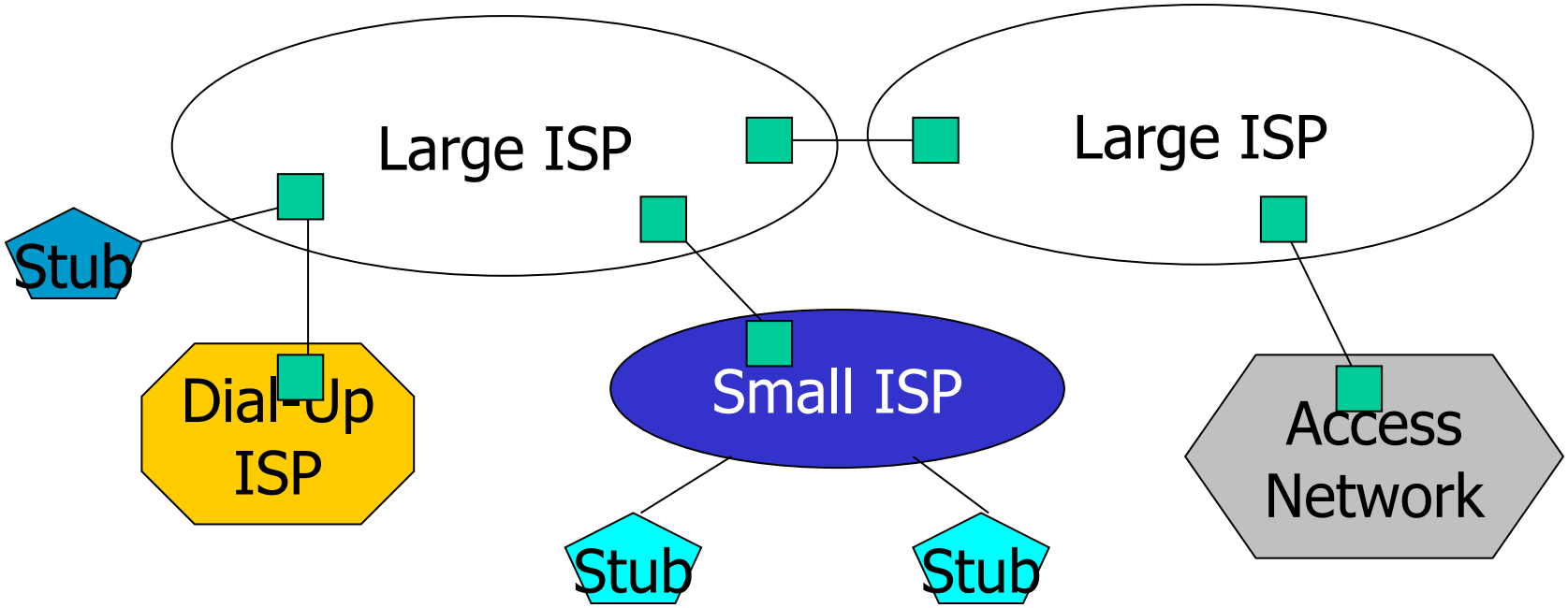
IP Layer: Inter-Domain Routing (BGP)

ECE 50863 – Computer Network Systems

Internet Structure

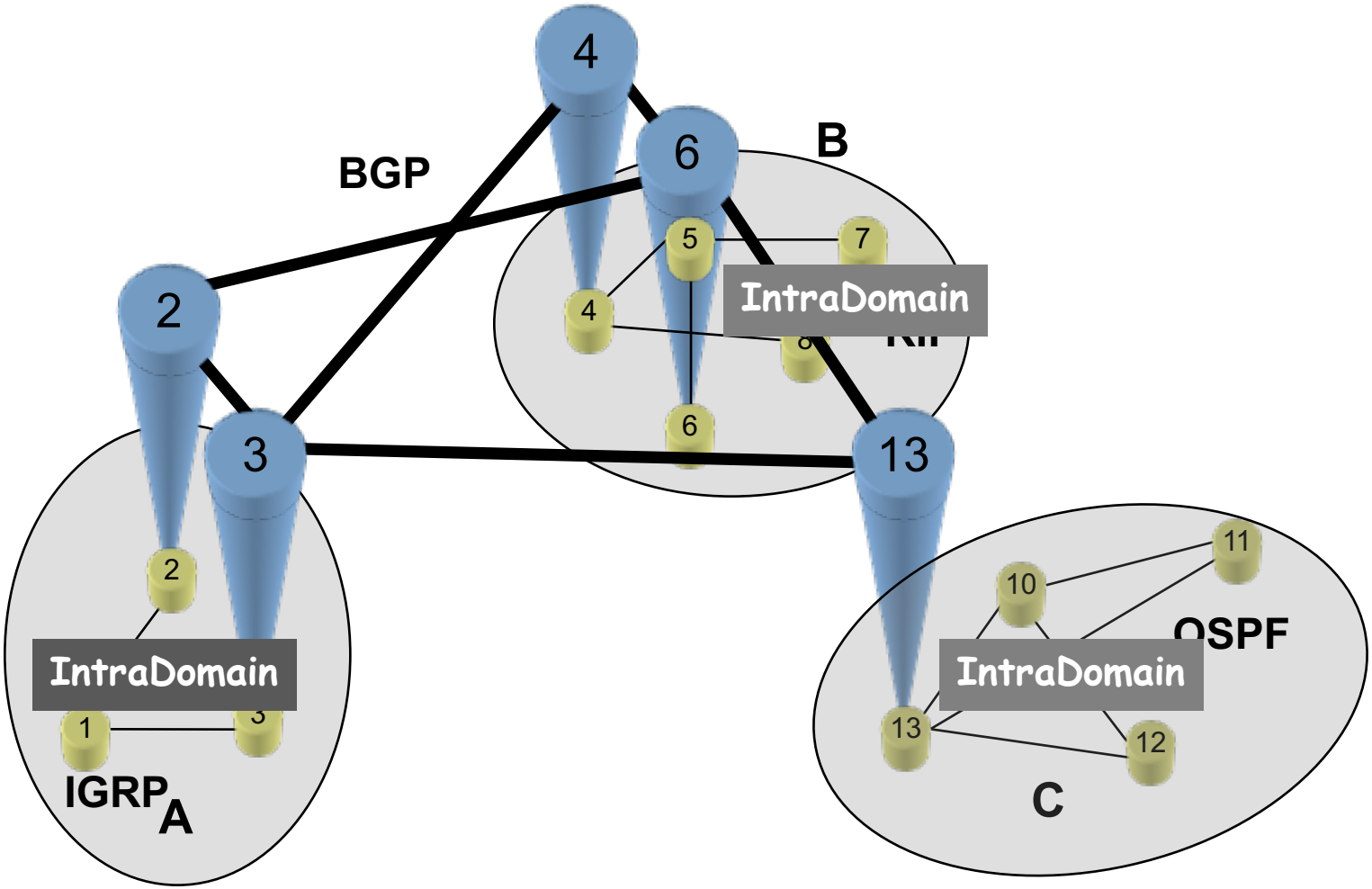


The Internet is a collection of networks, each controlled by different administrations

