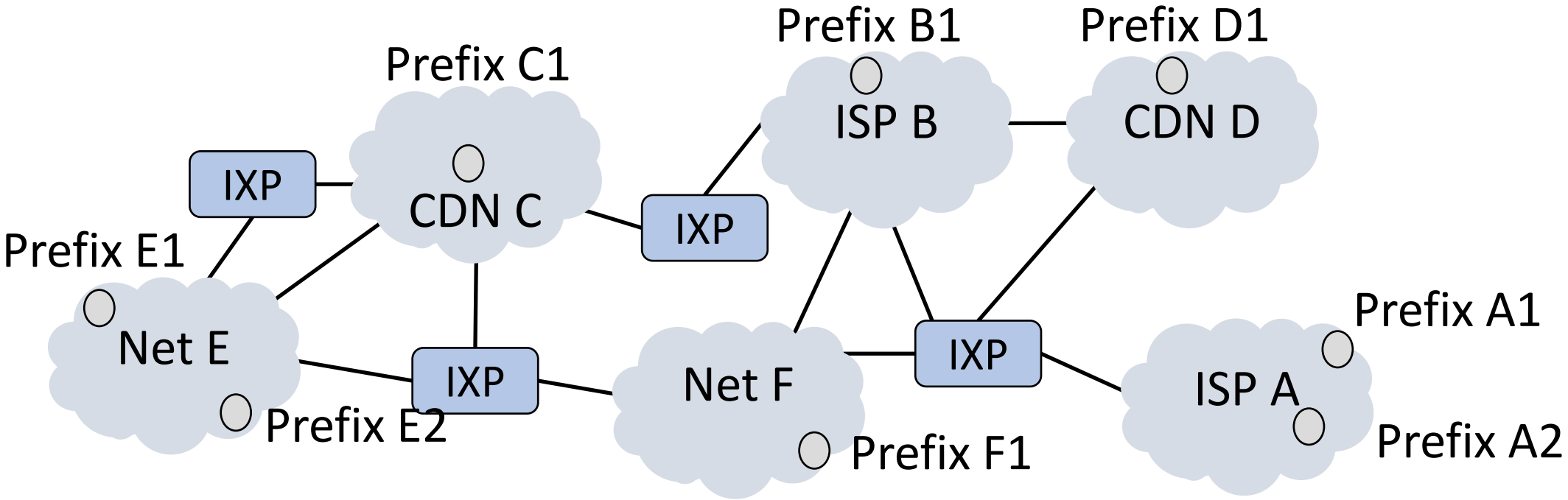
Network Layer (Routing)

Border Gateway Protocol

Structure of the Internet

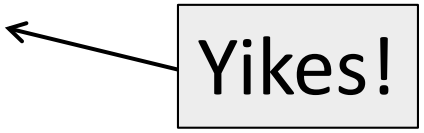
- Networks (ISPs, CDNs, etc.) group with IP prefixes
- Networks are richly interconnected, often using IXPs



