

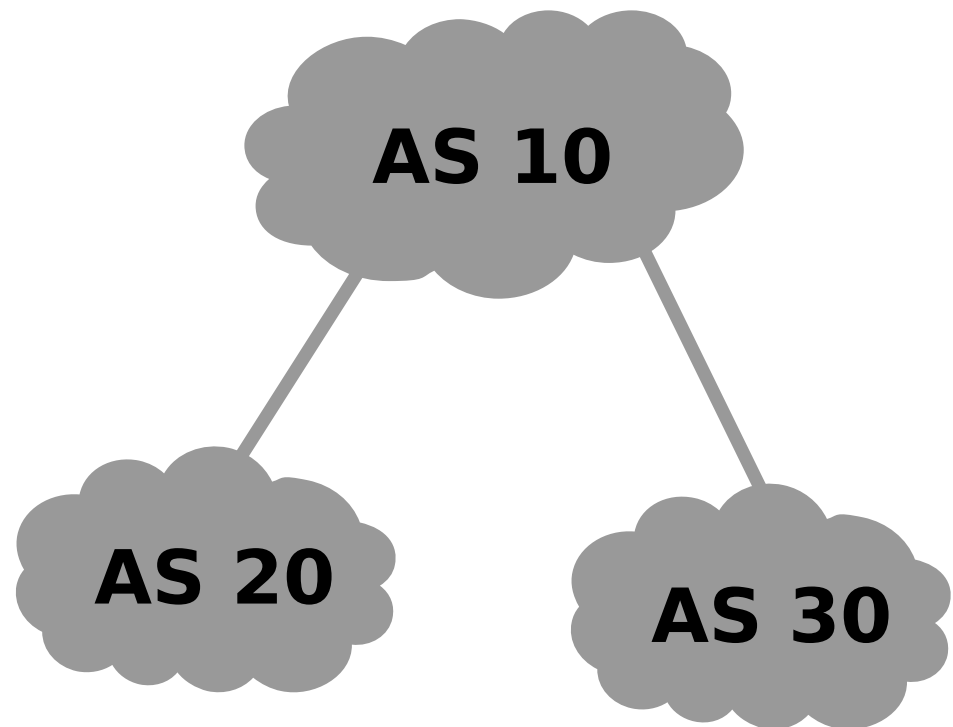
BGP Prefix Delegations: A Deep Dive

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tkrenc@inet.tu-berlin.de

