CSC 525: Computer Networks

Outline

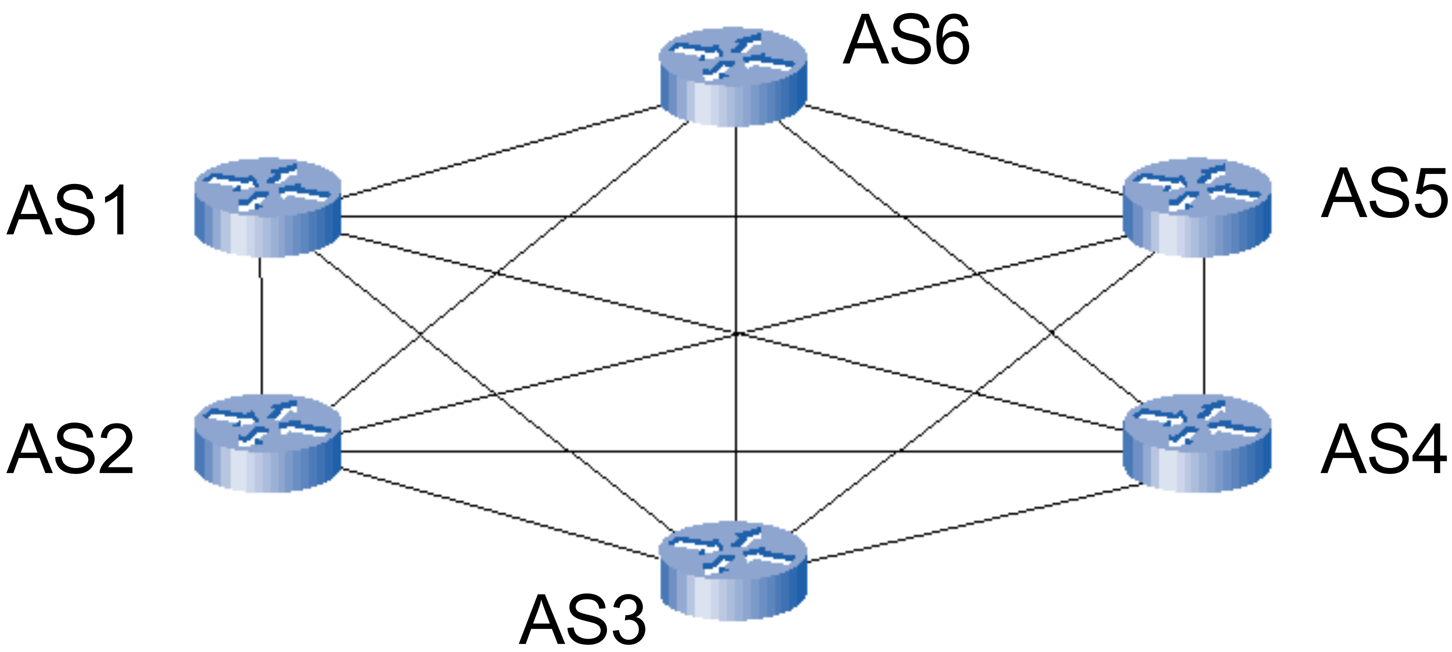
- ISP interconnection and settlement model
- AS relationship and routing policy
- Inferring AS relationship based on BGP routing paths

ISP Interconnection

- ISPs compete with each other for customers (end users and smaller ISPs).
- ISPs have to cooperate in order to deliver data.
- Thus they must
  - Interconnect
  - Have a settlement model to share profit and/or distribute cost
  - Make routing conform to the business relationship