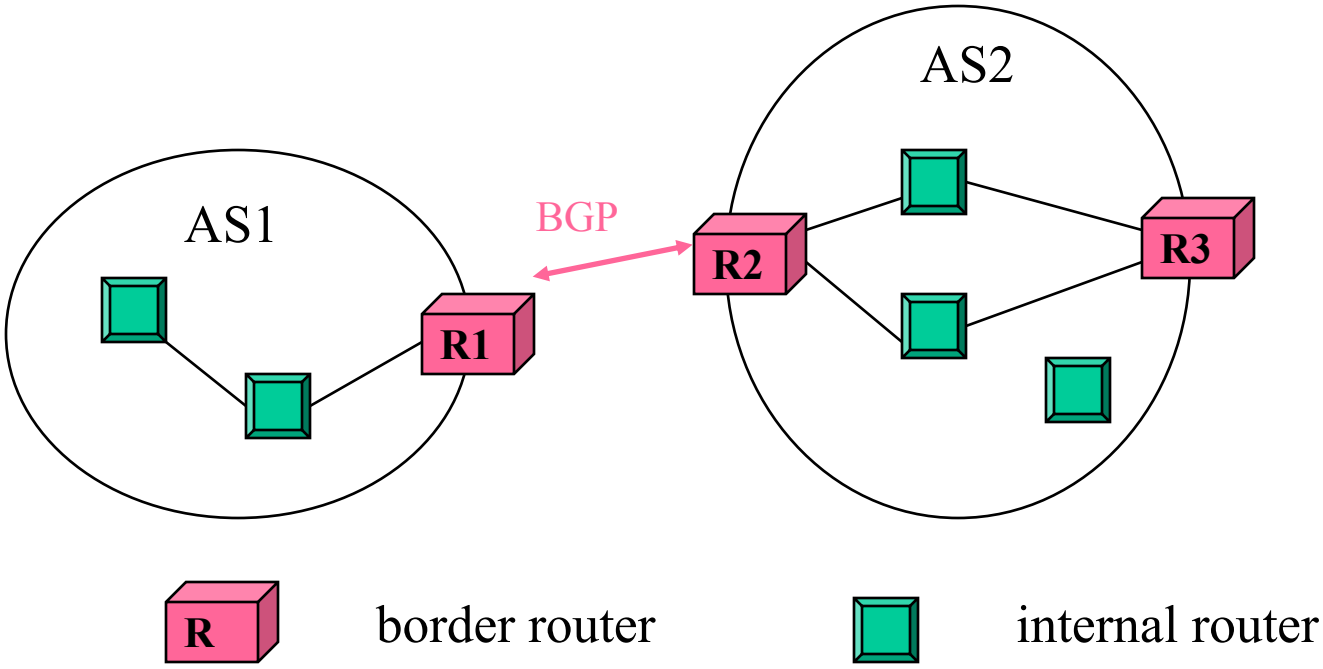
An autonomous system (AS) is a network under a single administrative control

Each AS assigned a number – e.g., Purdue's AS Number is 17.

Intradomain And Interdomain



Border Gateway Protocol



- Two types of routers
  - Border router (Edge), Internal router (Core)

Purpose of BGP

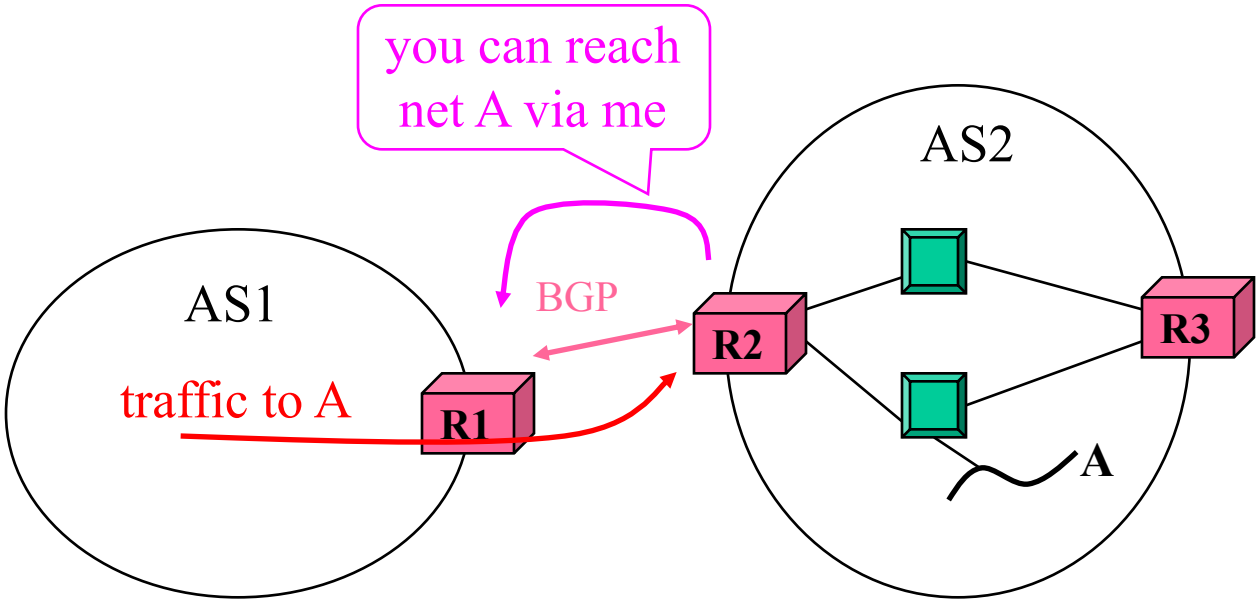


table at R1:

dest	next hop
A	R2

R border router

internal router

Share connectivity information across ASes

BGP: Key Considerations

- **Scale**
  - Forward packets destined to any address in Internet
  - Order of 140,000 CIDR prefixes
- **Domains are autonomous**
  - No idea what interior protocol/metrics used within each AS
- **Dominated by policy, business considerations**
  - Provider A unwilling to believe advertisements of Provider B.
  - Provider A unwilling to carry traffic between Providers B, C