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anja@inet.tu-berlin.de

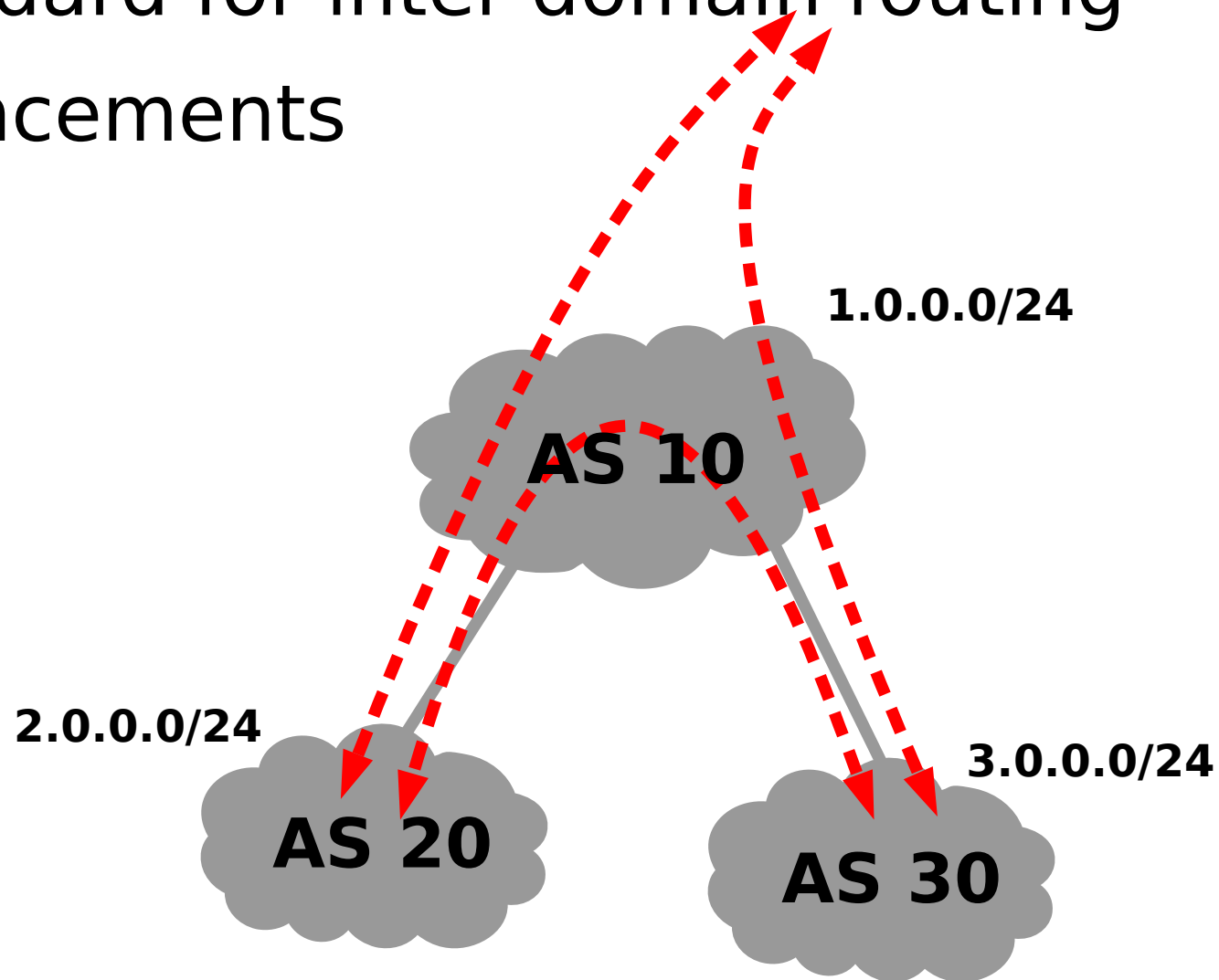
Border Gateway Protocol

- De-facto standard for inter-domain routing