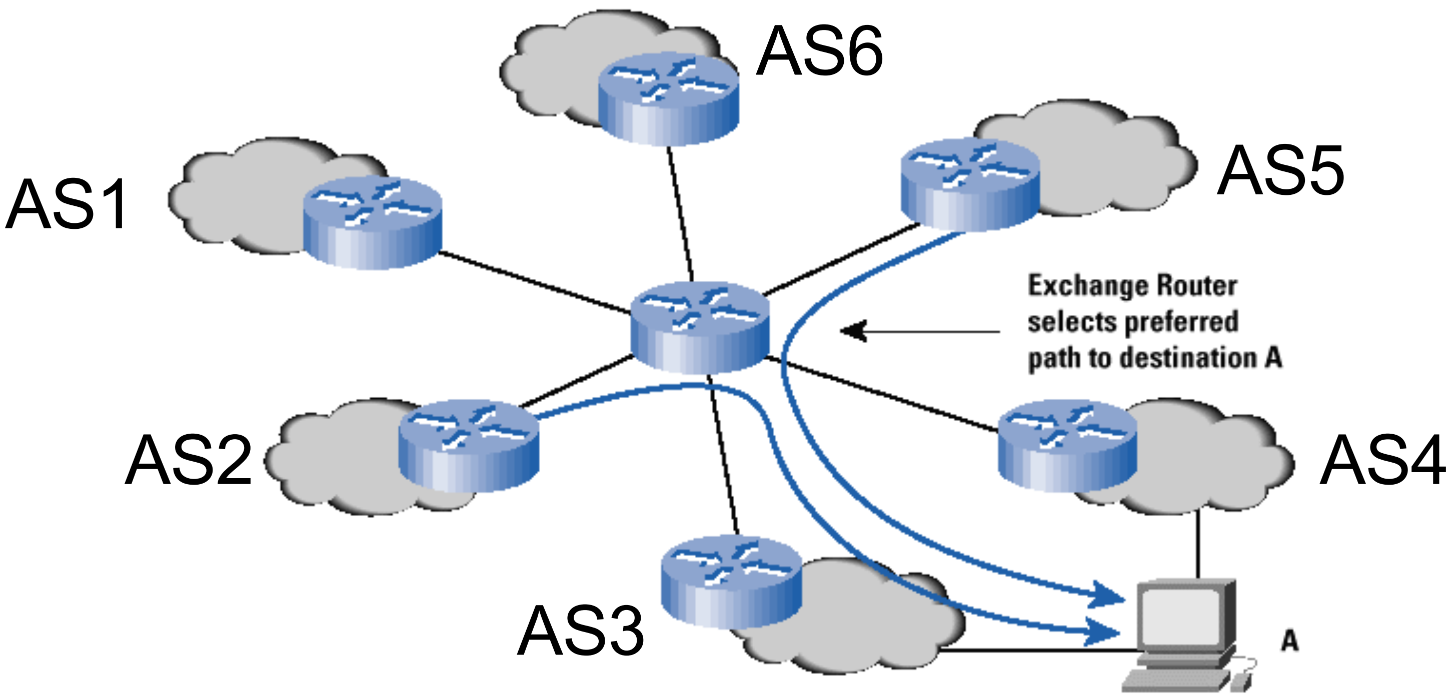
Private Links

- High cost, configuration/maintenance overhead
- Dedicated bandwidth
- You know whom to call when there's a problem



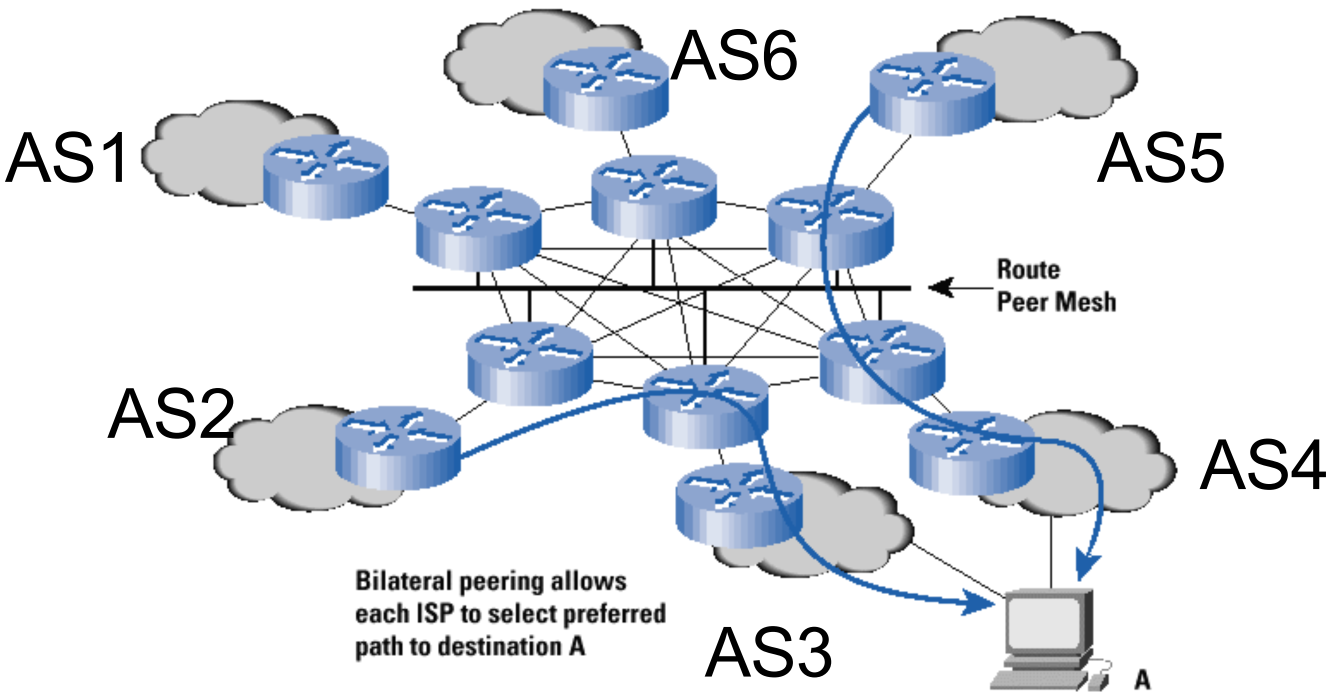
Exchange Router

- An exchange router provided by a neutral party (Internet Exchange Point, IXP) connects with every participating ISP.
- Rely on the exchange router for routing decision.