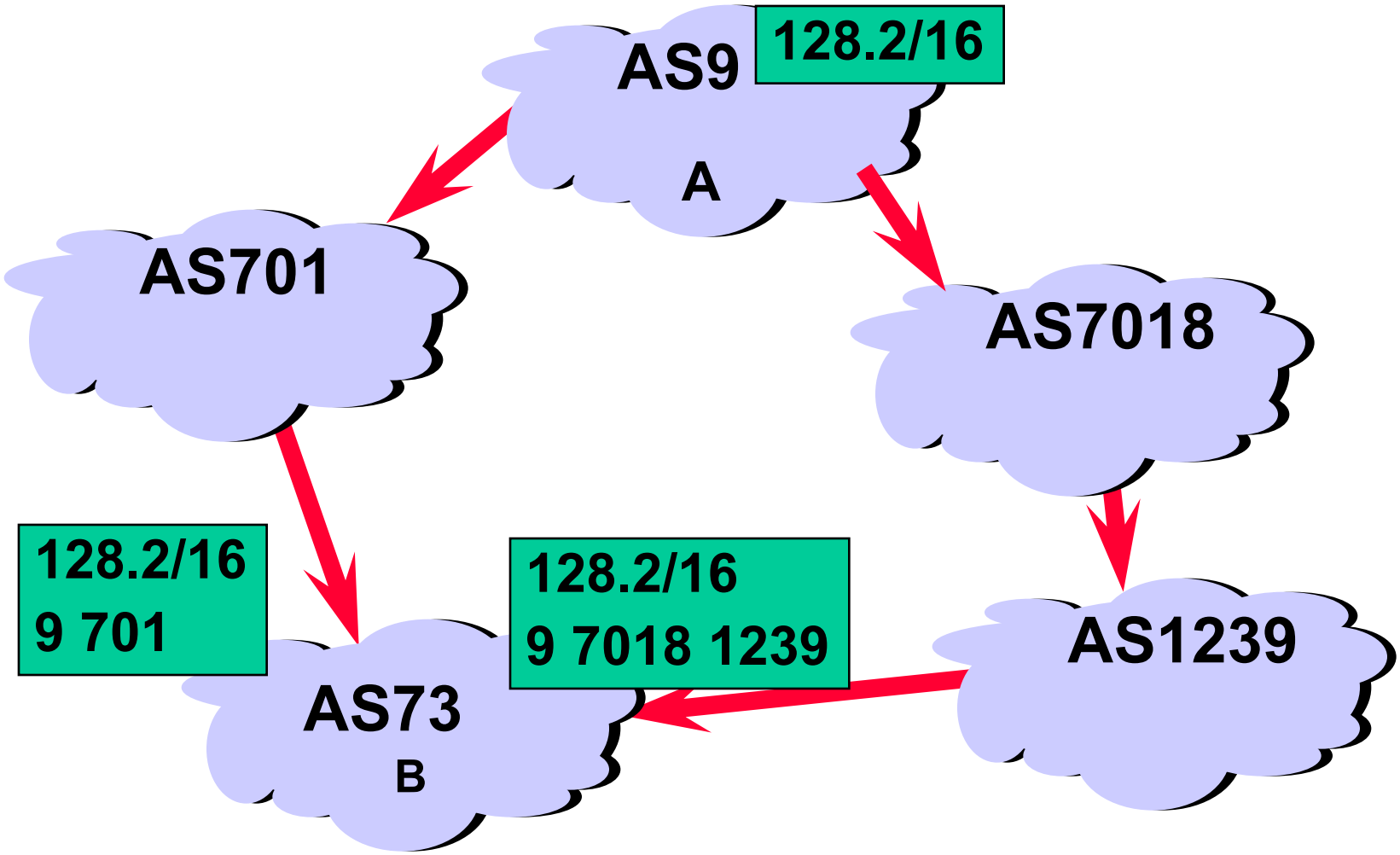
Consequences

- **Goal of BGP:**
  - Simply find some path between A and B.
  - Does not try to “optimize” path

Path Vector Protocol

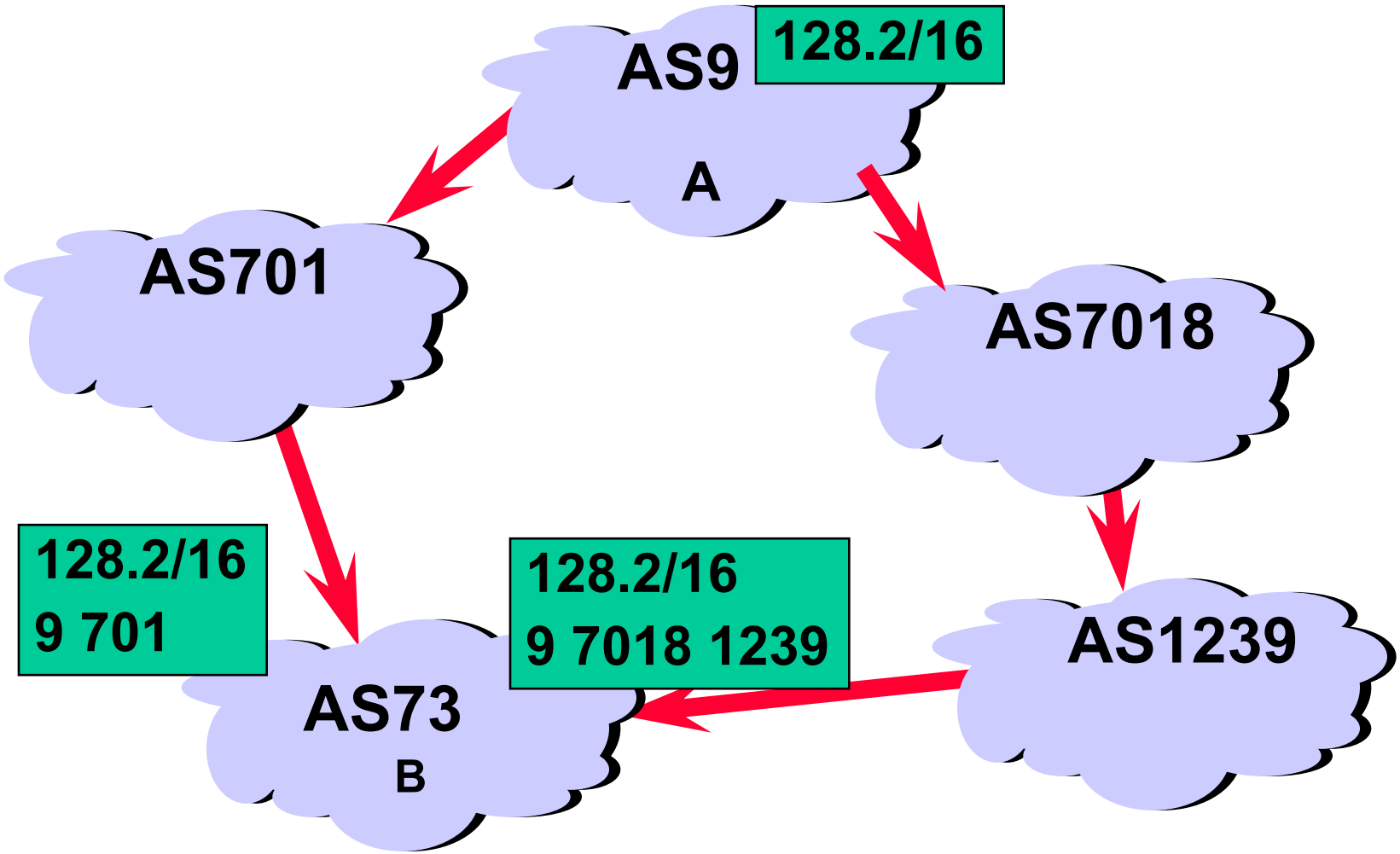
- **Distance Vector based or Link State based?**
- **Distance vector algorithm with extra information**
  - For each route, store the complete AS path
    - Note this does not include the actual routers, just list of ASs
  - No extra computation, just extra storage
- **Advantages:**
  - can make policy choices based on set of ASs in path
  - can avoid loops

