

CSCI-1680

Network Layer:

Inter-domain Routing

Rodrigo Fonseca



Administrivia

- **IP due on Tuesday!**
- **Rodrigo's office hours:**
 - Monday 1-3 (or by appointment)



Today

- **Last time: Intra-Domain Routing (IGP)**
 - RIP distance vector
 - OSPF link state
- **Inter-Domain Routing (EGP)**
 - Border Gateway Protocol
 - Path-vector routing protocol



Why Inter vs. Intra

- **Why not just use OSPF everywhere?**
 - E.g., hierarchies of OSPF areas?
 - Hint: scaling is not the only limitation
- **BGP is a policy control and information hiding protocol**
 - intra == trusted, inter == untrusted
 - Different policies by different ASs
 - Different costs by different ASs

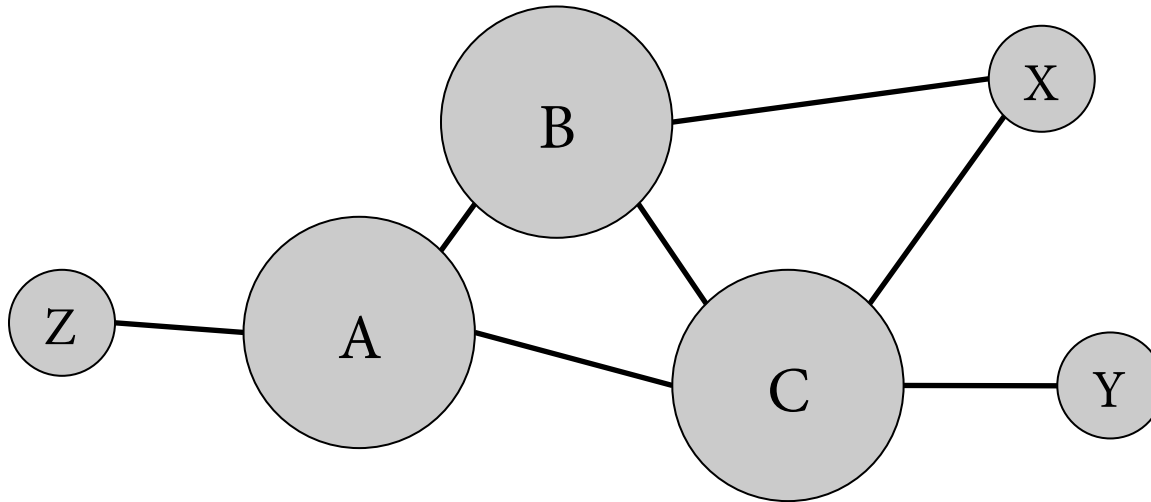


Types of ASs

- **Local Traffic – source or destination in local AS**
- **Transit Traffic – passes through an AS**
- **Stub AS**
 - Connects to only a single other AS
- **Multihomed AS**
 - Connects to multiple ASs
 - Carries no transit traffic
- **Transit AS**
 - Connects to multiple ASs and carries transit traffic



AS Relationships



- **How to prevent X from forwarding transit between B and C?**
- **How to avoid transit between CBA ?**
 - B: BAZ \rightarrow X
 - B: BAZ \rightarrow C ? (\Rightarrow Y: CBAZ and Y:CAZ)



Choice of Routing Algorithm

- **Constraints**
 - Scaling
 - Autonomy (policy and privacy)
- **Link-state?**
 - Requires sharing of complete information
 - Information exchange does not scale
 - Can't express policy
- **Distance Vector?**
 - Scales and retains privacy
 - Can't implement policy
 - Can't avoid loops if shortest path not taken
 - Count-to-infinity



Path Vector Protocol

- **Distance vector algorithm with extra information**
 - For each route, store the complete path (ASs)
 - No extra computation, just extra storage (and traffic)
- **Advantages**
 - Can make policy choices based on set of ASs in path
 - Can easily avoid loops



BGP - High Level

- **Single EGP protocol in use today**
- **Abstract each AS to a single node**
- **Destinations are CIDR prefixes**
- **Exchange prefix *reachability* with all neighbors**
 - E.g., “I can reach prefix 128.148.0.0/16 through ASes 44444 3356 14325 11078”
- **Select a single path by routing *policy***
- **Critical: learn many paths, propagate one**
 - Add your ASN to advertised path