Internet-wide Routing Issues

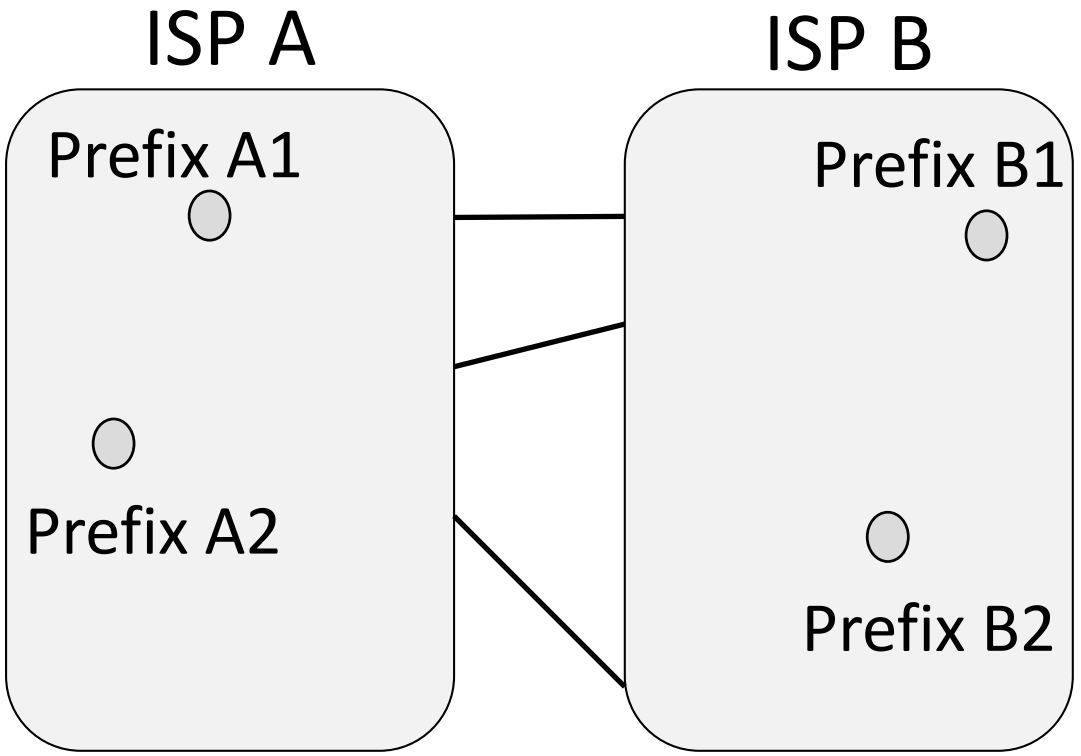
- Two problems beyond routing within a network

1. Scaling to very large networks
   - Techniques of IP prefixes, hierarchy, prefix aggregation
2. Incorporating policy decisions
   - Letting different parties choose their routes to suit their own needs



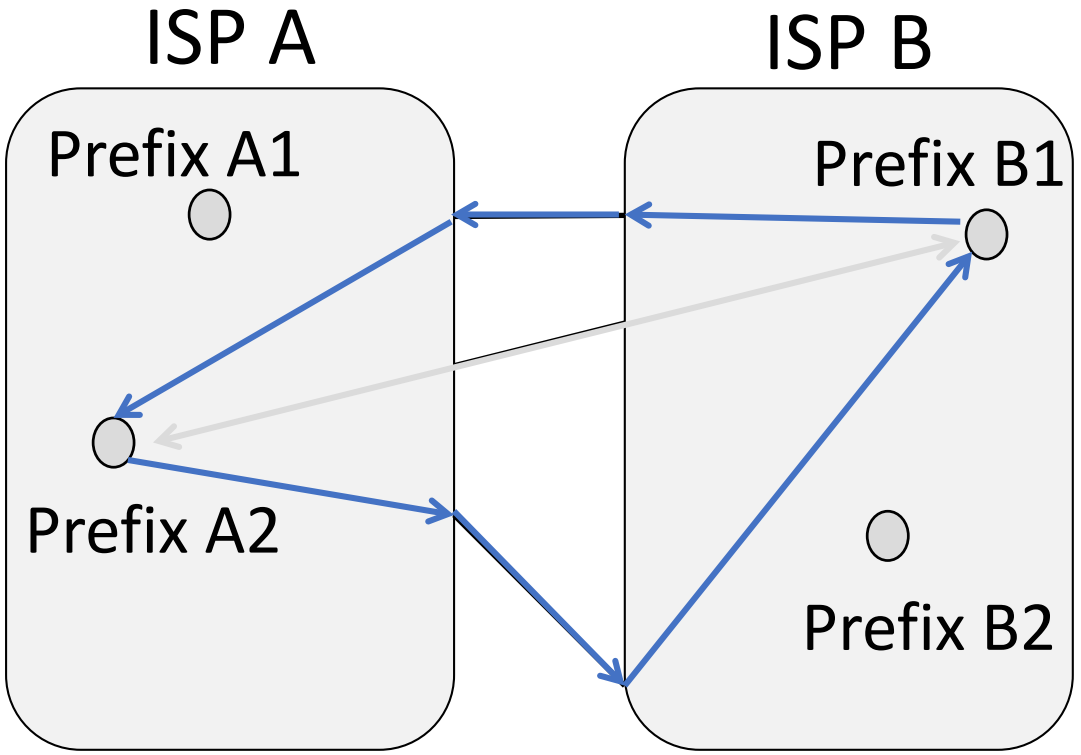
Effects of Independent Parties

- Each party selects routes to suit its own interests
  - e.g, shortest path in ISP
- What path will be chosen for A2→B1 and B1→A2?
  - What is the best path?