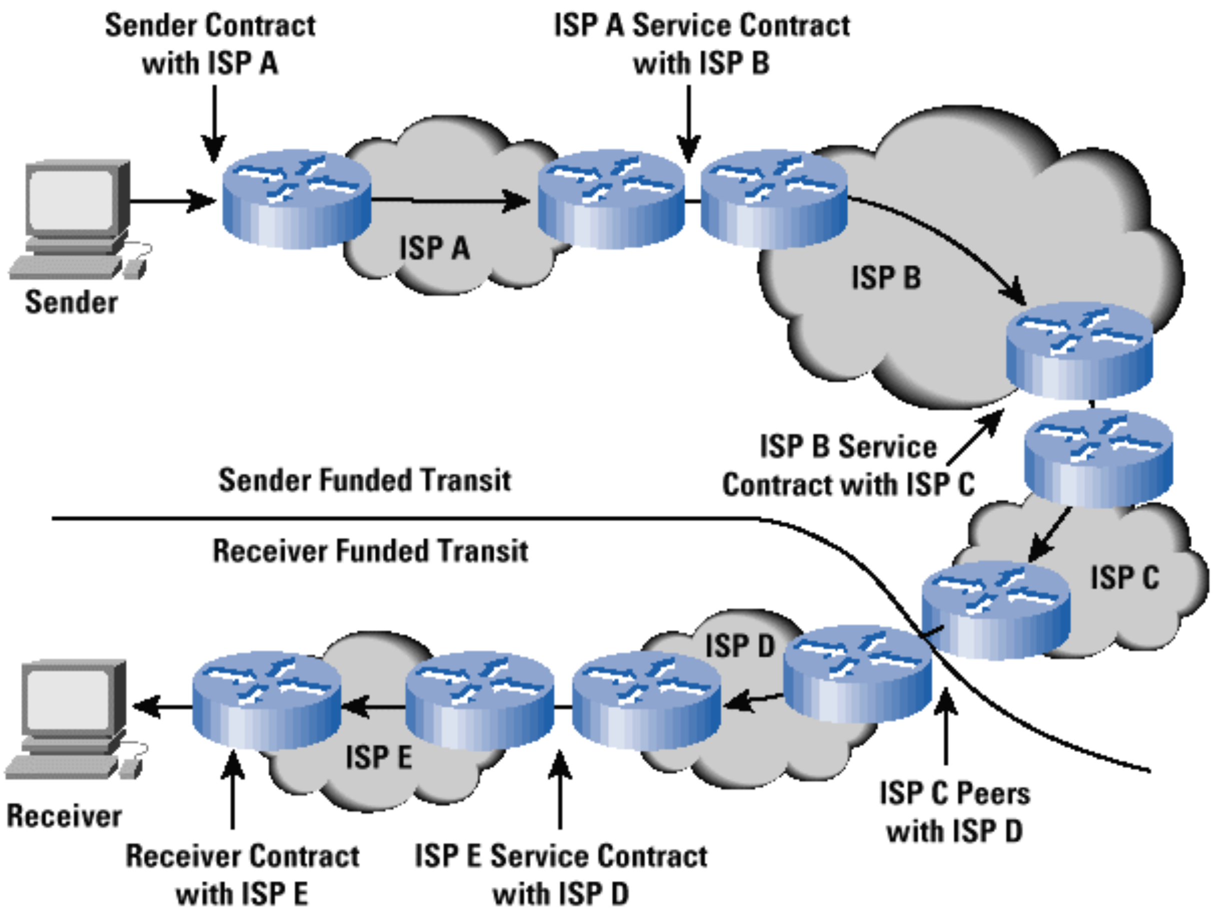


Exchange LAN

- Use Gigabit Ethernet to provide the physical connectivity
- Up to individual ISPs to decide whether to establish BGP sessions between them or not.
- Exchange LAN and private links are common in practice.