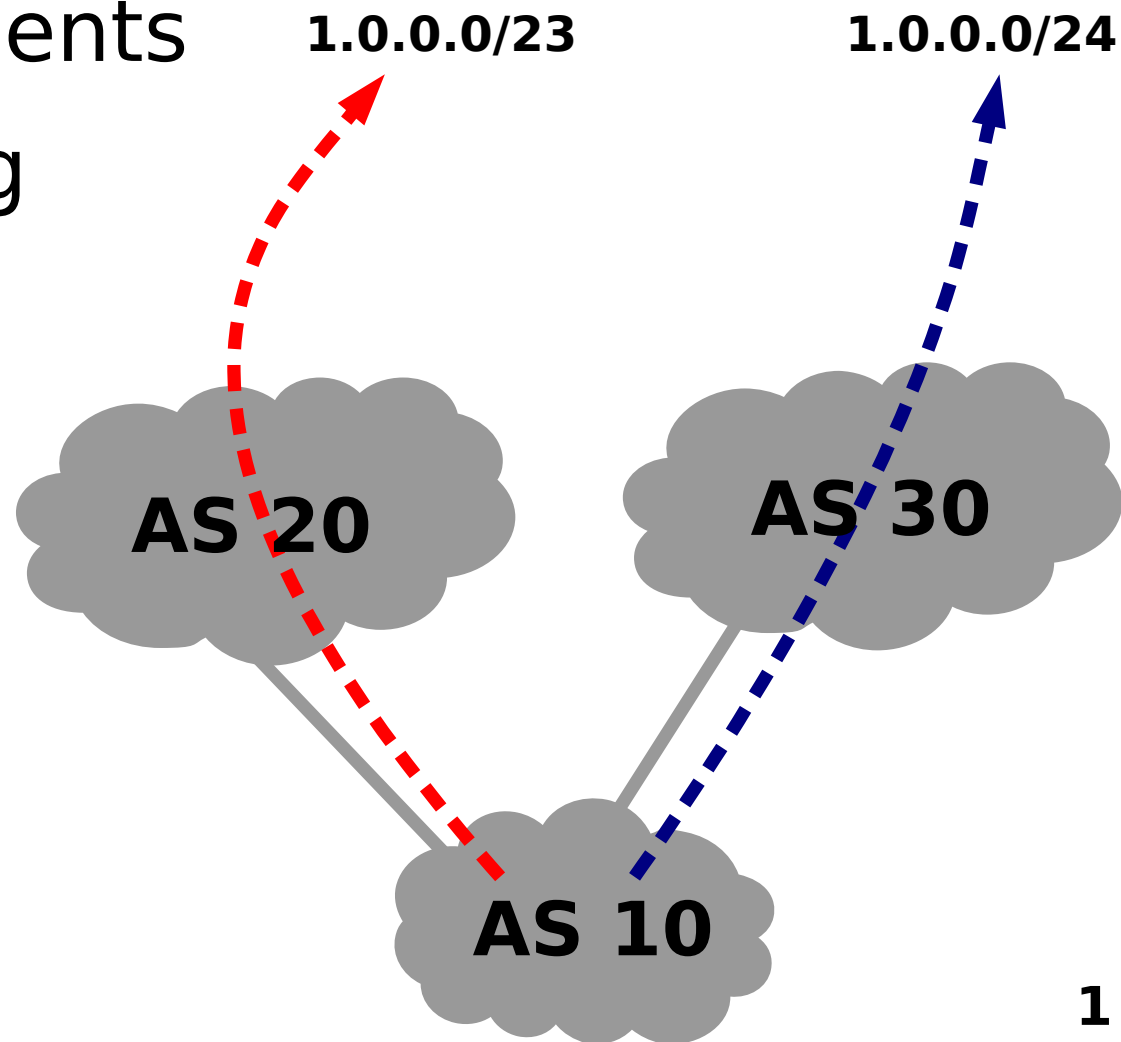
Border Gateway Protocol

- De-facto standard for inter-domain routing
- Prefix announcements

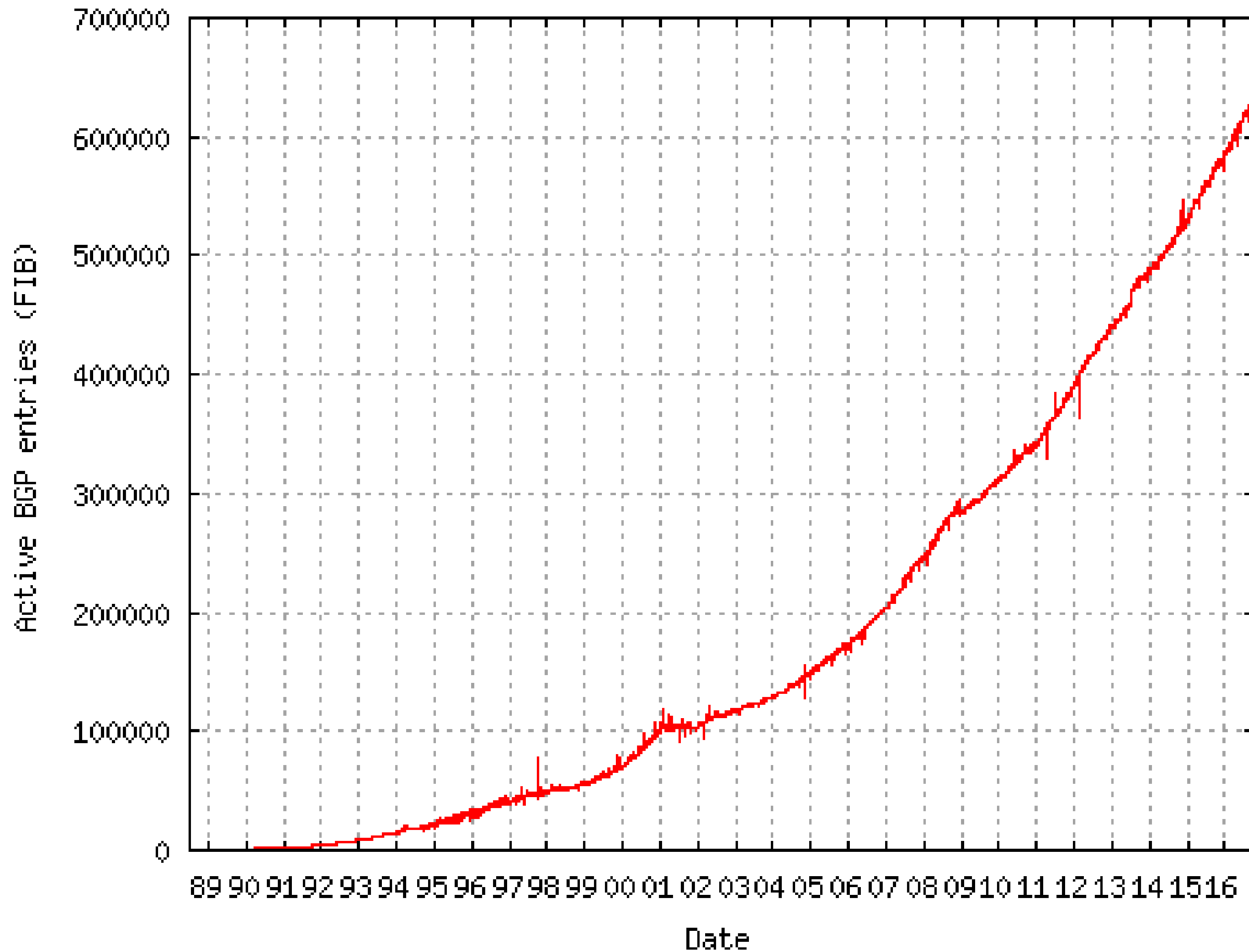