Effects of Independent Parties (2)

- Selected paths are longer than overall shortest path
  - And symmetric too!
- This is a consequence of independent goals and decisions, not hierarchy

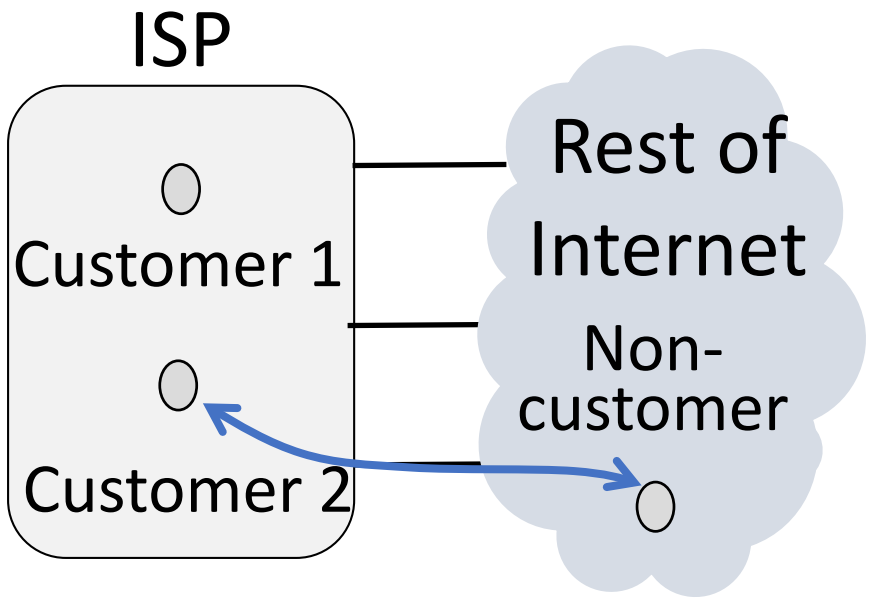


Routing Policies

- Capture the goals of different parties
  - Could be anything
  - E.g., Internet2 only carries non-commercial traffic
- Common policies we'll look at:
  - ISPs give TRANSIT service to customers
  - ISPs give PEER service to each other

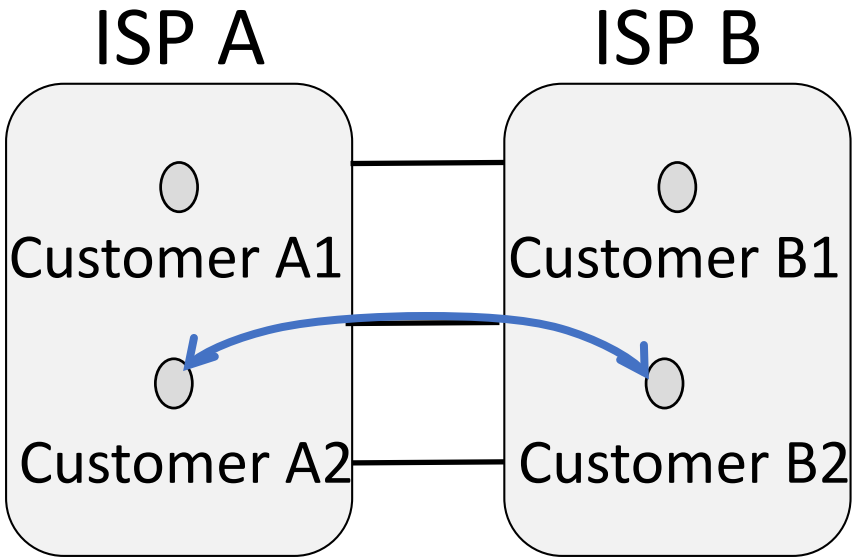
Routing Policies – Transit

- One party (customer) gets TRANSIT service from another party (ISP)
  - ISP accepts traffic for customer from the rest of Internet
  - ISP sends traffic from customer to the rest of Internet
  - Customer pays ISP for the privilege