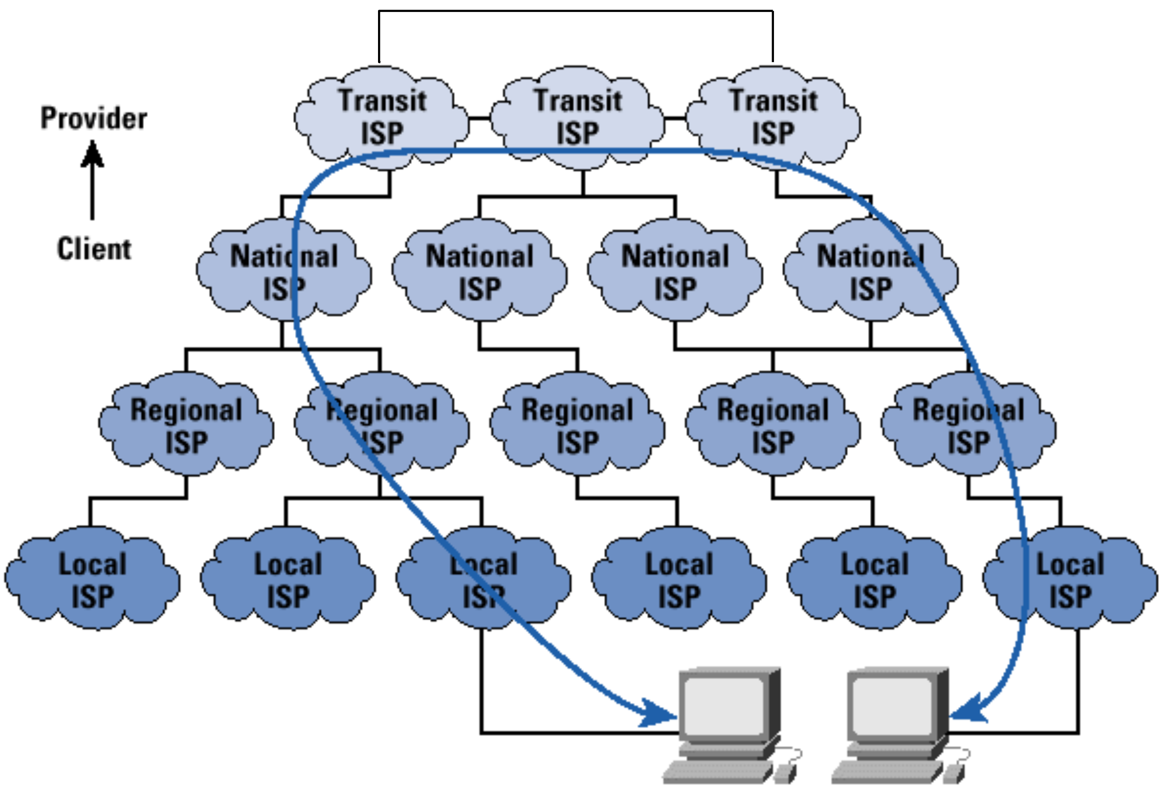
Financial Settlement



- Telephony: originator pays the entire path.
- Internet: sender and receiver each pays part of the path.
  - Customer pays providers for transit service
  - No money change hand between peers.

Routing Hierarchy

- The top tier ISPs (a dozen or so worldwide) peer with each other in a **full-mesh** to guarantee global reachability.
- Lower-tier ISPs pay upper tier ISPs for transit service.



Peering

- In reality, some lower tier ISPs peer with each other
  - Reduce cost by bypassing providers
  - Improve data delivery performance (shorter delay to users)
- To peer or not to peer
  - A contentious issue in the ISP business
  - Potential peers are also potential customers
  - Potential peers are also competitors.
  - Trial period and periodic re-negotiation
- Large ISPs tend to have restricted peering policy, while content providers tend to have open peering policy.

AOL's Settlement-free Interconnection Policy

- Operational requirements on a peer network
  - Handle a single-node outage w/o traffic impact
  - Single AS number
  - Network Operations Center staffed at all times
- Backbone capacity
  - At least 10 gigabits/sec between 8 or more cities
  - Minimum peering link speed of 622 megabits/sec
- Peering locations (in U.S.)
  - At least four locations
  - Must include D.C. area, middle of country, Bay area, and NYC or Atlanta
- http://www.atdn.net/settlement_free_int.shtml

AOL's Settlement-free Interconnection Policy

- Consistent routing advertisements
  - All customer routes
  - At all peering points
  - With the same AS path length
- Address blocks
  - Routes aggregated as much as possible
  - No address blocks smaller than /24
  - Address blocks are registered (e.g., with ARIN)
- No default routing
  - Only send traffic to destinations advertised by AOL.