Border Gateway Protocol

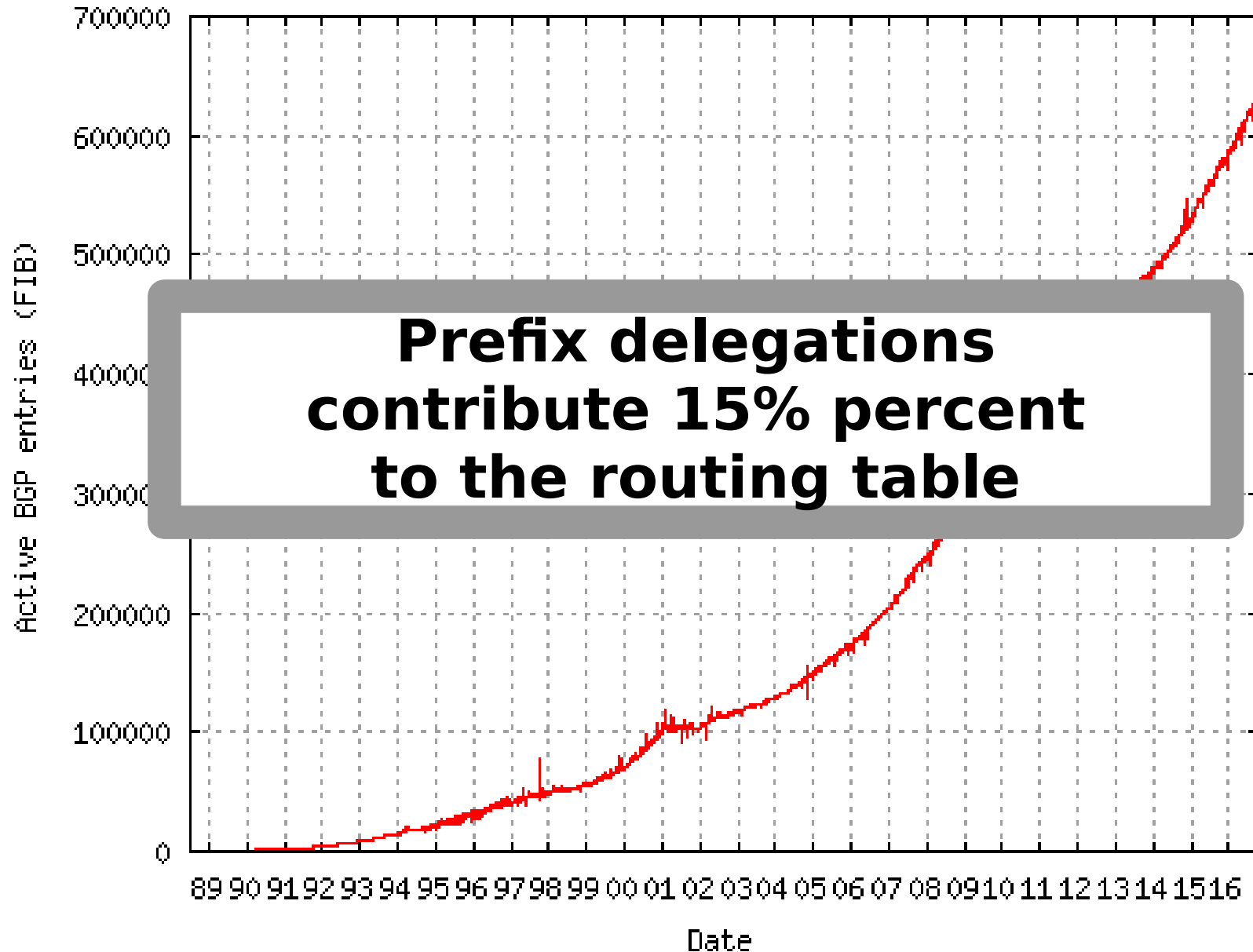
- De-facto standard for inter-domain routing
- Prefix announcements
- Traffic engineering