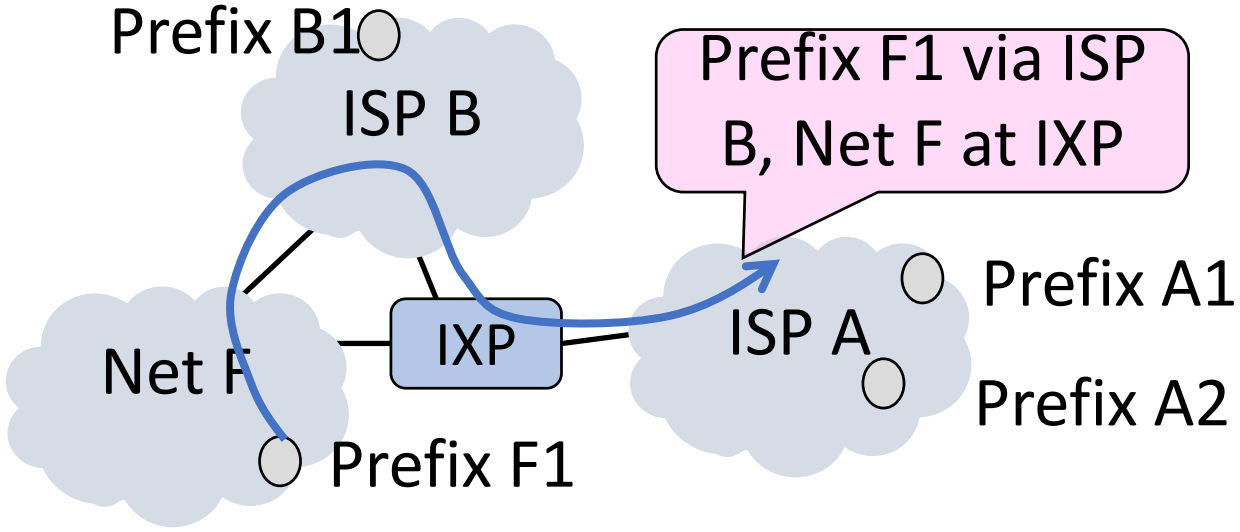
Routing Policies – Peer

- Both party (ISPs in example) get PEER service from each other
  - Each ISP accepts traffic from the other ISP only for their customers
  - ISPs do not carry traffic to the rest of the Internet for each other
  - ISPs don't pay each other



Routing with BGP (Border Gateway Protocol)

- iBGP is for internal routing
- eBGP is interdomain routing for the Internet
  - Path vector, a kind of distance vector