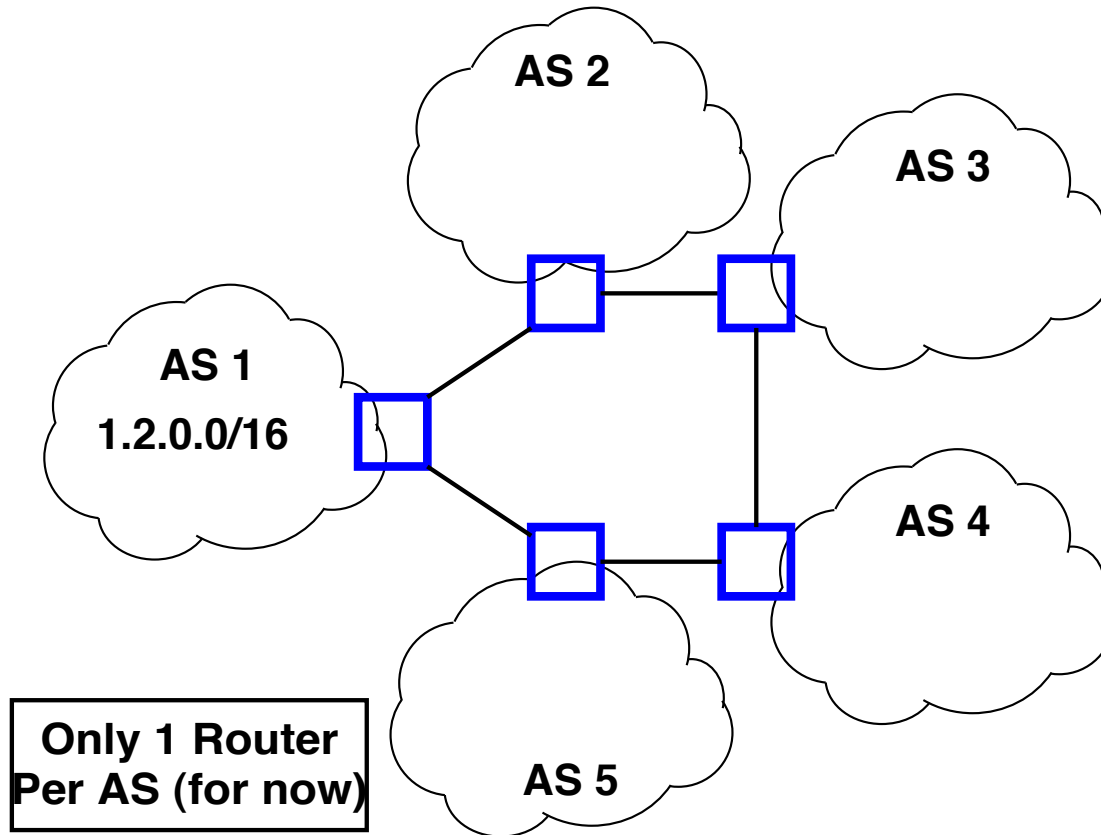


Why study BGP?