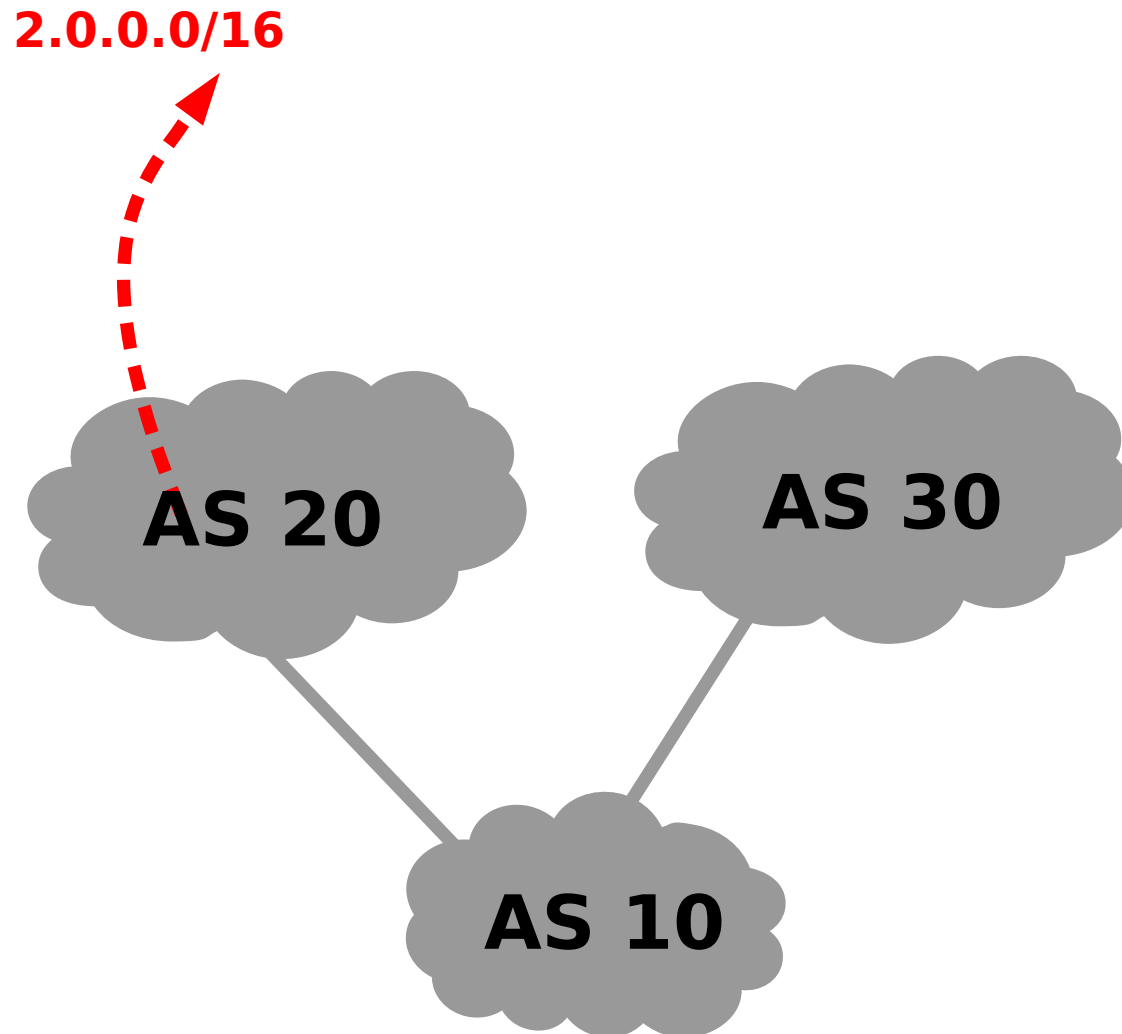
Routing Table Growth



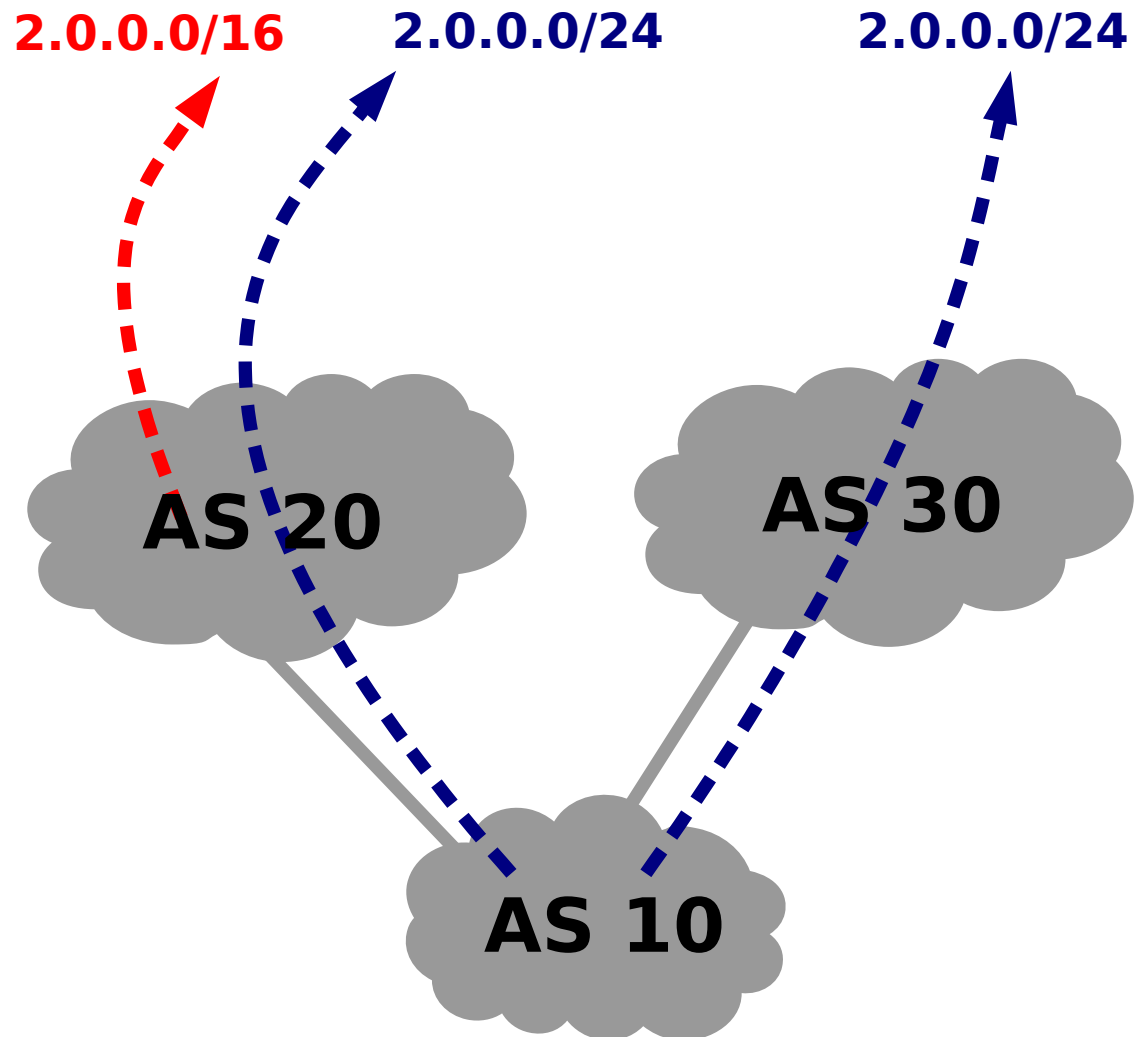
Routing Table Growth



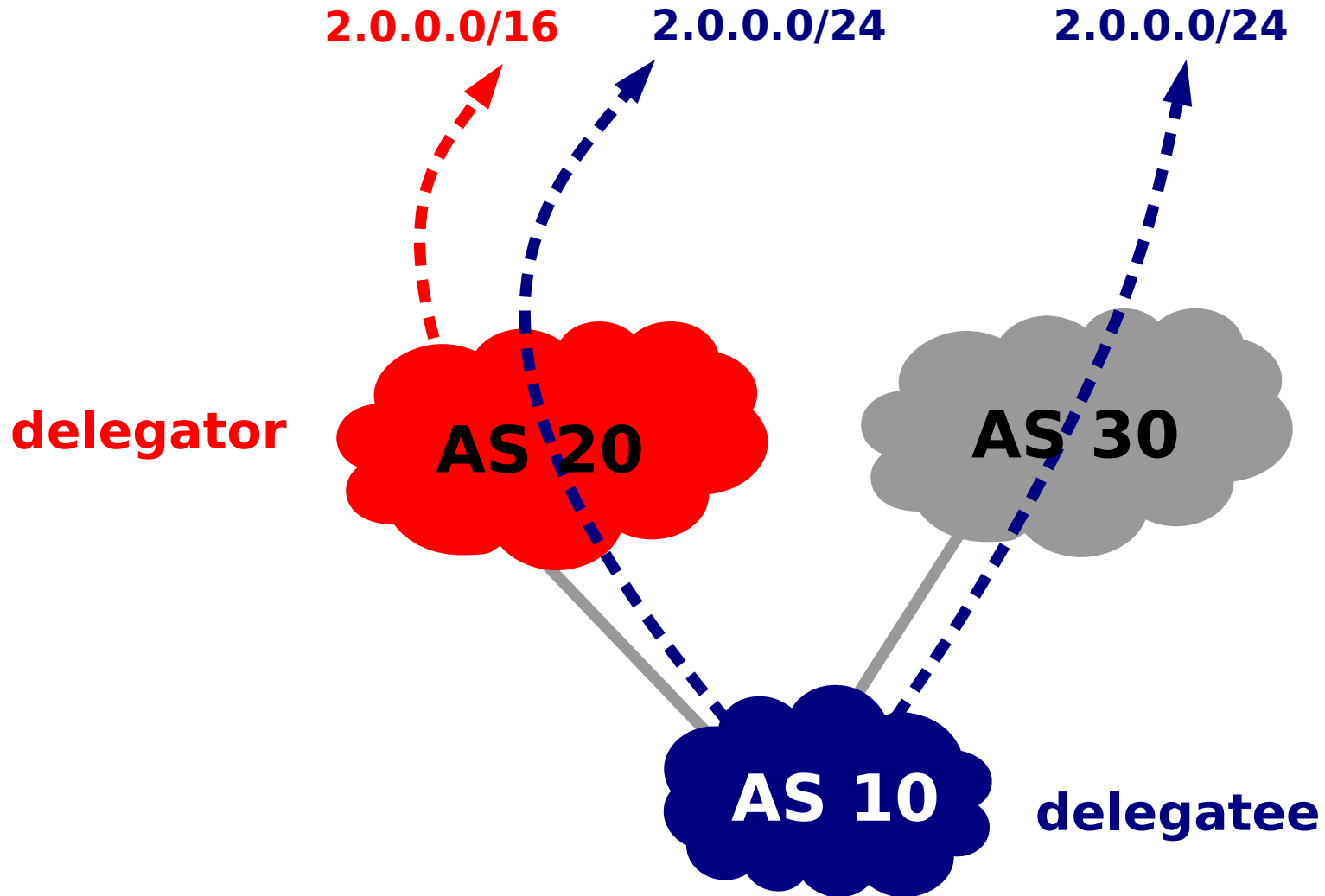
Prefix Delegations



Prefix Delegations



Prefix Delegations

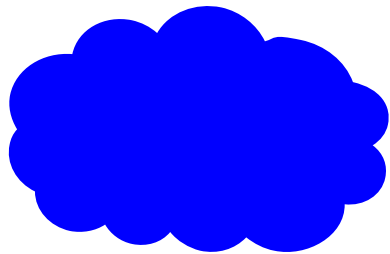
