

# Four Types of BGP Messages

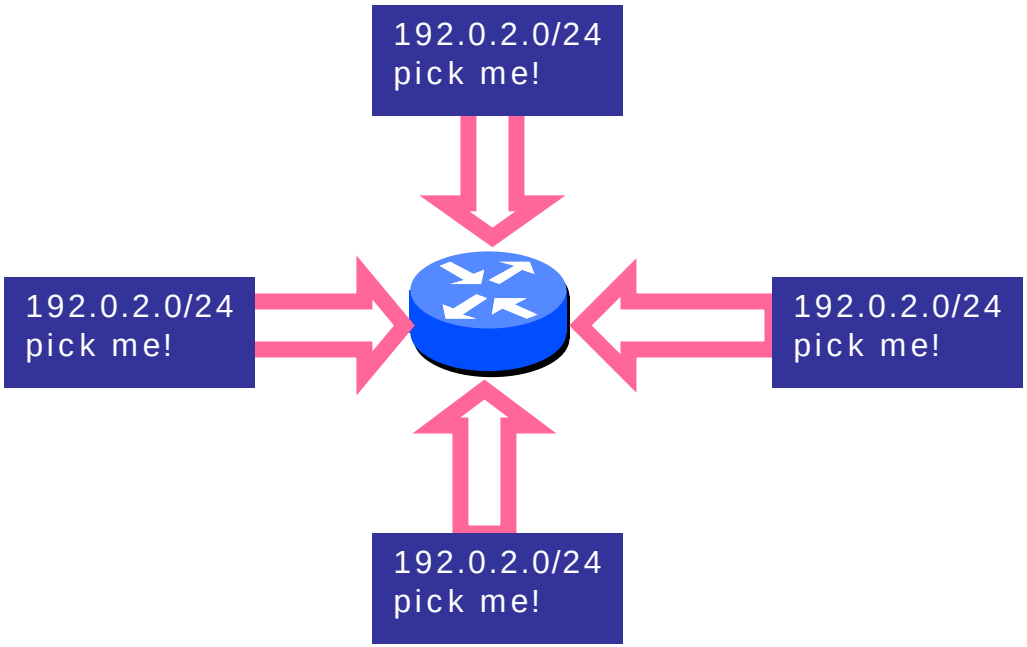
- Open : Establish a peering session.
- Keep Alive : Handshake at regular intervals.
- Notification : Shuts down a peering session.
- Update : Announcing new routes or withdrawing previously announced routes.