Example: Multiple AS Paths

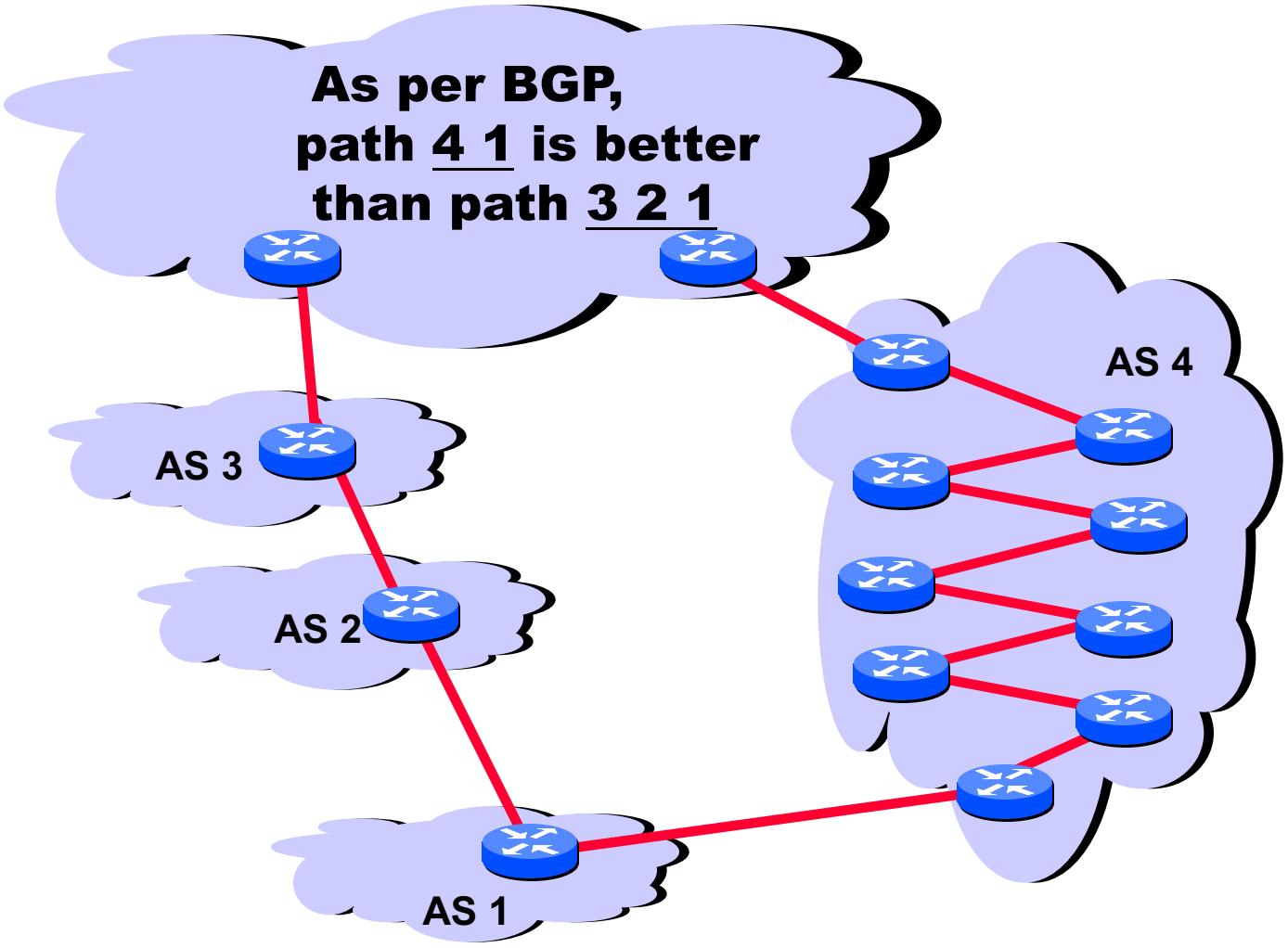


Example

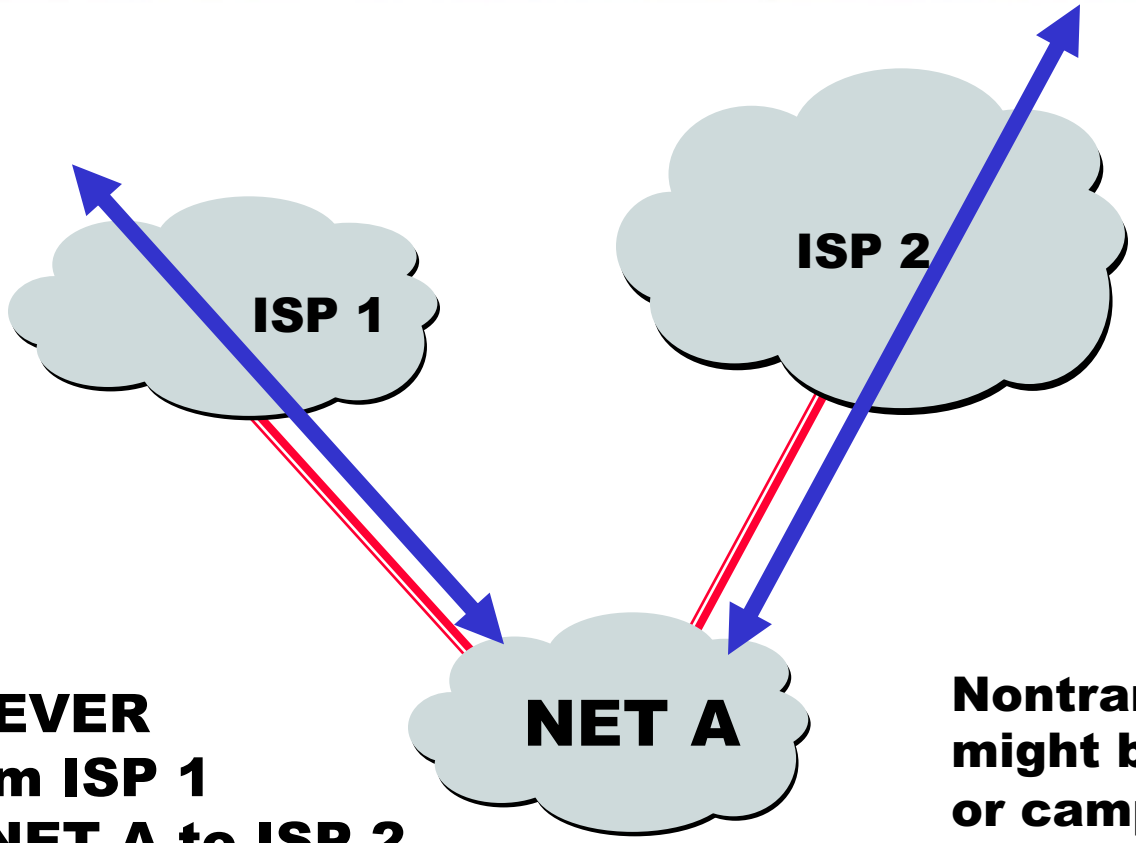
Typical policy: prefer path with minimum AS hops