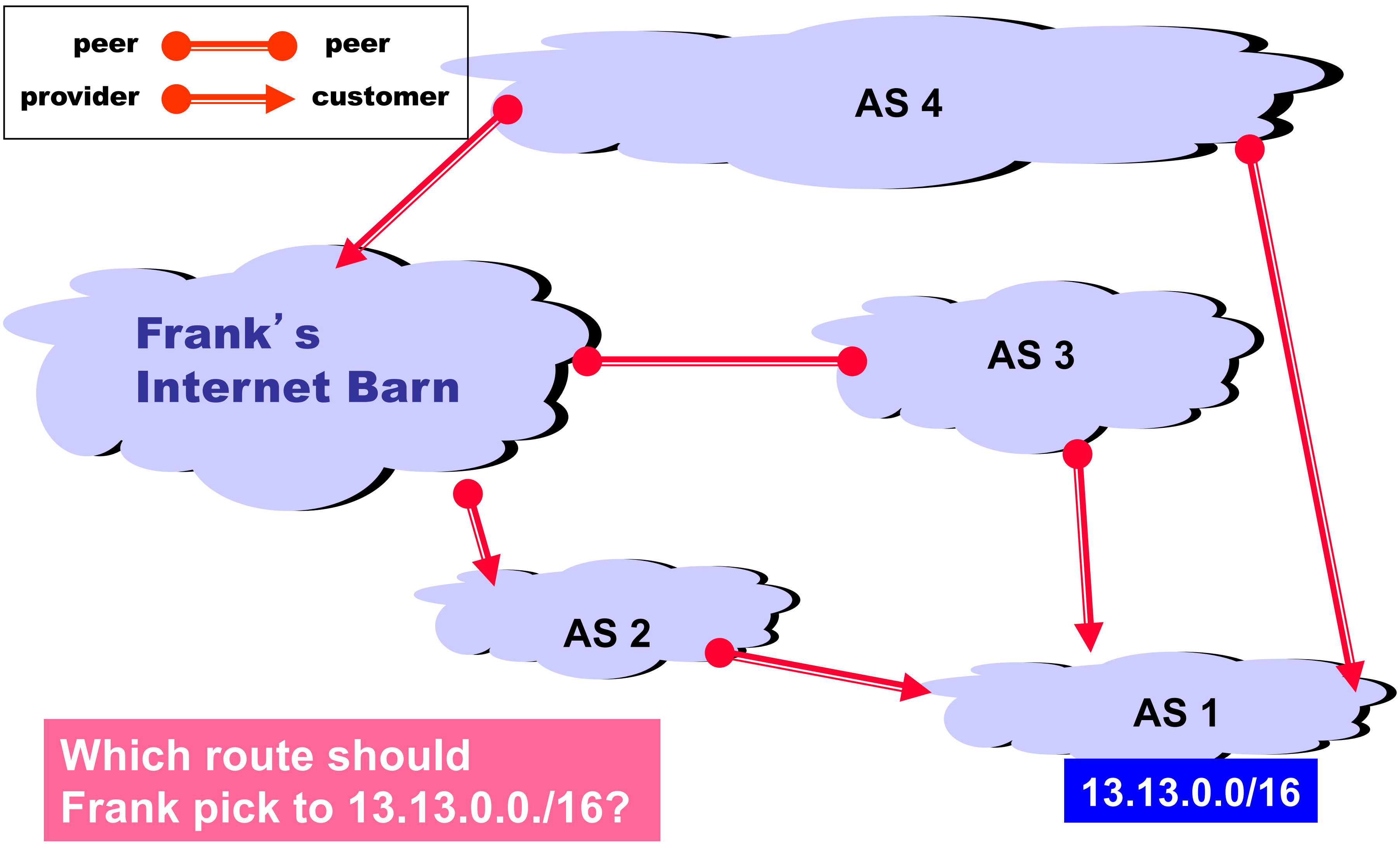
AS Relationship

- **Customer and provider**
  - Customers pay provider for the traffic
- **Peers**
  - Peers don't pay each other.
- Sibling
  - Same company but multiple ASes, merger, acquisition
  - Mutual transit service, like within the same AS
- Backup
  - Use only when the primary provider link fails
- Geography-specific or prefix-specific
  - Customer in US, but peer in Europe
- Others