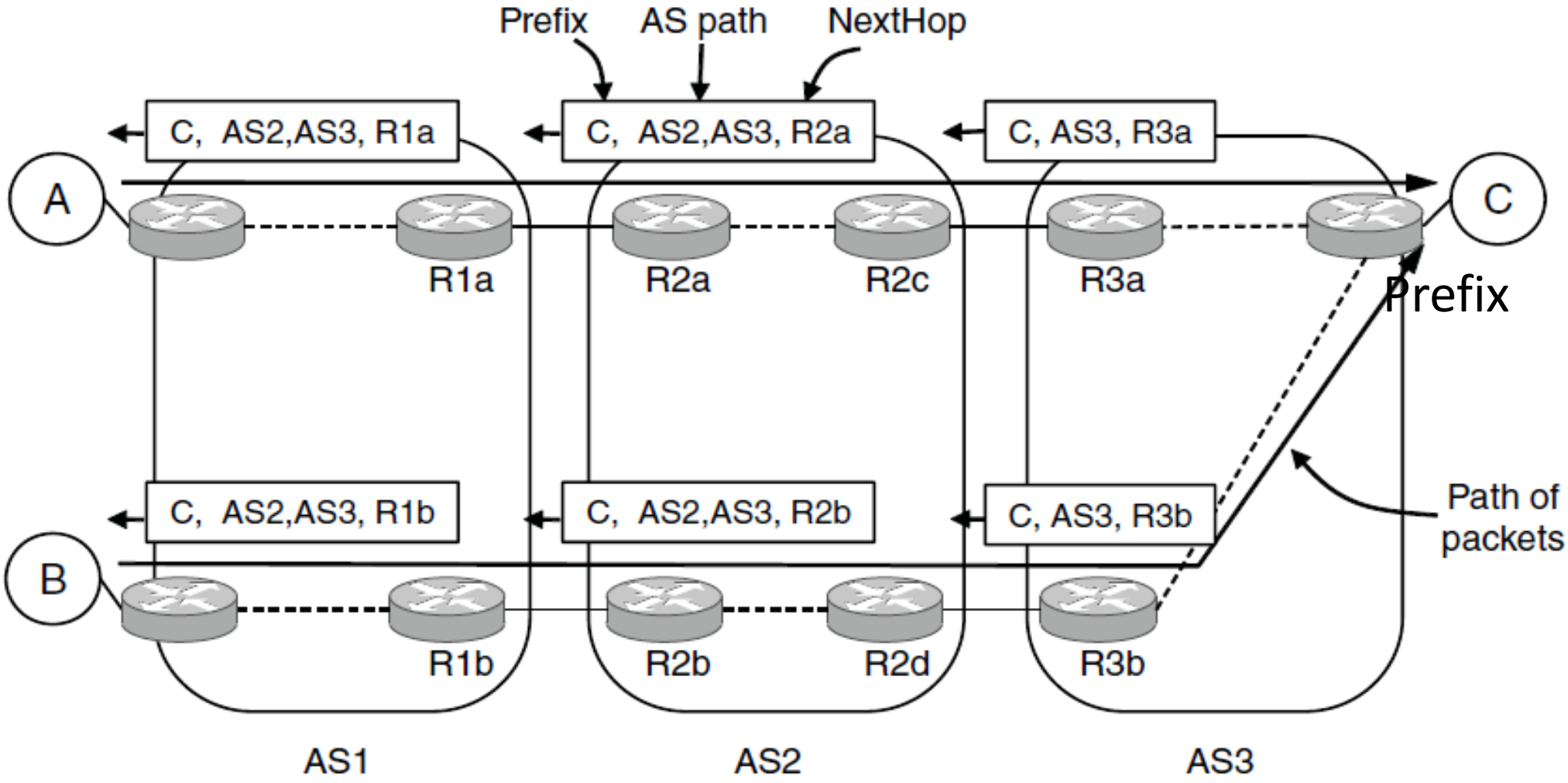
Routing with BGP (2)

- Parties like ISPs are called AS (Autonomous Systems)
- AS's **MANUALLY** configure their internal BGP routes/advertisements
- External routes go through complicated filters for forwarding/filtering
- AS BGP routers communicate with each other to keep consistent routing rules

Routing with BGP (2)

- Border routers of ASes announce BGP routes
- Route announcements have IP prefix, path vector, next hop
  - Path vector is list of ASes on the way to the prefix
  - List is to find loops
- Route announcements move in the opposite direction to traffic

Routing with BGP (3)