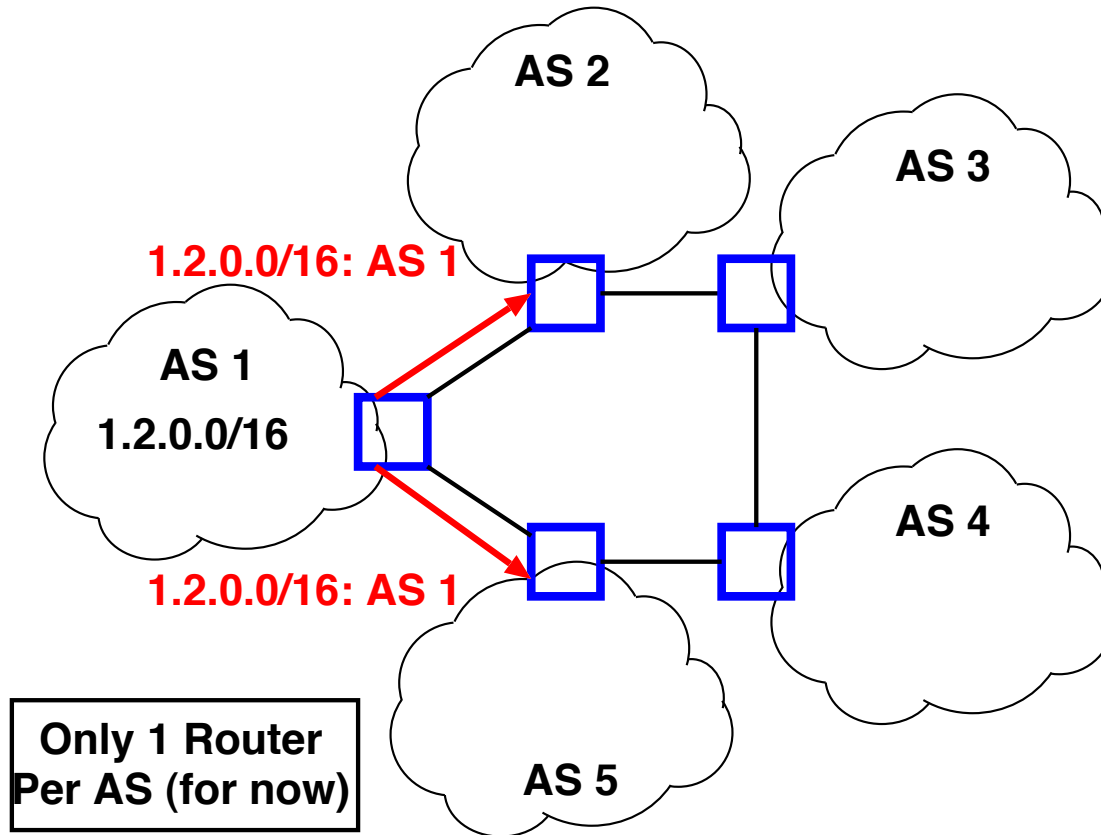
- **Critical protocol: makes the Internet run**
 - Only widely deployed EGP
- **Active area of problems!**
 - Efficiency
 - Cogent vs. Level3: Internet Partition
 - Spammers use prefix hijacking
 - Pakistan accidentally took down YouTube
 - Egypt disconnected for 5 days