Announcement
=
prefix + attributes values

# BGP Attributes

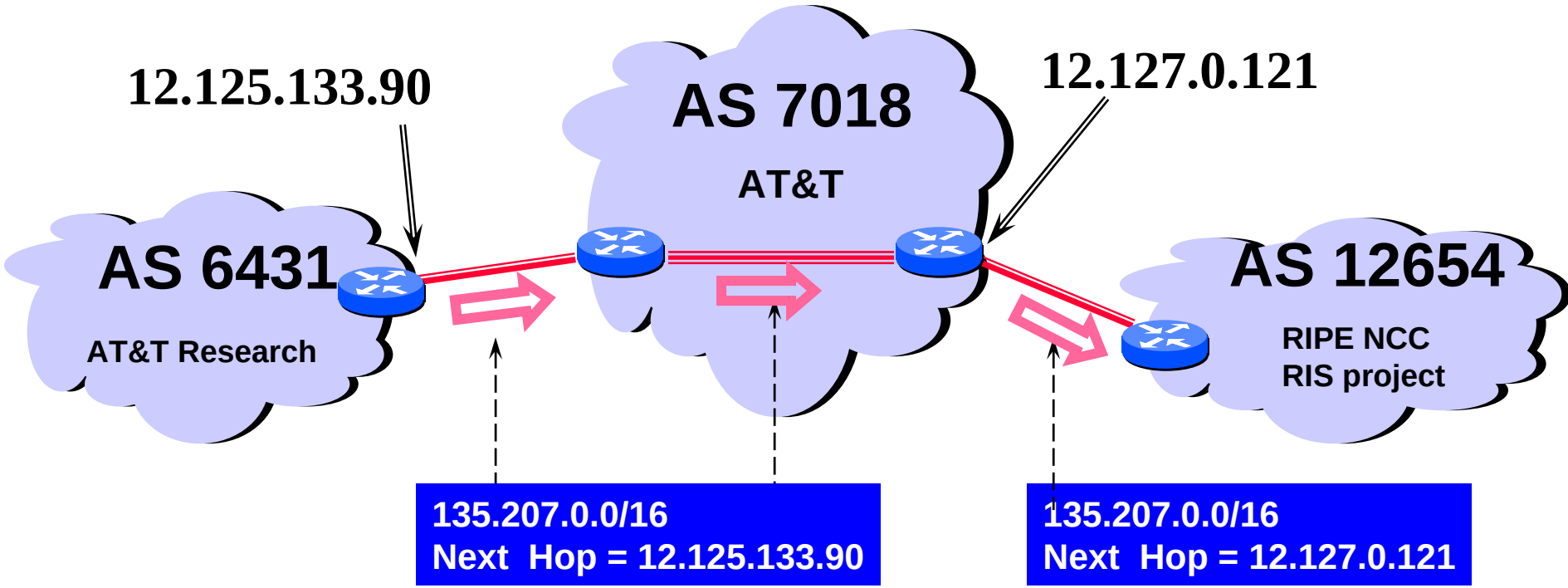
| Value | Code | Reference |
|---|---|---|
| 1 | ORIGIN | [RFC1771] |
| 2 | AS_PATH | [RFC1771] |
| 3 | NEXT_HOP | [RFC1771] |
| 4 | MULTI_EXIT_DISC | [RFC1771] |
| 5 | LOCAL_PREF | [RFC1771] |
| 6 | ATOMIC_AGGREGATE | [RFC1771] |
| 7 | AGGREGATOR | [RFC1771] |
| 8 | COMMUNITY | [RFC1997] |
| 9 | ORIGINATOR_ID | [RFC2796] |
| 10 | CLUSTER_LIST | [RFC2796] |
| 11 | DPA | [Chen] |
| 12 | ADVERTISER | [RFC1863] |
| 13 | RCID_PATH / CLUSTER_ID | [RFC1863] |
| 14 | MP_REACH_NLRI | [RFC2283] |
| 15 | MP_UNREACH_NLRI | [RFC2283] |
| 16 | EXTENDED COMMUNITIES | [Rosen] |
| ... | | |
| 255 | reserved for development | |