  - Generally AS relationship and arrangement is confidential, and can be quite complicated.

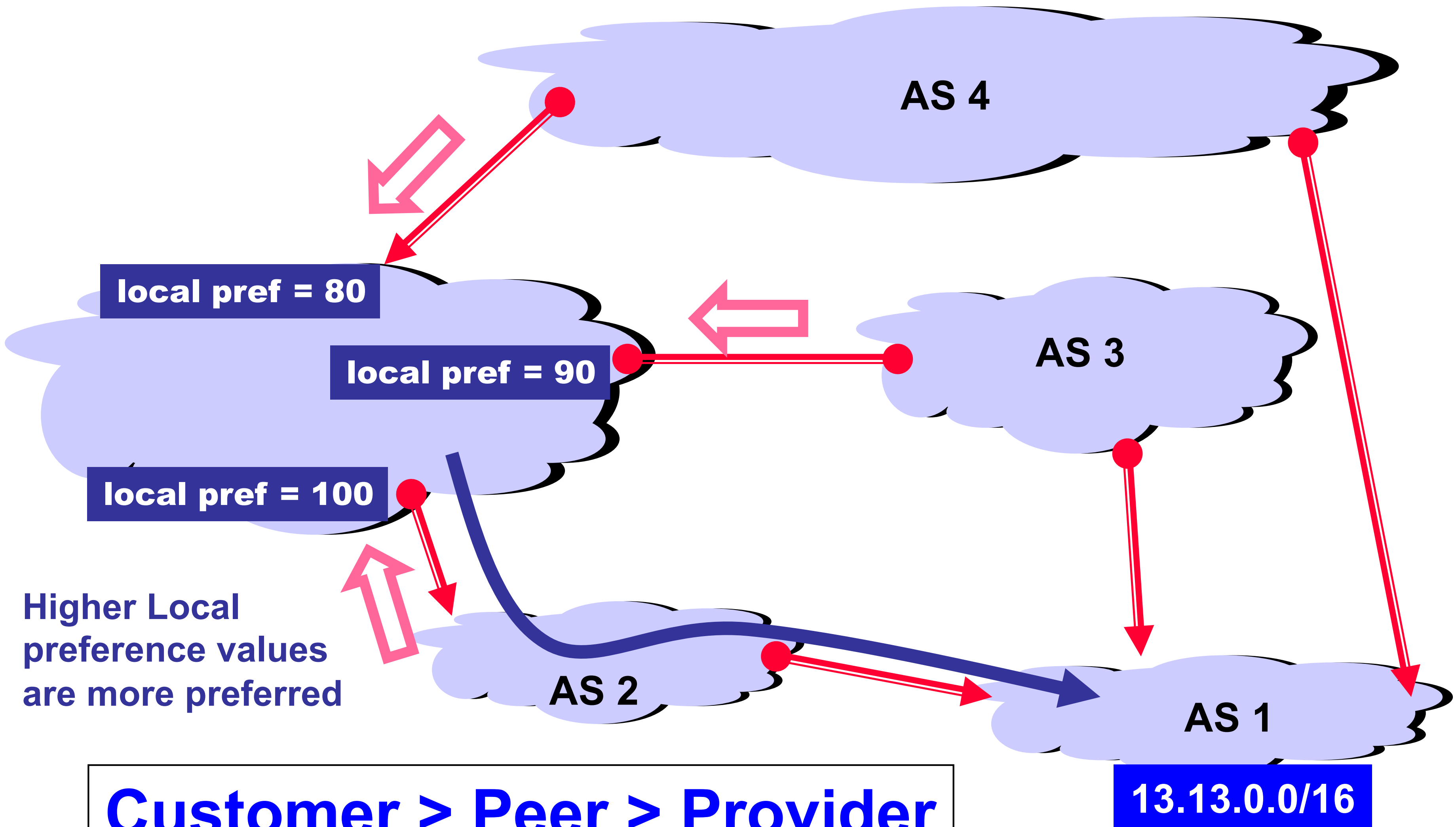
Implement AS Relationship in BGP

- ***Path selection****: which path to pick as the best path?*
  - To control *outgoing* traffic
  - Set local preference: customer > peer > provider
- ***Path export****: which path to advertise to which neighbor?*
  - To control *incoming* traffic
  - Outbound filtering of routing updates