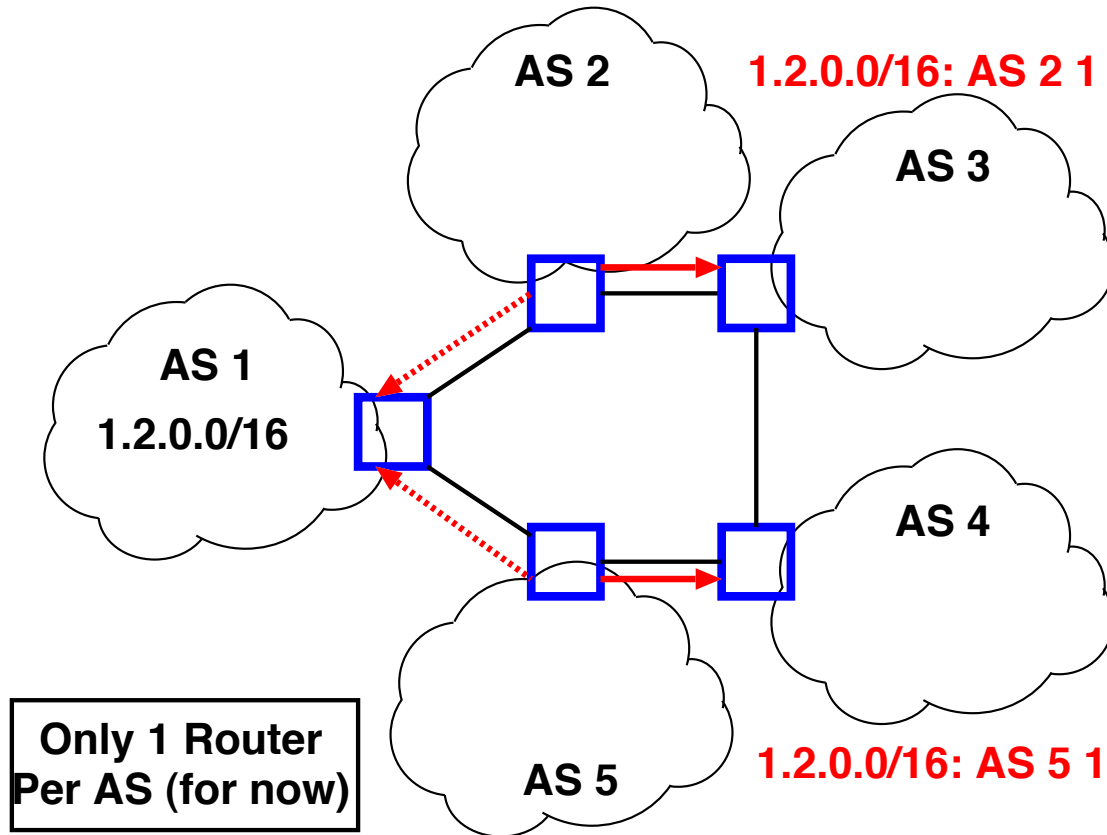
BGP Example



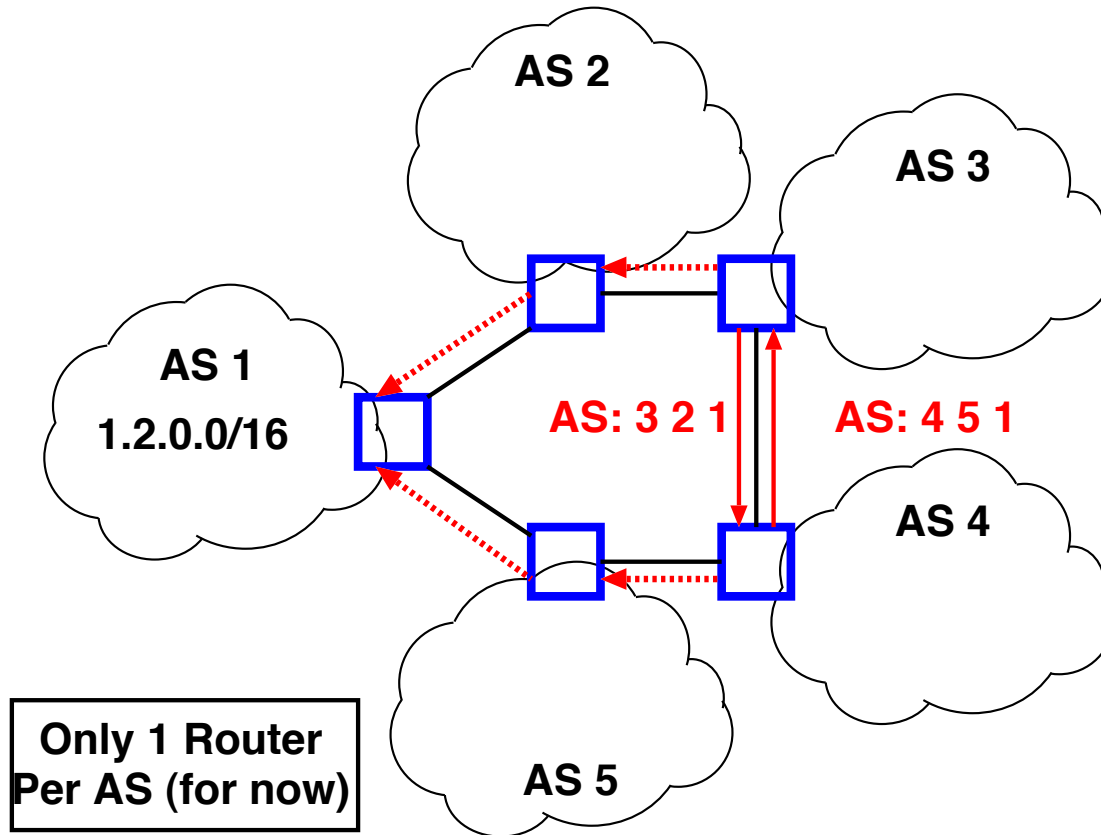
BGP Example



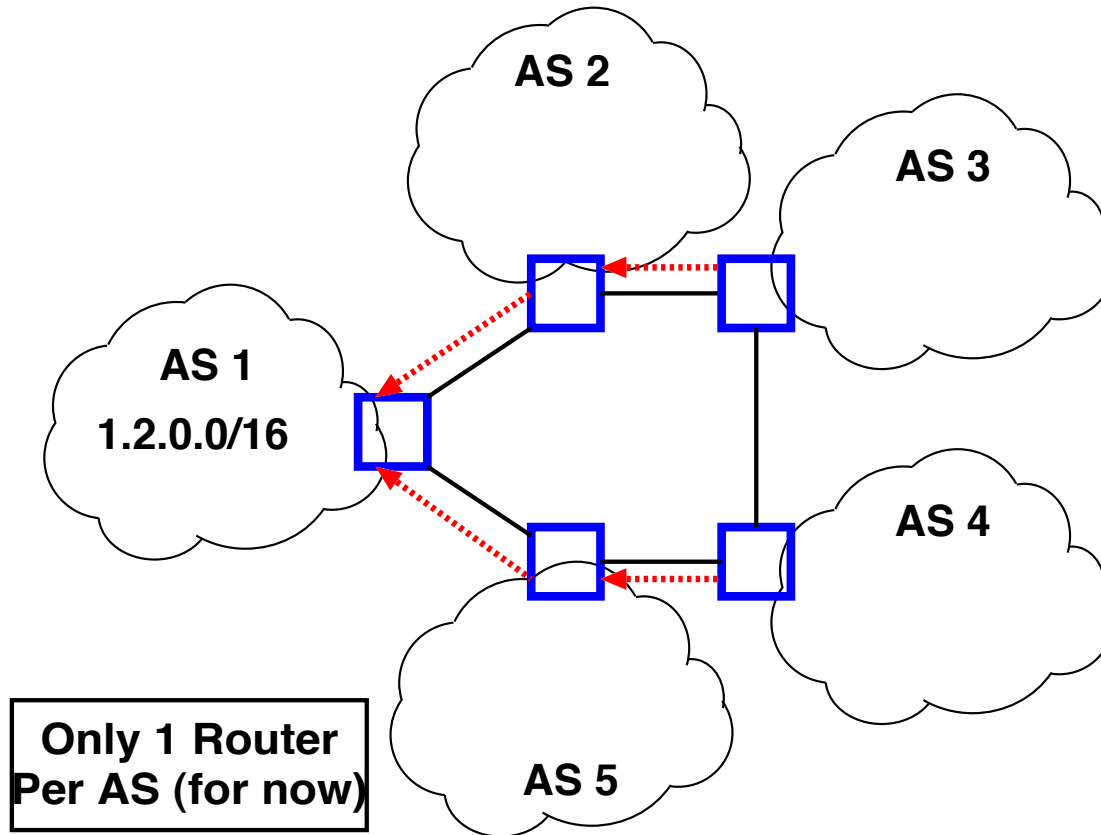
BGP Example



BGP Example



BGP Example



BGP Protocol Details

- **Separate roles of *speakers* and *gateways***
 - Speakers talk BGP with other ASs
 - Gateways are routes that border other Ass
 - Can have more gateways than speakers
 - Speakers know how to reach gateways
- **Speakers connect over TCP on port 179**
 - Bidirectional exchange over long-lived connection