Limitations



Nontransit vs. Transit ASes



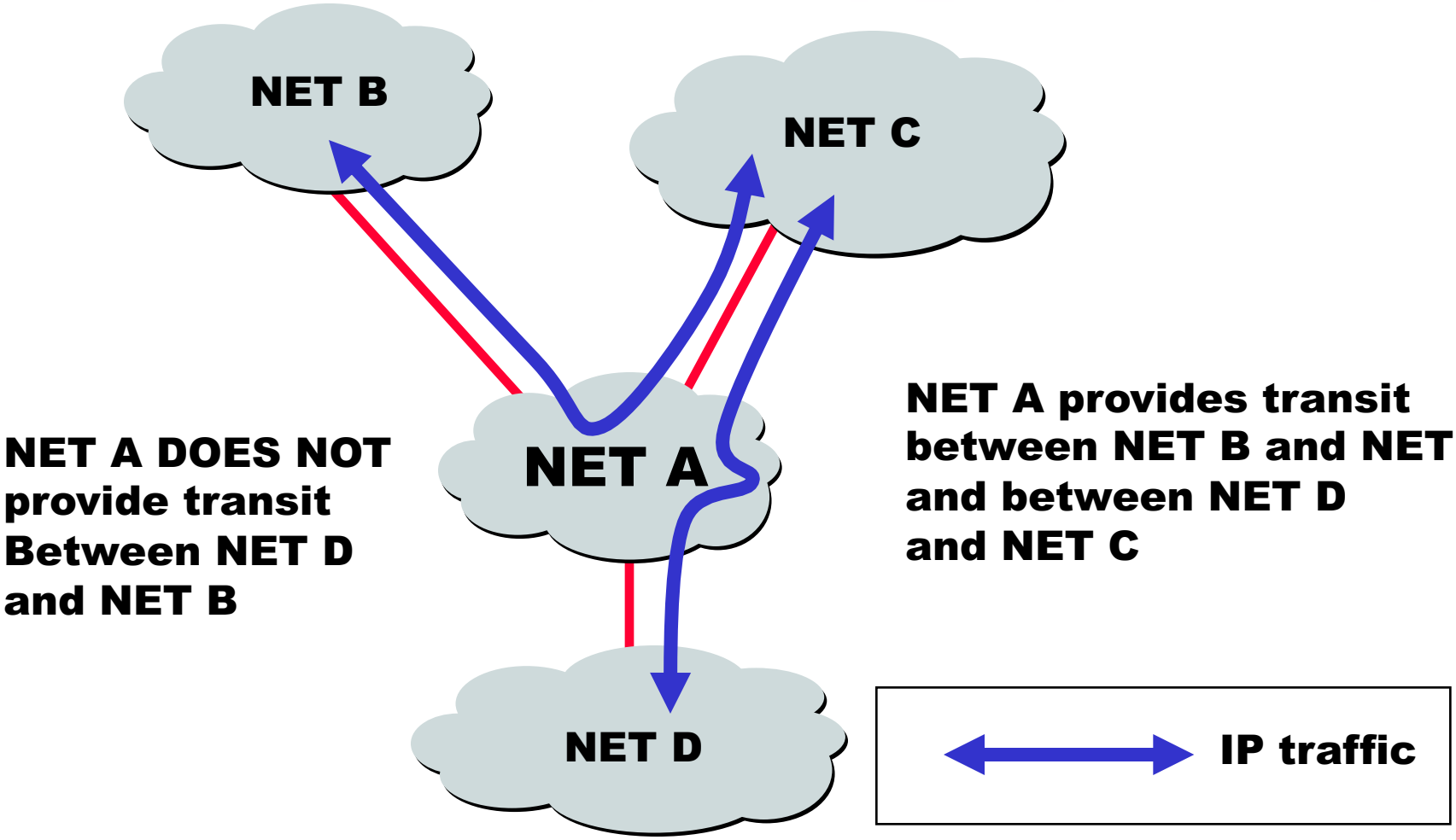
Internet Service providers (often) have transit networks

Traffic NEVER flows from ISP 1 through NET A to ISP 2 (At least not intentionally!)

Nontransit AS might be a corporate or campus network. Could be a “content provider”