# Attributes are Used to Select Best Routes



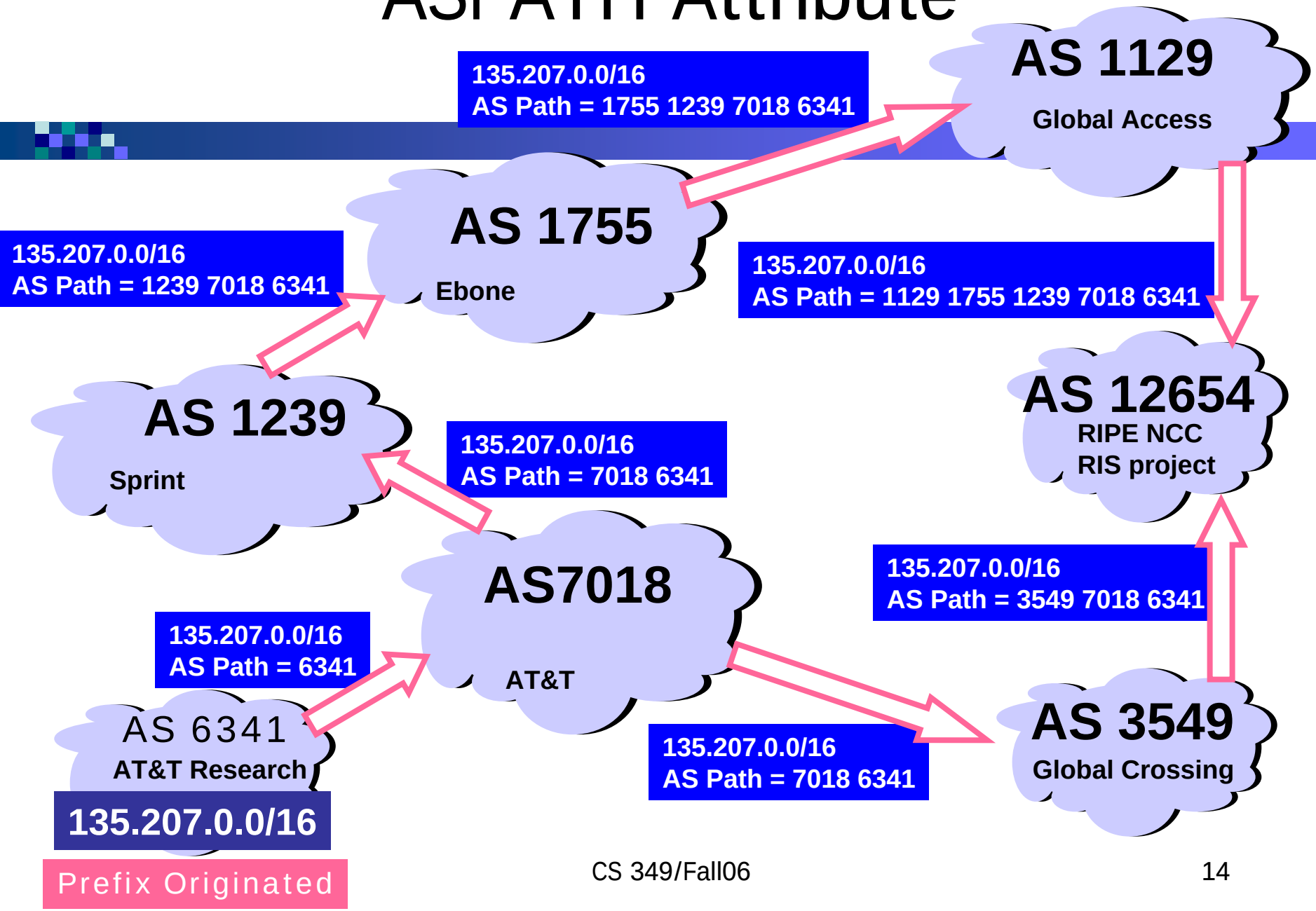

Given multiple routes to the same prefix, a BGP speaker must pick at most one best route
(Note: it could reject them all!)

# BGP Next Hop Attribute



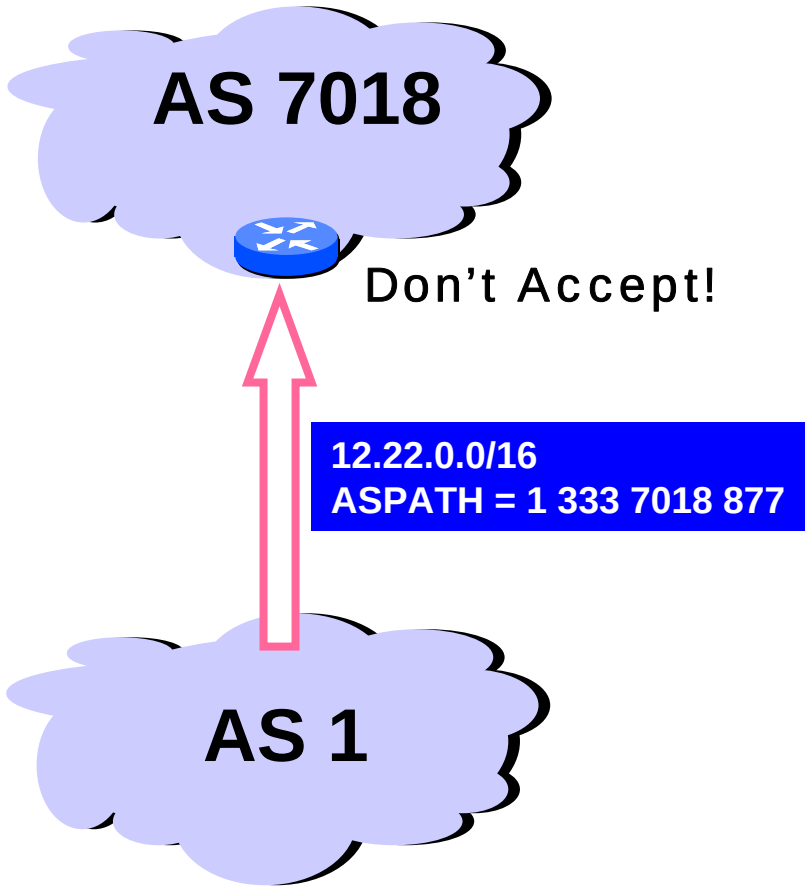

Every time a route announcement crosses an AS boundary, the Next Hop attribute is changed to the IP address of the border router that announced the route.