So Many Choices



Path Selection

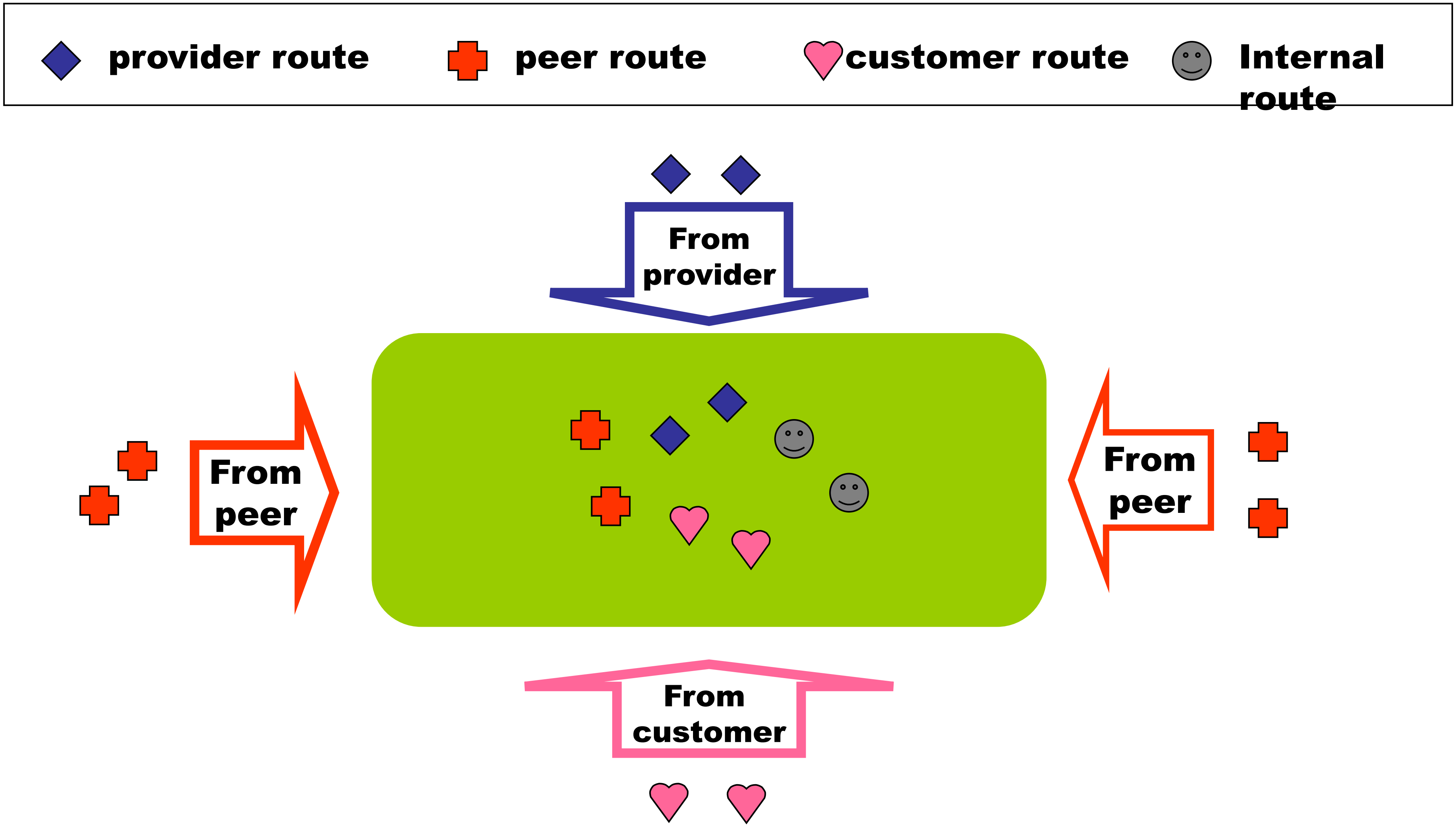


Customer > Peer > Provider

Implement AS Relationship in BGP

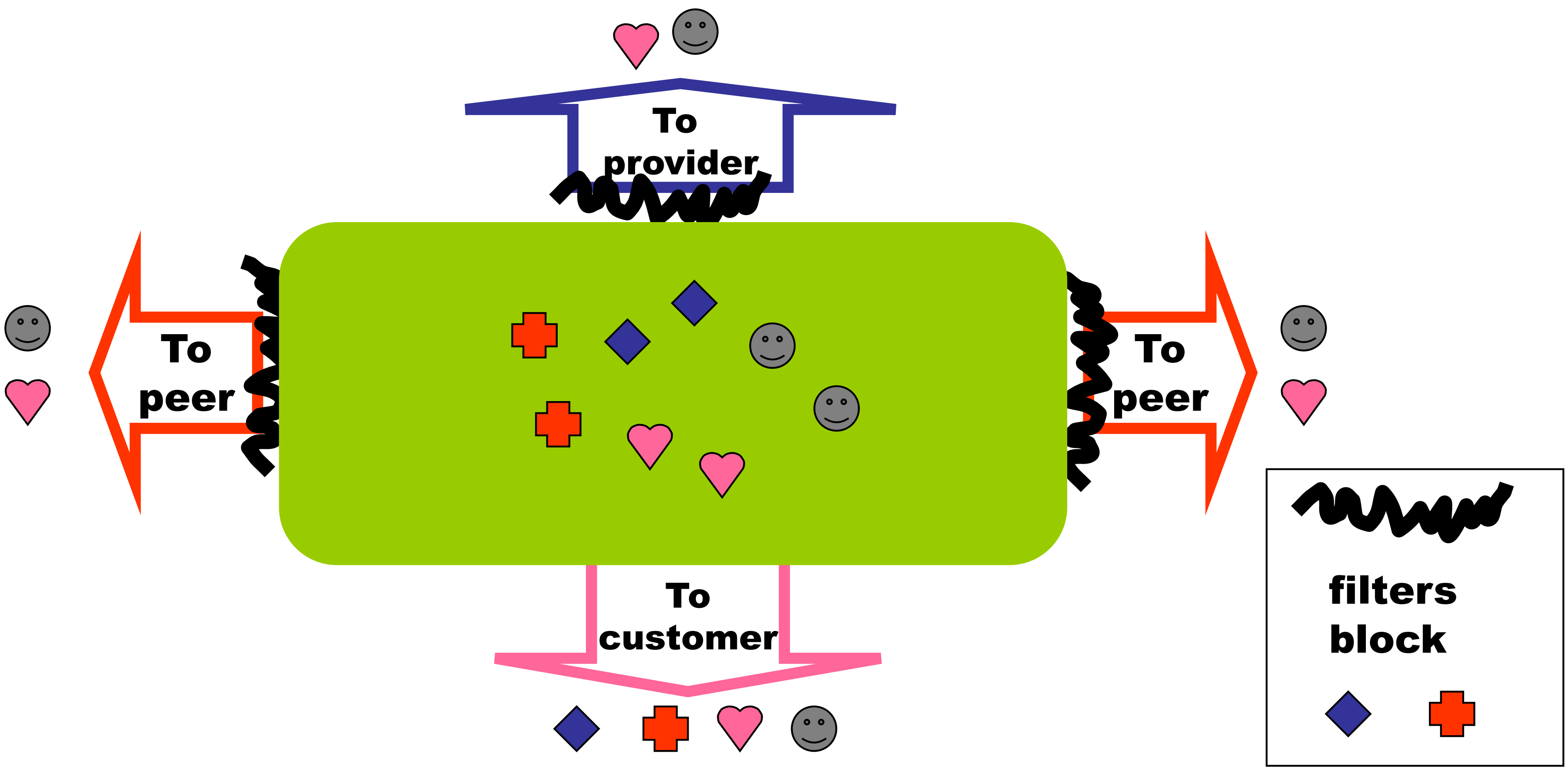
- Path selection: which path to pick as the best path?
  - To control outgoing traffic
  - Set local preference: customer > peer > provider
- *Path export: which path to advertise to which neighbor?*
  - To control incoming traffic
  - If I don't announce route to a neighbor, that neighbor will not send me traffic for that prefix.
  - Therefore need to control what routes/prefixes to announce to which neighbor.