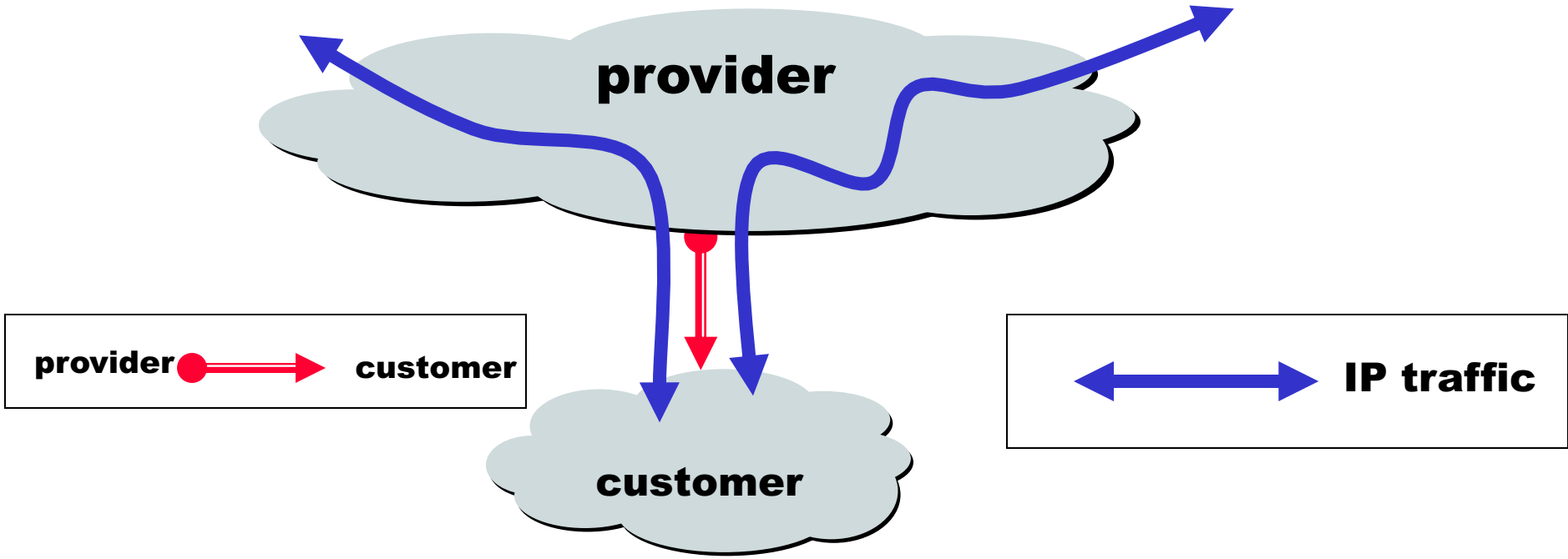
IP traffic

Selective Transit



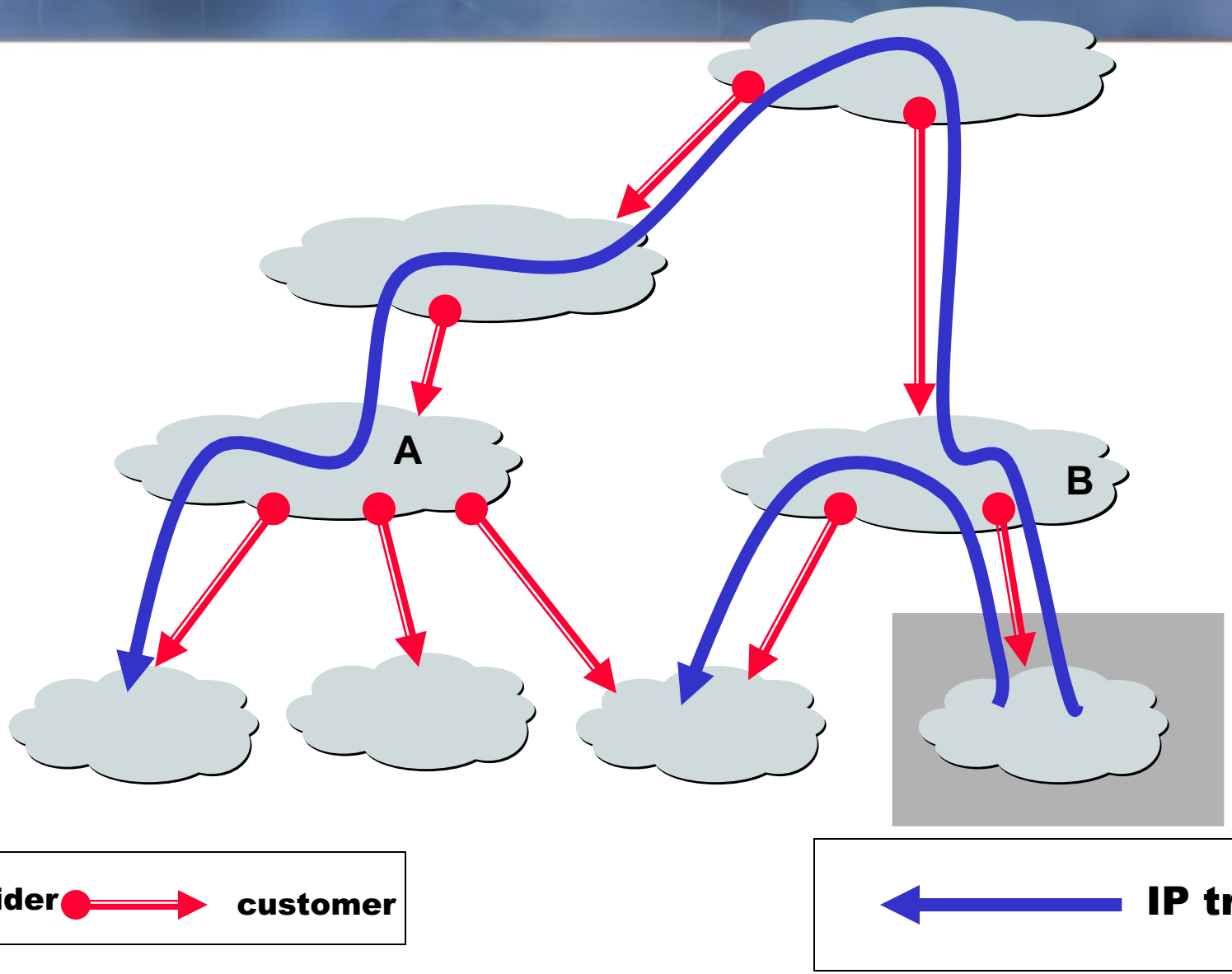
Most transit networks transit in a selective manner…