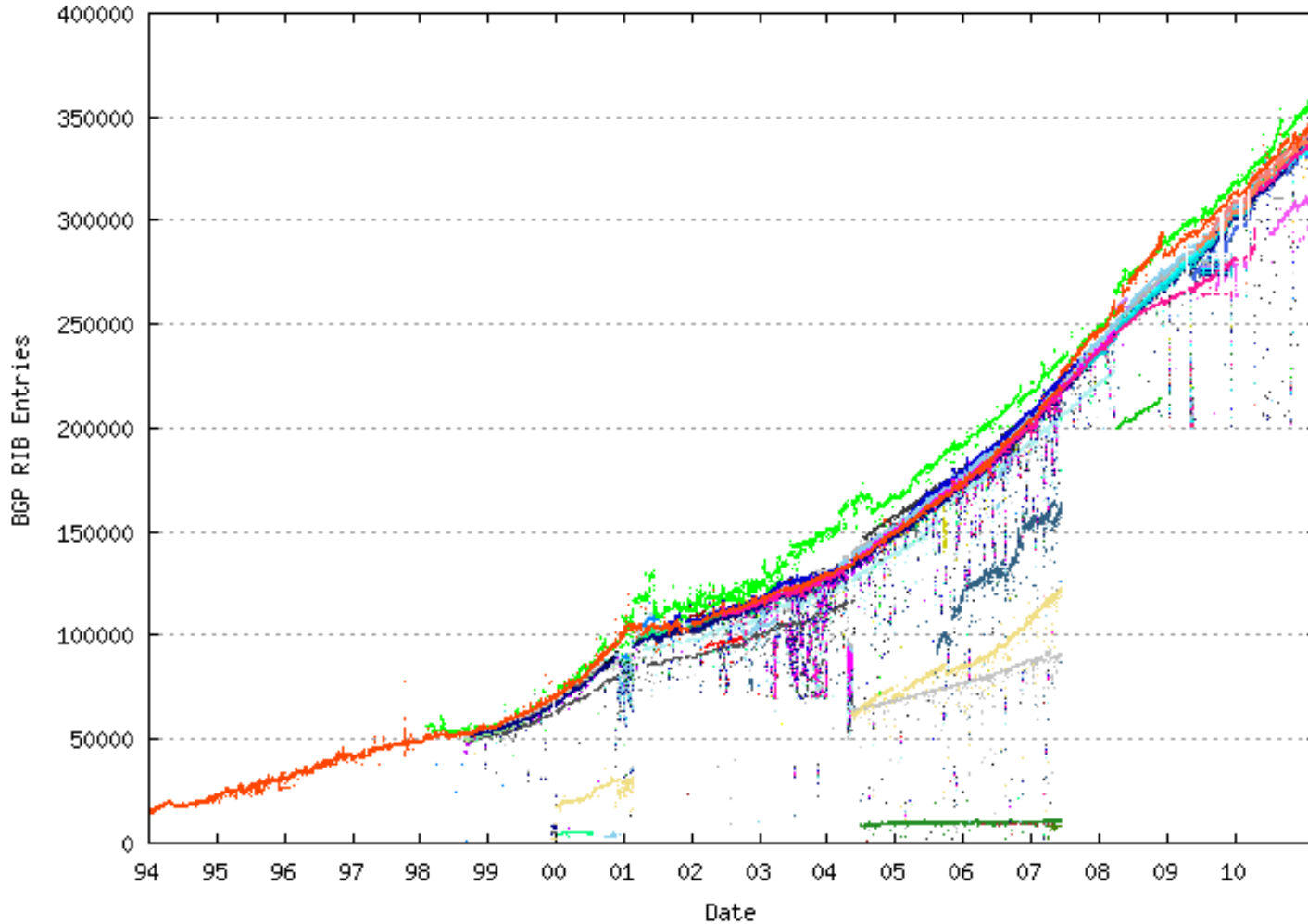


BGP Implications

- **Explicit AS Path == Loop free**
 - Except under churn, IGP/EGP mismatch
- **Reachability not guaranteed**
 - Decentralized combination of policies
- **Not all ASs know all paths**
- **AS abstraction -> loss of efficiency**
- **Scaling**
 - 37K ASs
 - 350K+ prefixes
 - ASs with one prefix: 15664
 - Most prefixes by one AS: 3686 (AS6389, BellSouth)