# ASPATH Attribute

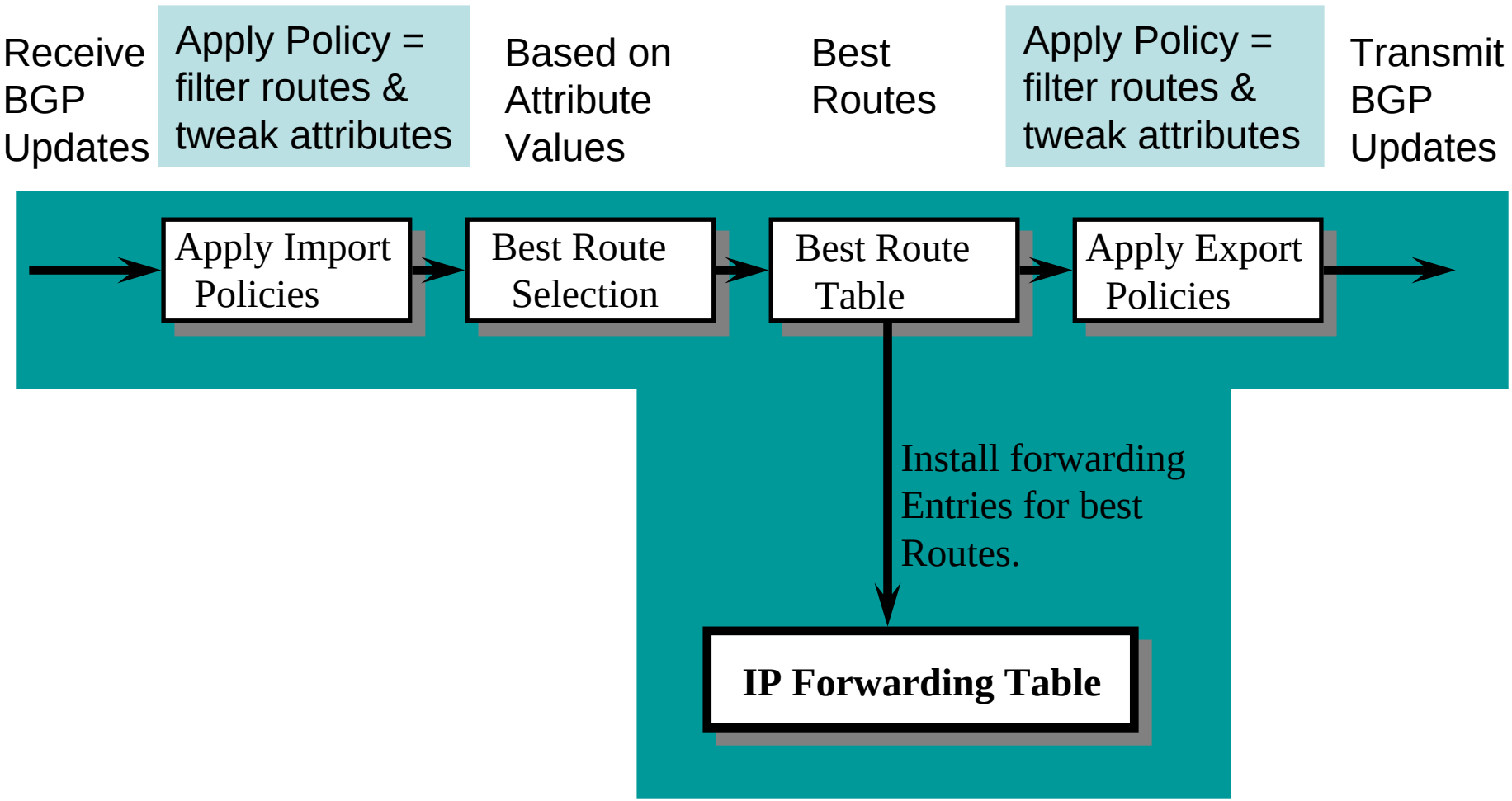


# Interdomain Loop Prevention