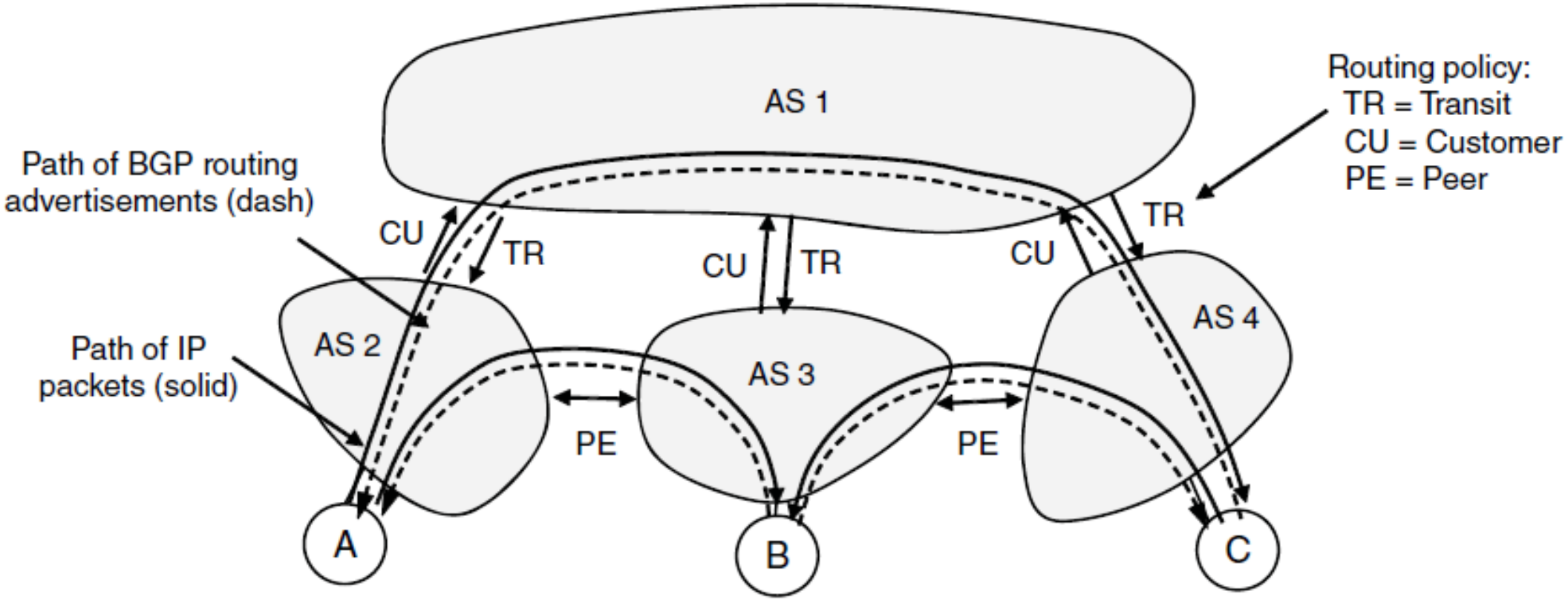
Routing with BGP (4)

Policy is implemented in two ways:

1. Border routers of ISP announce paths only to other parties who may use those paths
   - Filter out paths others can't use
2. Border routers of ISP select the best path of the ones they hear in any, non-shortest way

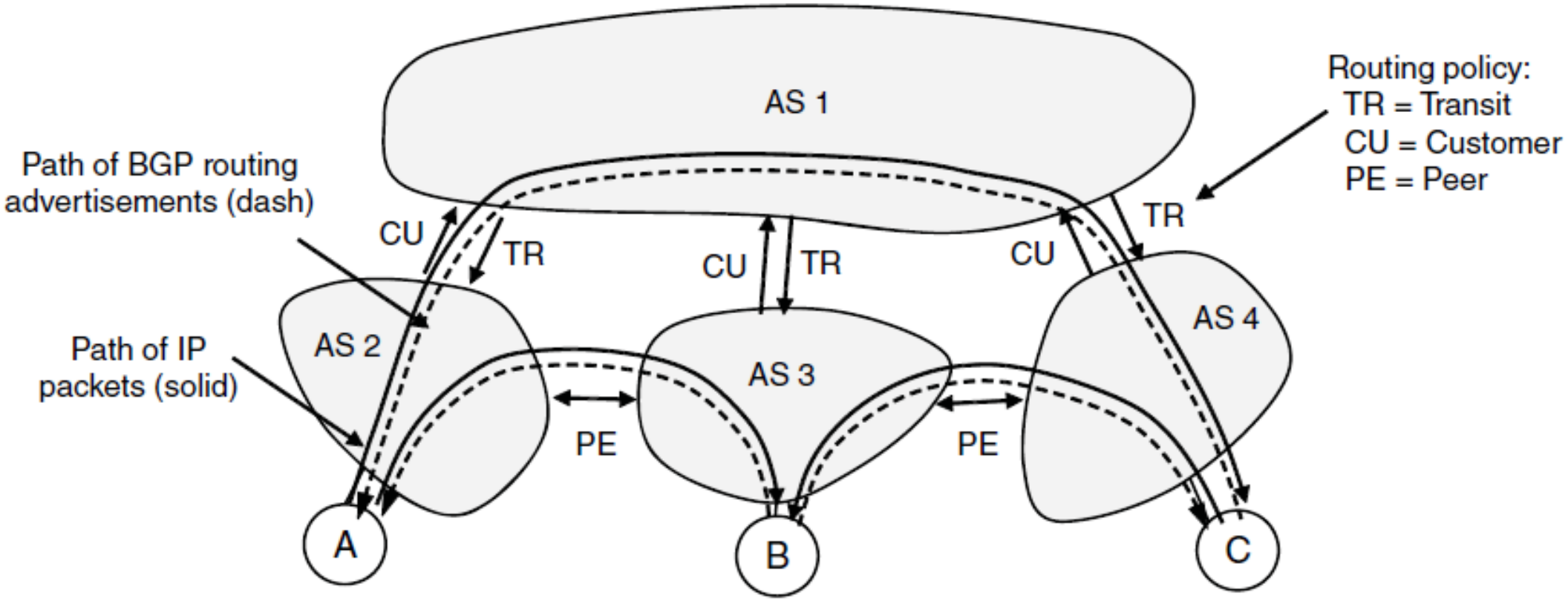
Routing with BGP (5)