Customers and Providers

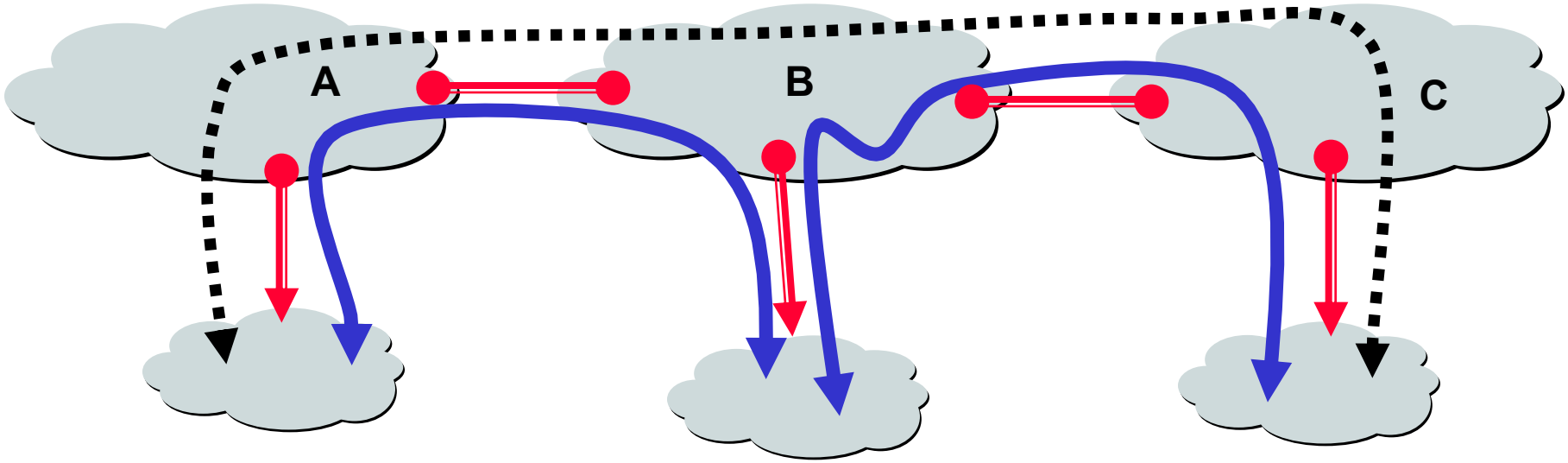


Customer pays provider for access to the Internet

Customer-Provider Hierarchy



The Peering Relationship



peer — peer

provider → customer

traffic allowed

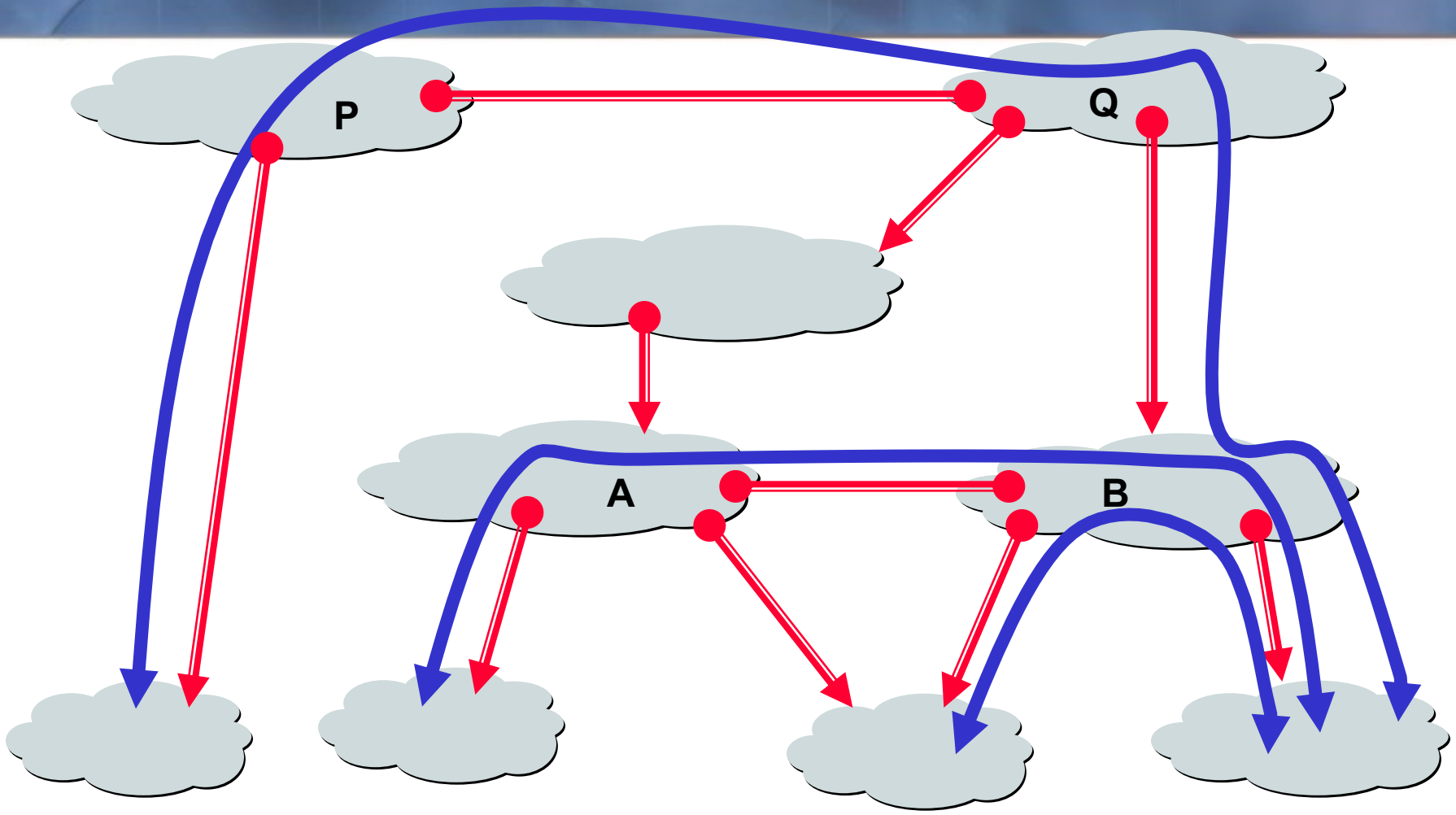
traffic NOT allowed

Peers provide transit between their respective customers

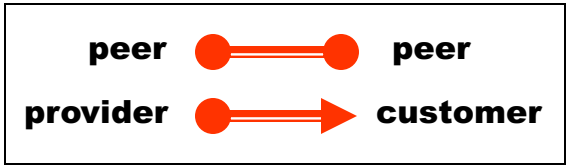
<u>Peers do not provide transit between peers</u>

Peers (often) do not exchange $$$

Peering Provides Shortcuts



Peering also allows connectivity between the customers of "Tier 1" providers.



Peering Wars

Peer

- Reduces upstream transit costs
- Can increase end-to-end performance
- May be the only way to connect your customers to some part of the Internet ("Tier 1")

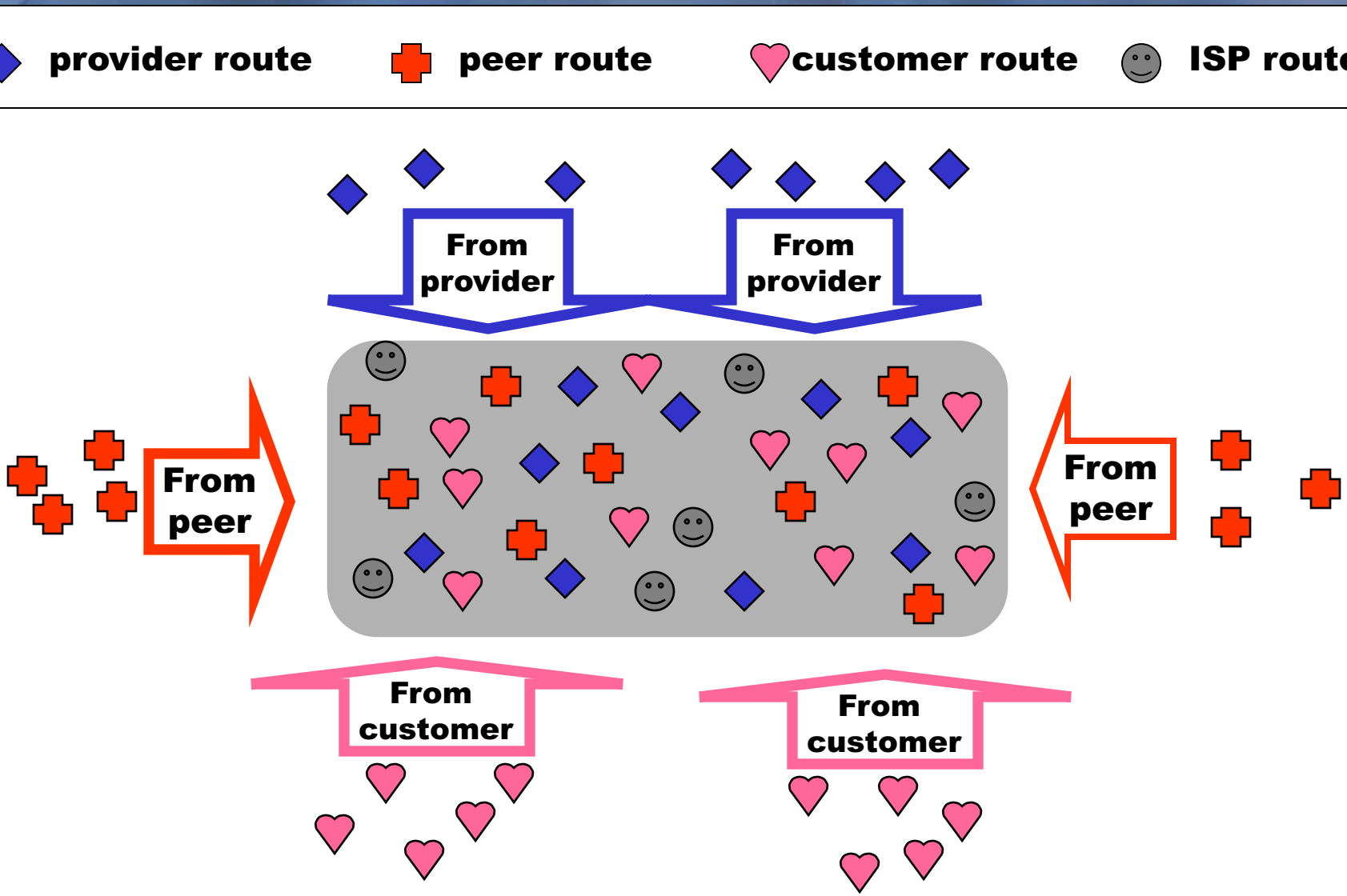
Don't Peer

- You would rather have customers
- Peers are usually your competition
- Peering relationships may require periodic renegotiation