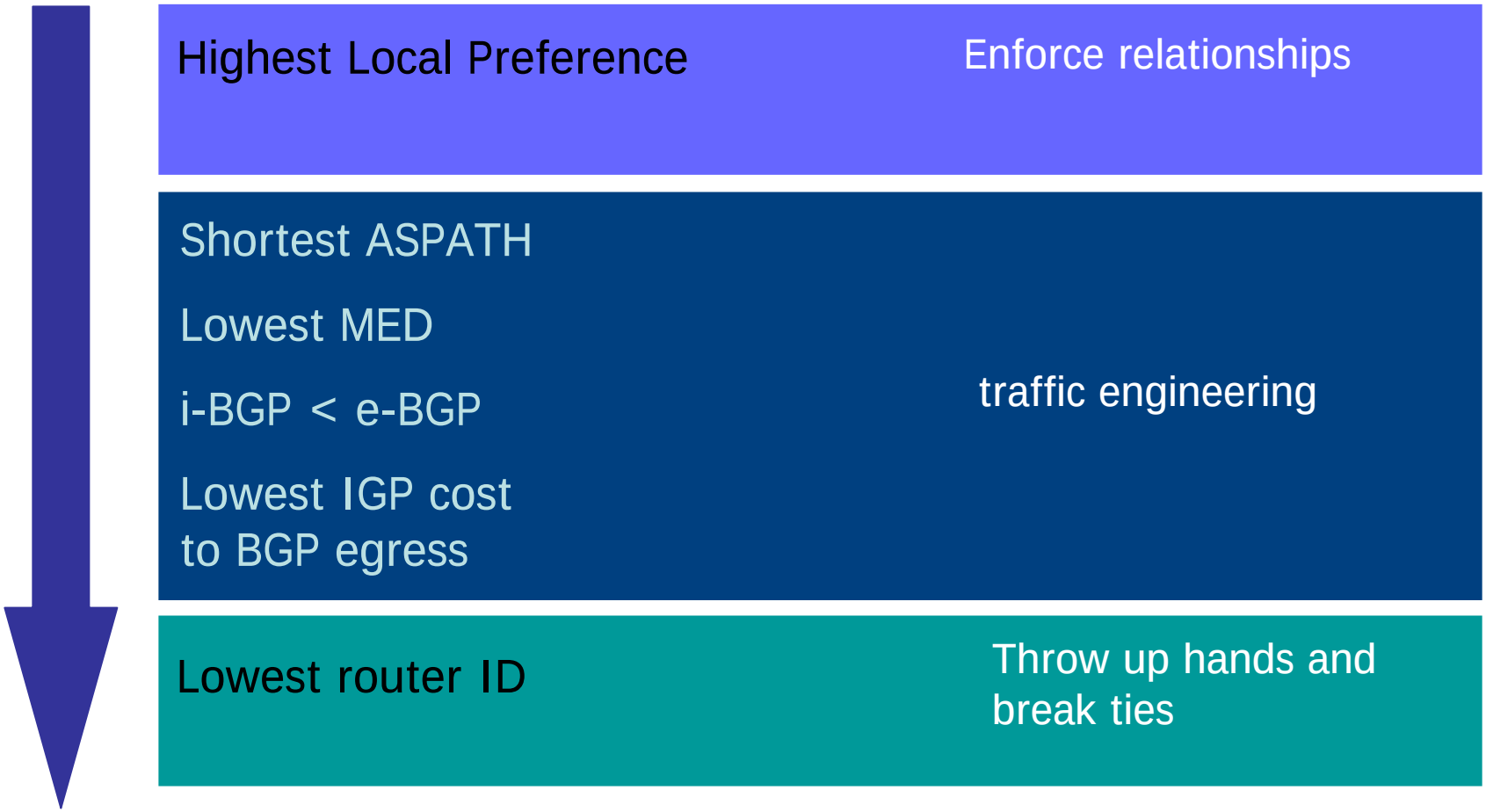
- BGP at AS YYY will never accept a route with ASPATH containing YYY