- TRANSIT: AS1 says [B, (AS1, AS3)], [C, (AS1, AS4)] to AS2



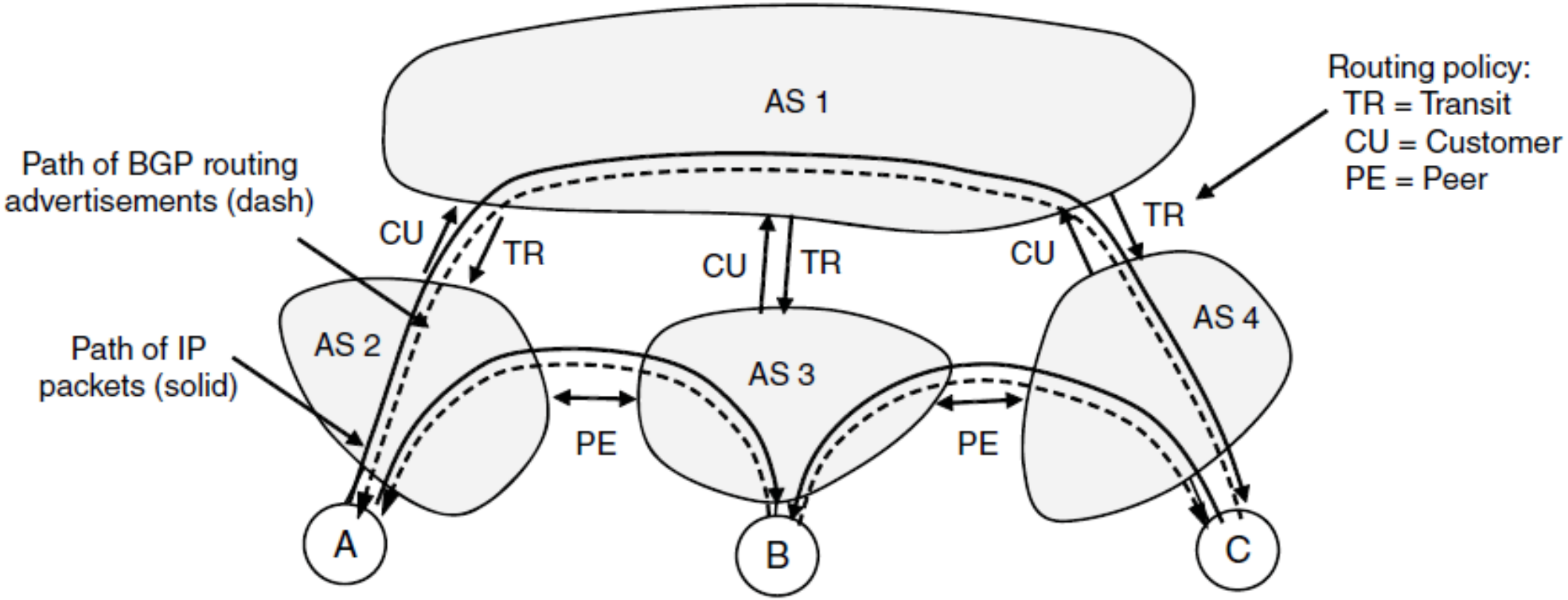
Routing with BGP (6)