BGP Table Growth



Source: bgp.potaroo.net

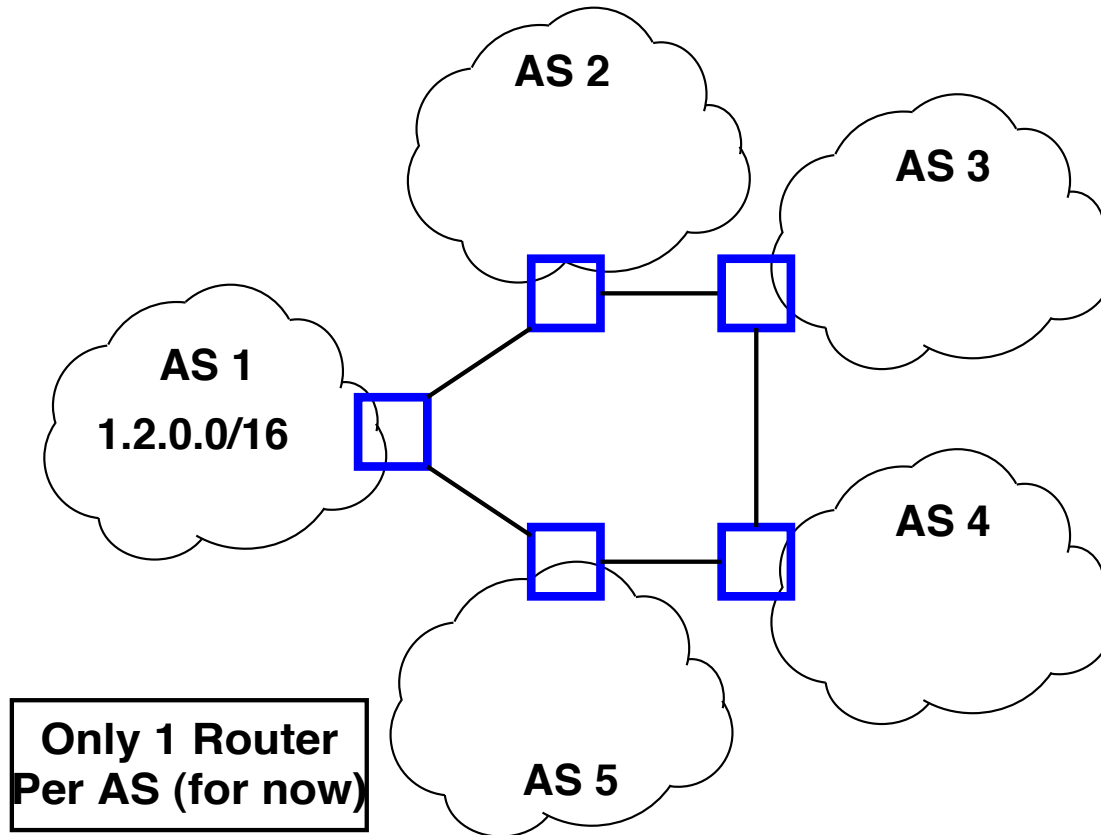


Integrating EGP and IGP

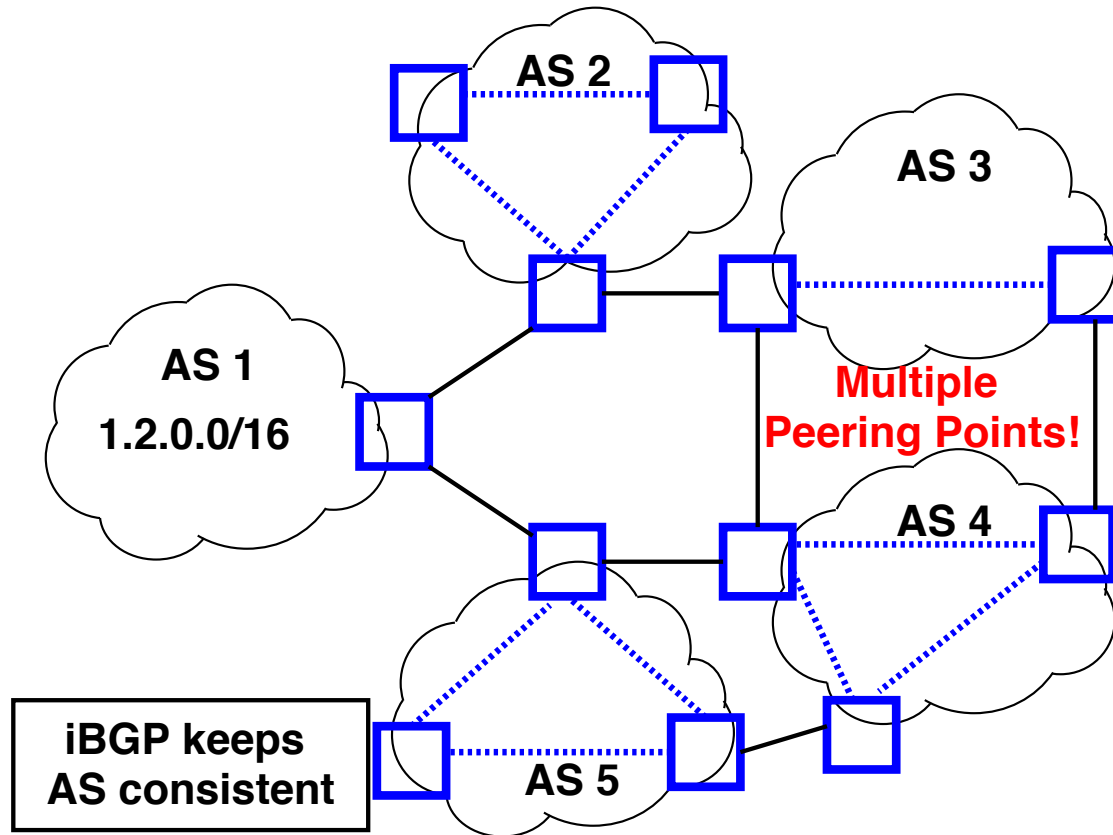
- **Stub ASs**
 - Border router clear choice for default route
 - Inject into IGP: “any unknown route to border router”
- **Inject specific prefixes in IGP**
 - E.g., Provider injects routes to customer prefix
- **Backbone networks**
 - Too many prefixes for IGP
 - Run internal version of BGP, iBGP
 - All routers learn mappings: Prefix -> Border Router
 - Use IGP to learn: Border Router -> Next Hop



iBGP



iBGP



BGP Messages

- **Base protocol has four message types**
 - **OPEN** – Initialize connection. Identifies peers and must be first message in each direction
 - **UPDATE** – Announce routing changes (most important message)
 - **NOTIFICATION** – Announce error when closing connection
 - **KEEPALIVE** – Make sure peer is alive
- **Extensions can define more message types**
 - E.g., ROUTE-REFRESH [RFC 2918]



Anatomy of an UPDATE

- **Withdrawn routes: list of withdrawn IP prefixes**
- **Network Layer Reachability Information (NLRI)**
 - List of prefixes to which path attributes apply