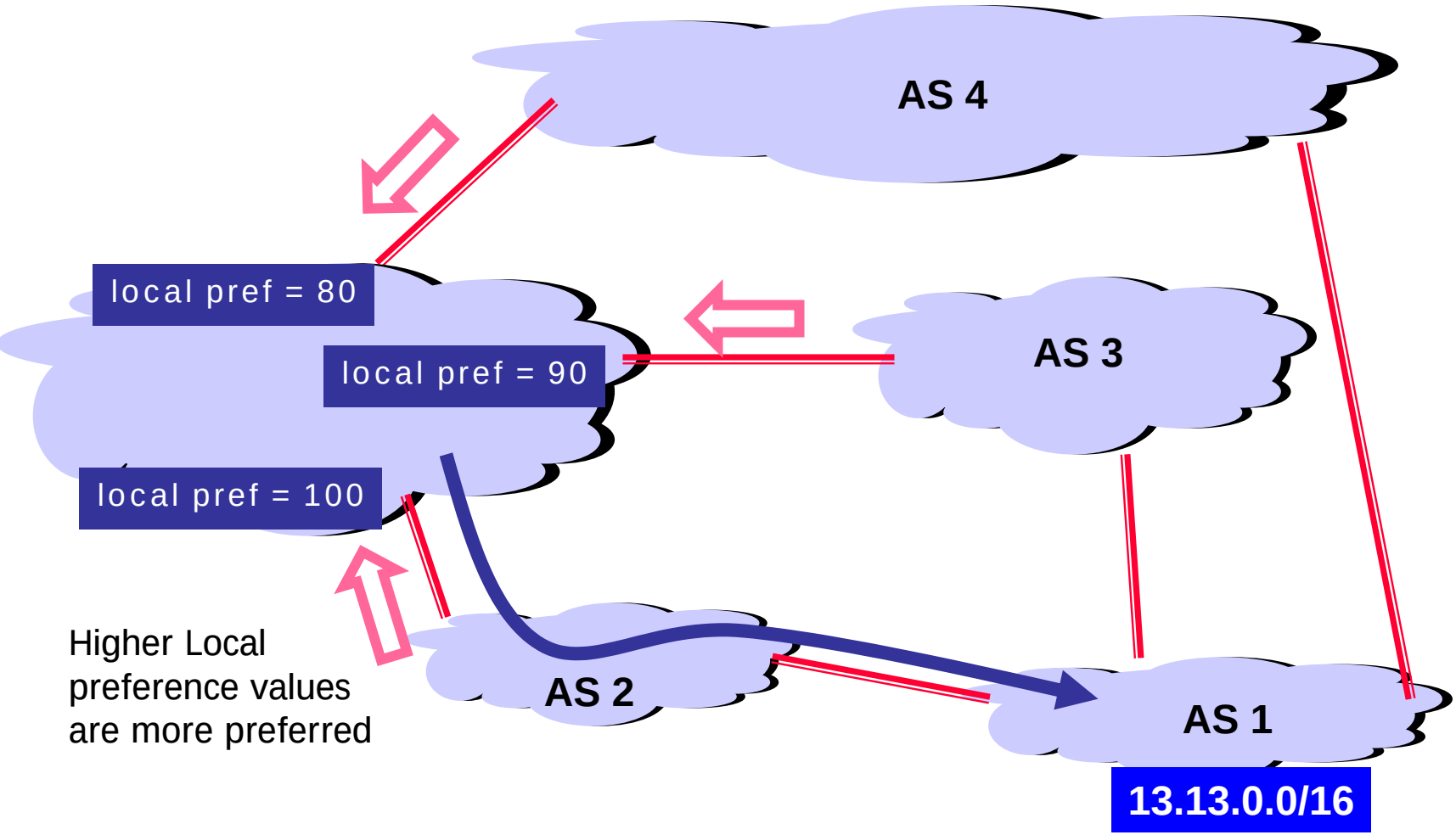
# BGP Route Processing



# Route Selection Summary



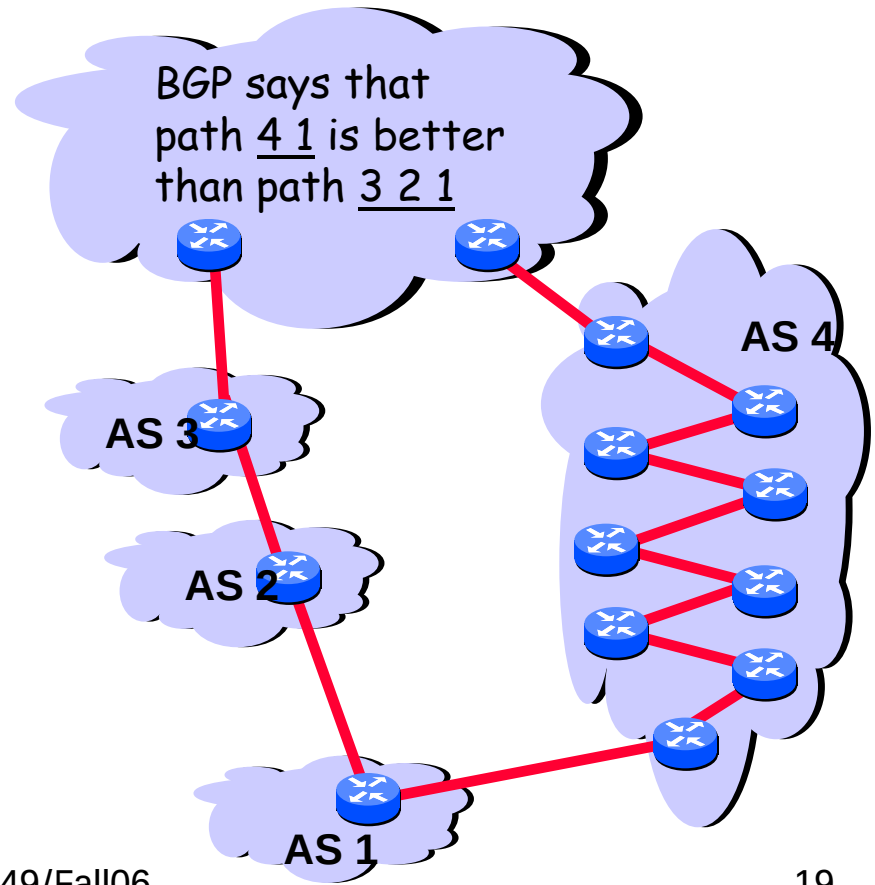
# Local Preference




Higher Local preference values are more preferred

# Shortest AS Path

- Route Selection Algorithm
  1. Local Pref
  2. Shortest AS Path
- Shortest AS Path != shortest path



# Outline

- Inter-domain Internet Routing
  - BGP
- Routing for mobile nodes
- Multicast routing

# Routing for Mobile Hosts

- Internet routing does not support mobile hosts
  - IP address is divided into network part and host part
  - Rest of the Internet knows how to forward packets to the network end-host is connected to
  - If end-host moves packets are delivered in the wrong network

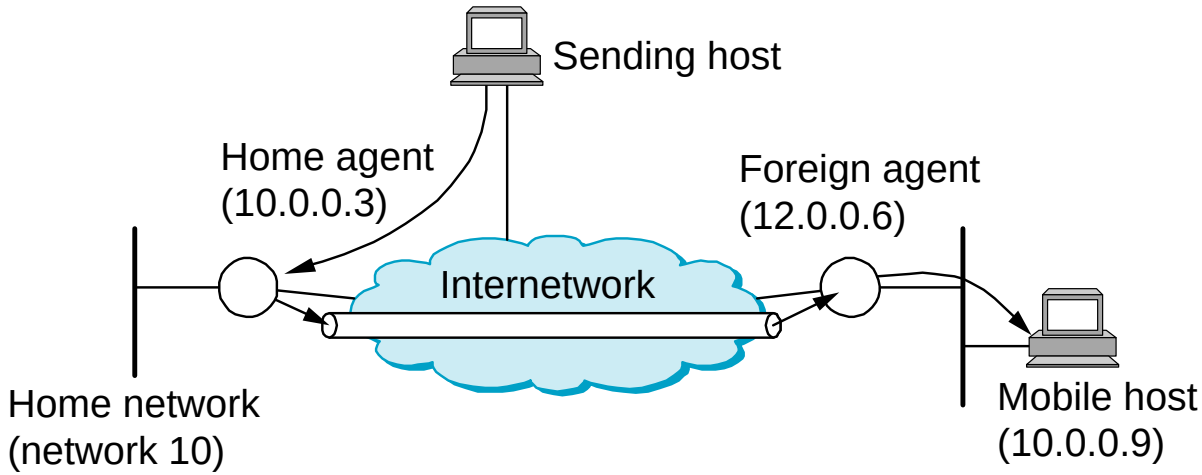
# Partial Solution

- As mobile node moves it acquires different IP addresses
  - DHCP
- This is adequate for some applications
  - Web browsing, etc
- Does not work for other applications
  - Mobile host is the server
  - Long lasting connections

# Mobile IP

- Solution proposed to solve the problem of mobility
- Does not require changes in most IP infrastructure
- Introduces three new entities
  - Home Agent (HA)
  - Foreign Agent (FA)
  - Mobile Host (MH)

# Example


Sending host
Home agent
(10.0.0.3)
Foreign agent
(12.0.0.6)
Internetwork
Home network
(network 10)
Mobile host
(10.0.0.9)

# Sub-problems

- How does the home agent intercept packets that are destined to the mobile node?
- How does the home agent deliver the packet to the foreign agent
- How does the foreign agent deliver the packet to the mobile node?