Import Routes

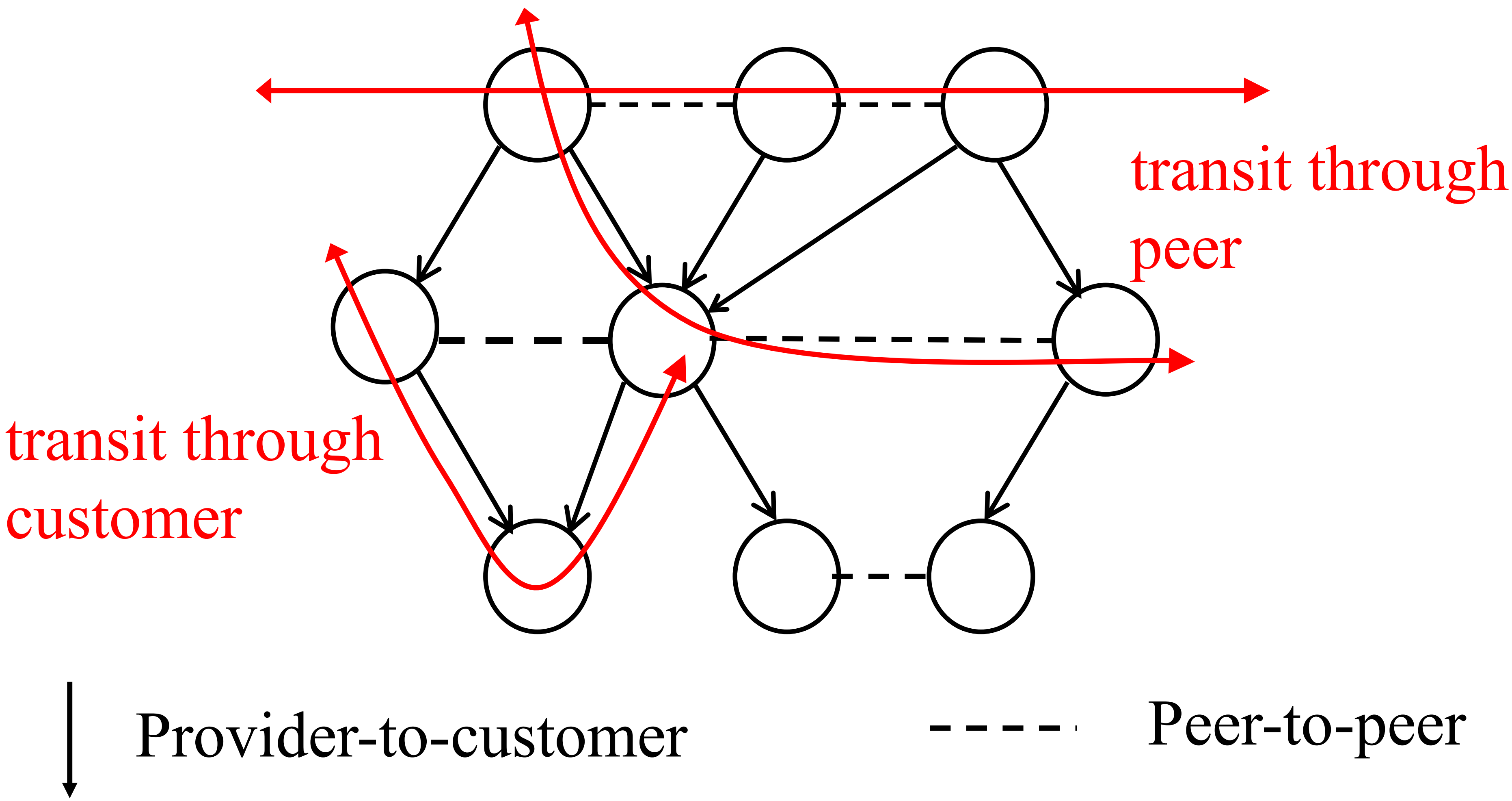


Export Routes

provider route | peer route | customer route | internal route



Paths You Should Never See ("Invalid Paths")



Pattern of Valid BGP Paths

- Uphill: a sequence of edges that are either customer-provider or sibling-to-sibling
- Downhill: a sequence of edges that are either provider-to-customer or sibling-to-sibling
- A *Valley-free* path has
  - Zero or one uphill sequence, followed by zero or one peer-peer link, followed by zero or one downhill sequence.

Why to infer AS Relationship

- Scientific understanding
  - Understanding Internet structure and evolution
  - Understanding why certain paths are used for traffic
- Placement of servers
  - Want to be close to most customer networks
- Business decisions
  - Selecting new peer or provider, or re-negotiating relations
- Security policies
  - Knowing which BGP routes are suspicious
- Analyzing BGP convergence
  - Relationships have a big impact

Type-of-Relationship Problem

- Given the input
  - AS graph *G(V,E)* with vertices *V* and edges *E*
  - Set of paths *P* on the graph *G* (from RouteViews etc)
- Find a solution that
  - Labels each edge with an AS relationship
  - Minimizes the number of "invalid" paths in *P*
- Rich area of research work
  - http://www-unix.ecs.umass.edu/~lgao/ton.ps
  - http://www.cs.princeton.edu/~jrex/papers/infocom02.pdf
  - http://www.cs.berkeley.edu/~sagarwal/research/BGP-hierarchy/
  - ...

The Basic Idea

- Need to identify the top of the hill
  - Customer-to-provider before the top
  - Provider-to-customer after the top
- Assumption:
  - higher node degree => bigger ISP => more likely to be a provider => more likely to be on the top of the hill.
  - comparable node degrees => comparable ISP sizes => more likely to be peers to each other.

Provider, Customer, Sibling

- Count every node's degree in the topology.
- Parse all BGP paths. For each path,
  - Pick the node with highest degree as the top provider
  - Assign transit service direction between every pair of neighbor ASes
- Assign relationship. Given an AS link,
  - If two ASes provide transit service for each other, they're siblings.
  - Otherwise, the one providing transit service is provider, the other is customer.

Peer

- The peer-to-peer edge is between the top provider and one of its neighbors only.
  - The neighbor with higher degree.
- The degree ratio between two peers should be no more than R times.

Result

- Provider and Customer
  - 90.5% relationships are provider-customer.
- Peer
  - 8%
  - Caveat: peer-to-peer links can only be observed by monitors at lower tiers (recall valley-free paths). We don't know how many peer-peer links are missing in the observed topology and BGP updates.
- Sibling
  - 1.5%

Verification

- With AT&T data
  - Overall 96% - 99% confirmed.
  - Most errors are at peer-to-peer edges and sibling edges
- With WHOIS data
  - Confirmed about half of the sibling edges.

Reasons for Inaccuracy

- Router Misconfiguration
  - Typo
  - Routes shouldn't be announced
- Special AS relationship
- Inaccuracy of the heuristic
  - The assumption on node degree

Summary

- Physical connectivity
  - Router level, exchange points
- BGP session
  - Logical links in AS graph
- BGP routes
  - Subject to AS relationship and policy
  - Dictate how data flow
  - Significantly less number of paths than what are physically possible.