- **Path attributes**
 - ORIGIN, AS_PATH, NEXT_HOP, MULTI-EXIT-DISC, LOCAL_PREF, ATOMIC_AGGREGATE, AGGREGATOR, ...
 - Each attribute has 1-byte type, 1-byte flags, length, content
 - Can introduce new types of path attribute – e.g., AS4_PATH for 32-bit AS numbers



Example

- **NLRI: 128.148.0.0/16**
- **AS Path: ASN 44444 3356 14325 11078**
- **Next Hop IP: same as in RIPv2**
- **Knobs for traffic engineering:**
 - Metric, weight, LocalPath, MED, Communities
 - Lots of voodoo



BGP State

- **BGP speaker conceptually maintains 3 sets of state**
- **Adj-RIB-In**
 - “Adjacent Routing Information Base, Incoming”
 - Unprocessed routes learned from other BGP speakers
- **Loc-RIB**
 - Contains routes from Adj-RIB-In selected by policy
 - First hop of route must be reachable by IGP or static route
- **Adj-RIB-Out**
 - Subset of Loc-RIB to be advertised to peer speakers



Demo

- **Route views project:** <http://www.routeviews.org>
 - telnet route-views.linx.routeviews.org
 - show ip bgp 128.148.0.0/16 longer-prefixes
- **All paths are learned internally (iBGP)**
- **Not a production device**



Next class

- **BGP Policy Routing and Security**