- CUSTOMER (other side of TRANSIT): AS2 says [A, (AS2)] to AS1



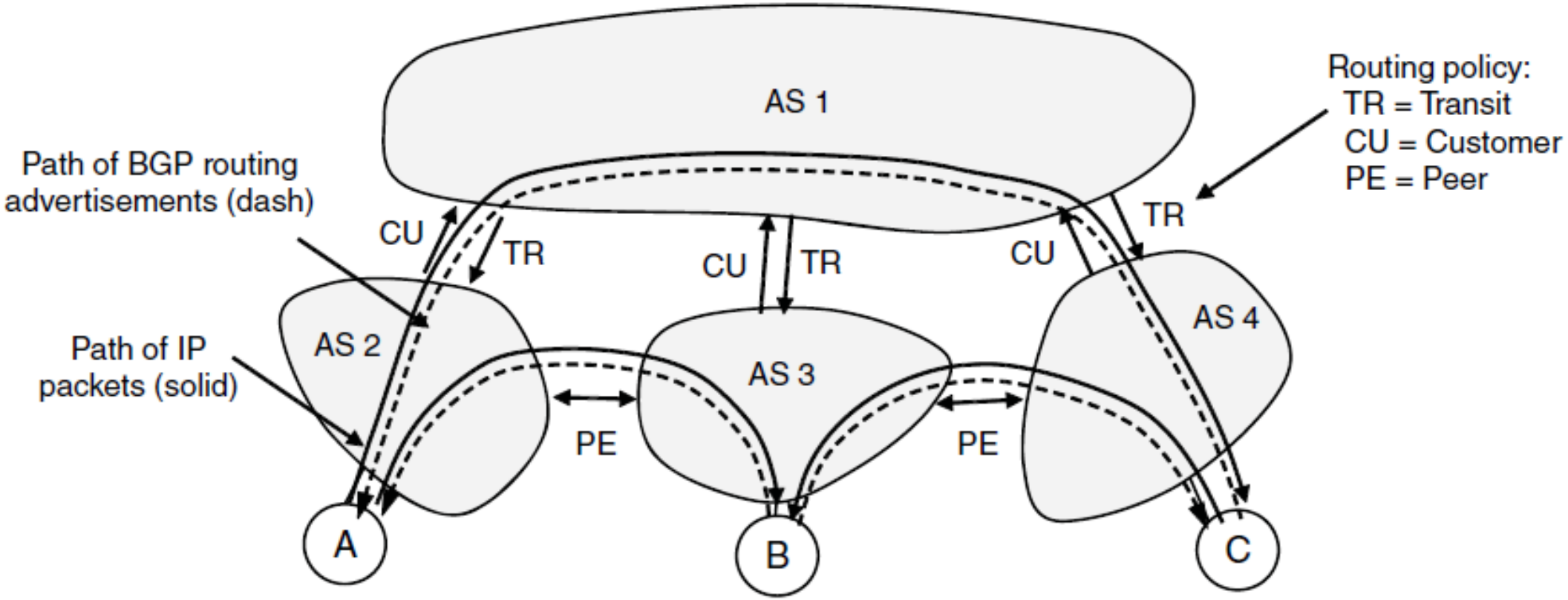
Routing with BGP (7)

- PEER: AS2 says [A, (AS2)] to AS3, AS3 says [B, (AS3)] to AS2



Routing with BGP (8)

- AS2 has two routes to B (AS1, AS3) and chooses AS3 (Free!)



BGP Thoughts

- Much more beyond basics to explore!
- Policy is a substantial factor
  - Can independent decisions be sensible overall?
- Other important factors:
  - Convergence effects
  - How well it scales
  - Integration with intradomain routing
  - And more …