# Home Agent Intercept

- Packets from Corresponding Agents (CAs) arrive at the home network
- Home agent issues proxy ARP
  - Replies with its own MAC to queries for the Mobile Hosts IP
  - Packets are delivered to the Home Agent
- When Mobile Host returns to the home network
  - Gratuitous ARP

# Tunneling

- A *tunnel* exists between HA and FA
  - Home agent encapsulates IP packets for the Mobile Host using the FA's IP address
  - Rest of the Internet forwards packet as if it was destined for the FA
  - When packet arrives at the FA, it decapsulates the packet

# FA Delivery

- FA bypasses regular IP routing for registered MHs and delivers directly to the MAC address
- MH can be the FA
- What about packets sourced by the MH?
  - Sent from the remote network with the MH's permanent address
  - Reverse tunnel

# Route Optimization

- Packets from CA ->HA->FA follow suboptimal route
- If CA is upgraded it can create tunnel directly to the FA
  - HA sends binding update to the CA when packets arrive to it
  - FA can also send binding updates
- Security implications?

# Outline

- Inter-domain Internet Routing
  - BGP
- Routing for mobile nodes
- Multicast routing

# Multicast Routing

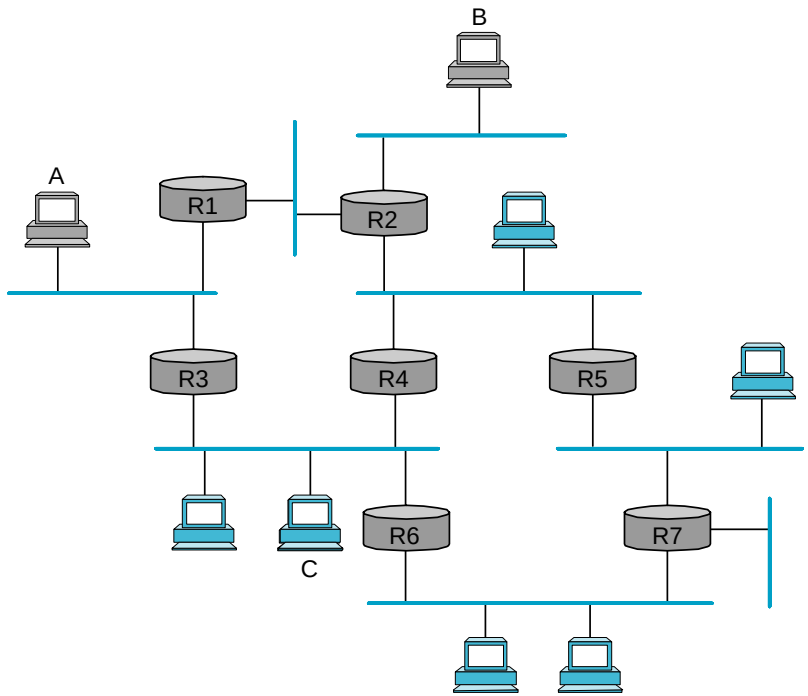
- Applications that want to send same data to multiple destinations
  - Audio, Video, Stock Updates
- Multicast model
  - Sender sends to Multicast Address
  - Receivers join Multicast Address
    - IGMP
  - Packets are delivered to all hosts that joined the multicast address
- How do the receivers know which multicast group to join?

# Distance-Vector Multicast

- DVMRP uses a two step approach
  - Flooding mechanism that delivers packets to the whole network
  - *Pruning* networks that have no receivers

# Reverse-Path Broadcast

- Flood packets from S to everyone
  - Router forwards packets to all interfaces (minus incoming) if packet arrives on correct interface
    - Interface R would use to send packets to S
  - Packet will be sent multiple times if multiple routers connected on same LAN
    - Designate parent for each network
    - Router with shortest distance to S



# Reverse-Path Multicast

- RPB delivers packets to all networks
  - Obviously undesirable
- Leaf networks know if any interested receivers are present
- Routers propagate this information to upstream neighbors
  - Tree is pruned
- What happens if a new receiver joins at a pruned network?

# Alternatives

- DVMRP not appropriate for *sparse* groups
- Protocol Independent Multicast (PIM) solves this issue
  - Rendezvous Point (RP)