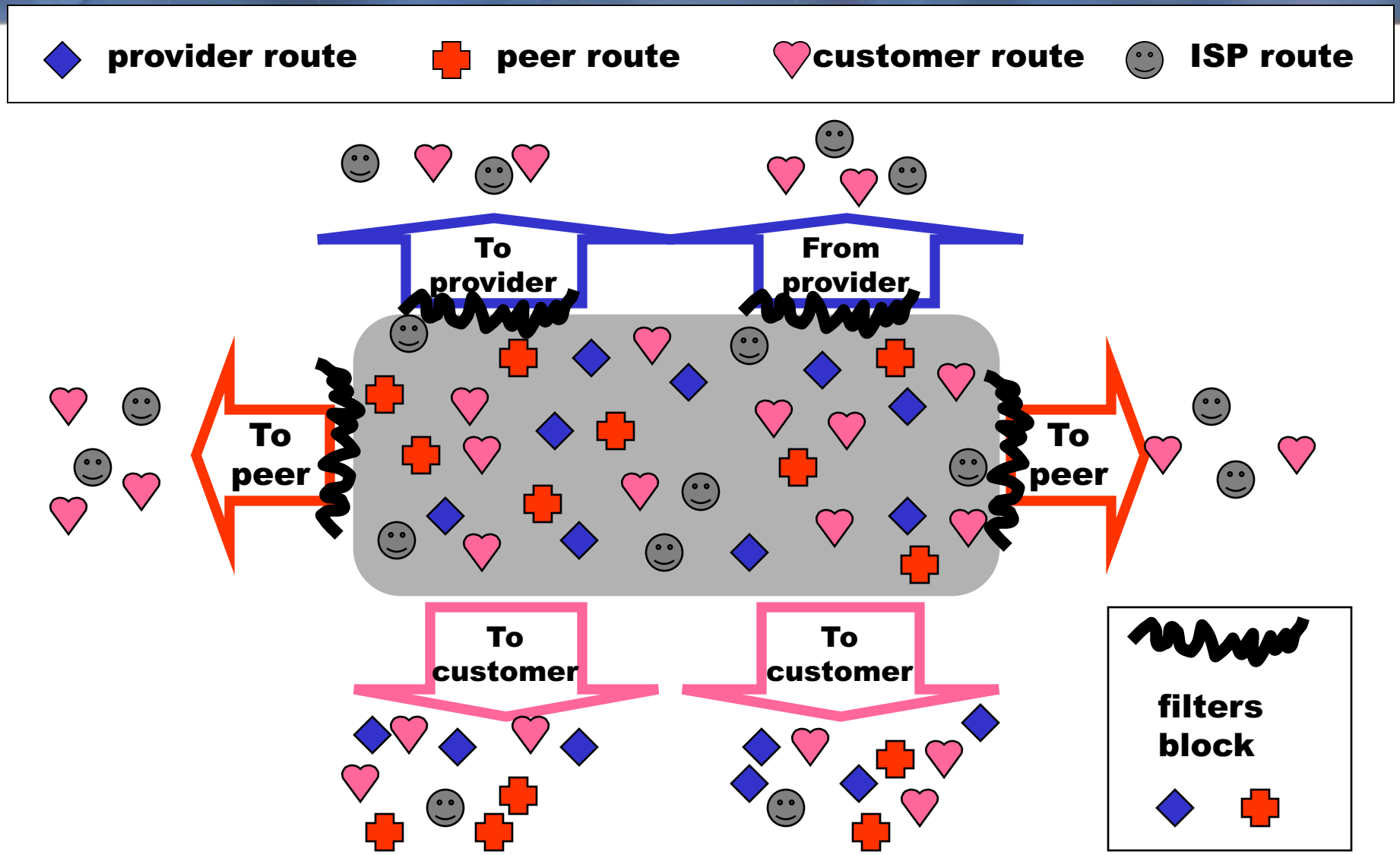
Peering struggles are by far the most contentious issues in the ISP world.

Peering agreements are often confidential.

Import Routes



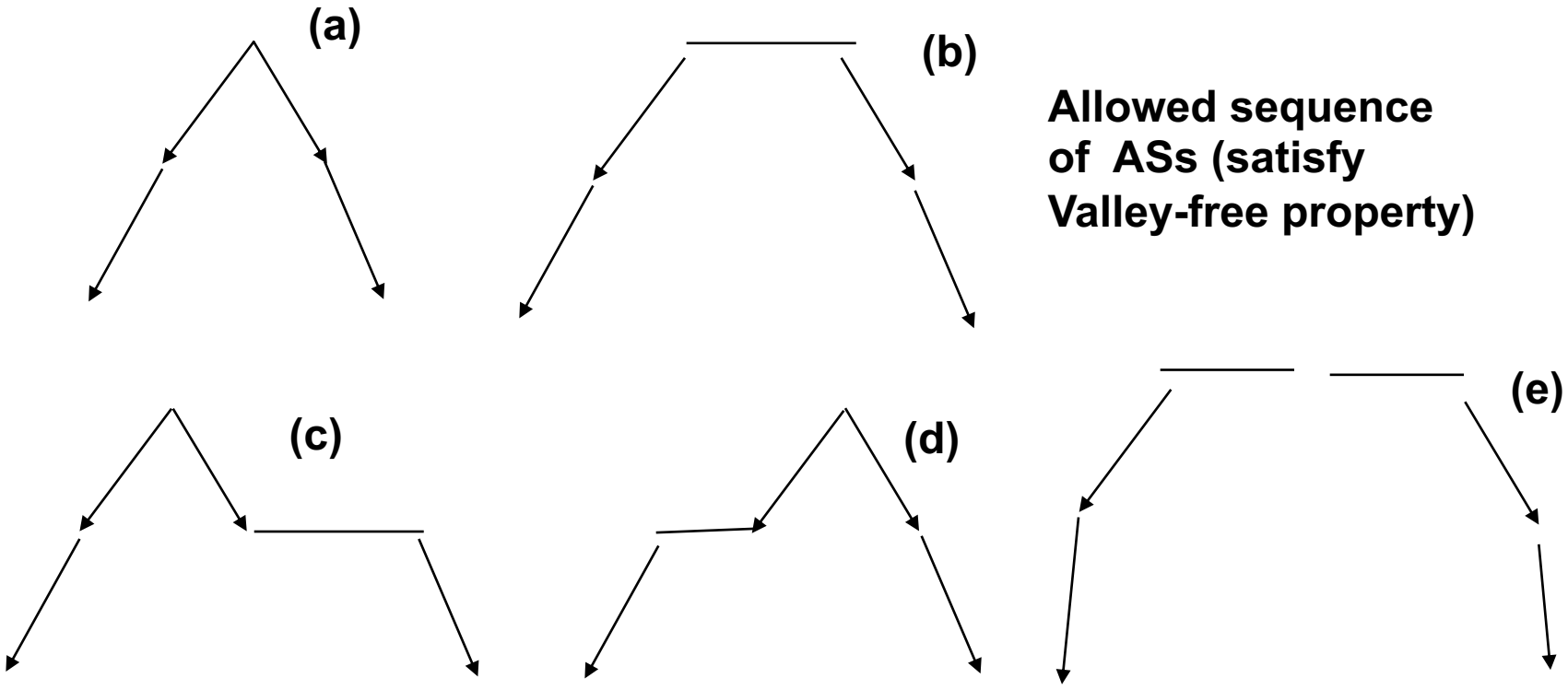
Export Routes



Valley-Free Routing

- **Valid path from one AS to another AS involves:**
  - Going through series of providers
  - Then, at most one peering relationship
  - Then, series of customers
- **Other kinds of paths are not allowed.**

Examples



Allowed sequence of ASs (satisfy Valley-free property)

Disallowed sequence of ASs (violate valley-free property

Reality of BGP in ISPs today

- **Not simple path-vector protocol**
- **Tons of mechanisms**
  - Conflict/overlap in unpredictable ways
  - Complex policies, unforeseen vulnerabilities, misconfigurations
- **Comes from ISPs trying to achieve diverse goals**
  - E.g., load-balancing, traffic engineering, business relationships