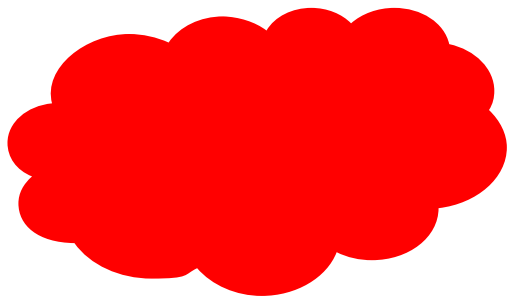


Agenda

- Tracking delegations
 - Delegation identification
 - based on overlapping prefix pairs and origin AS
 - Delegation classification
 - based on AS path information
- Understanding delegations
 - AS size and business relations
 - CAIDA customer cone and AS business relationships
 - Data plane
 - CAIDA Ark traceroutes

Delegation Identification

- Based on overlapping prefixes announced by two different ASes



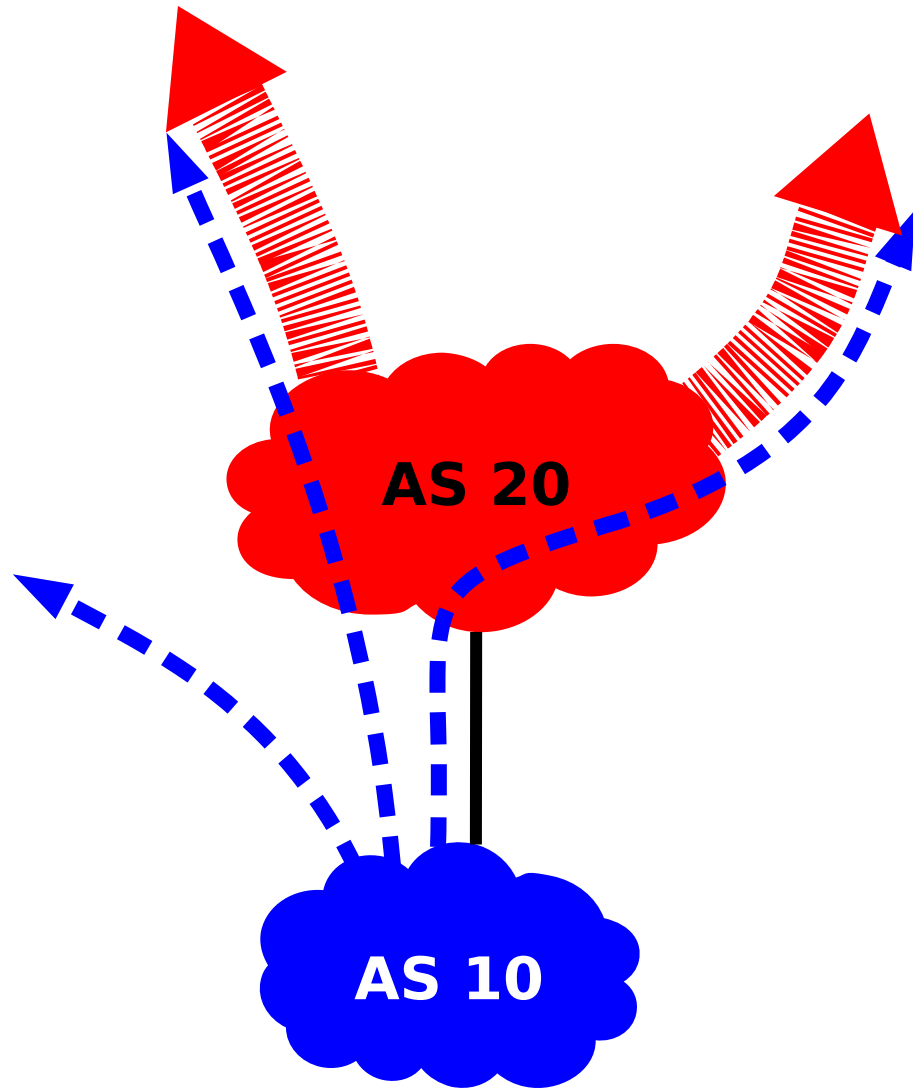
less specific:

2.0.0.0/16

more specific:

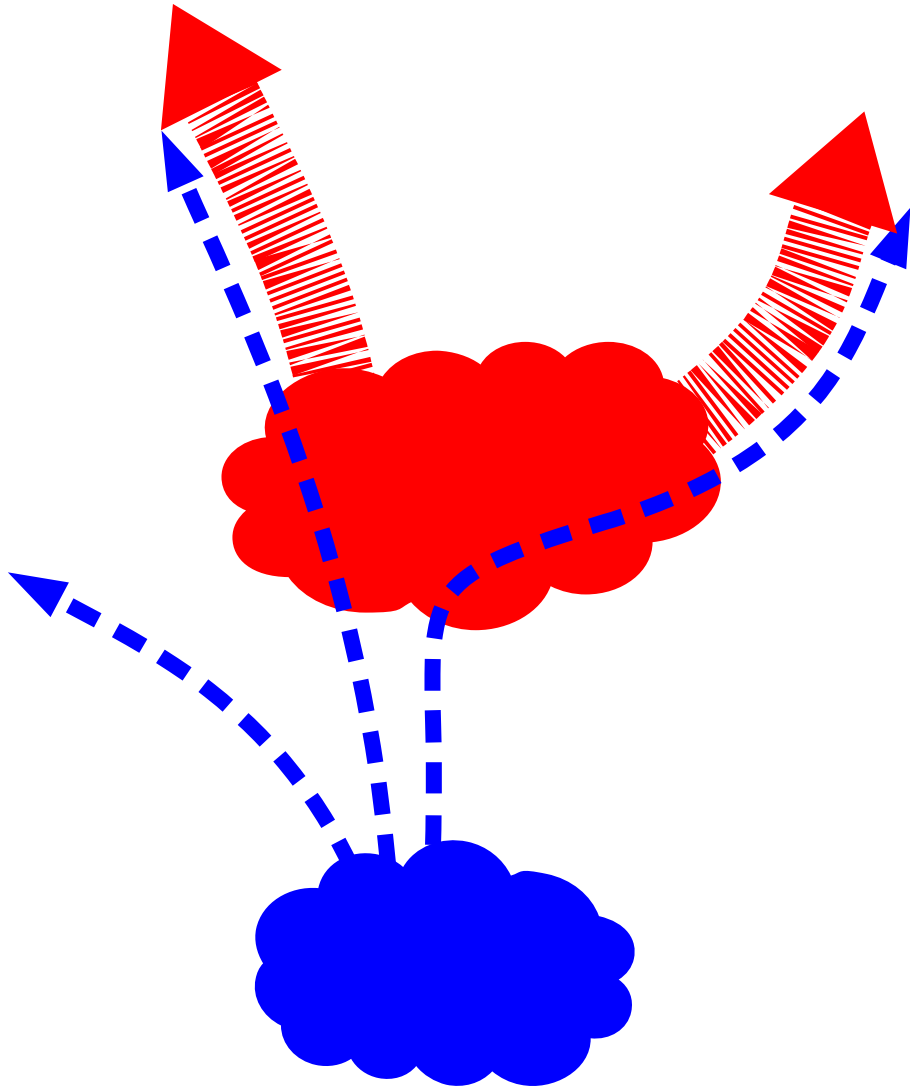
2.0.0.0/24

Delegation Classification



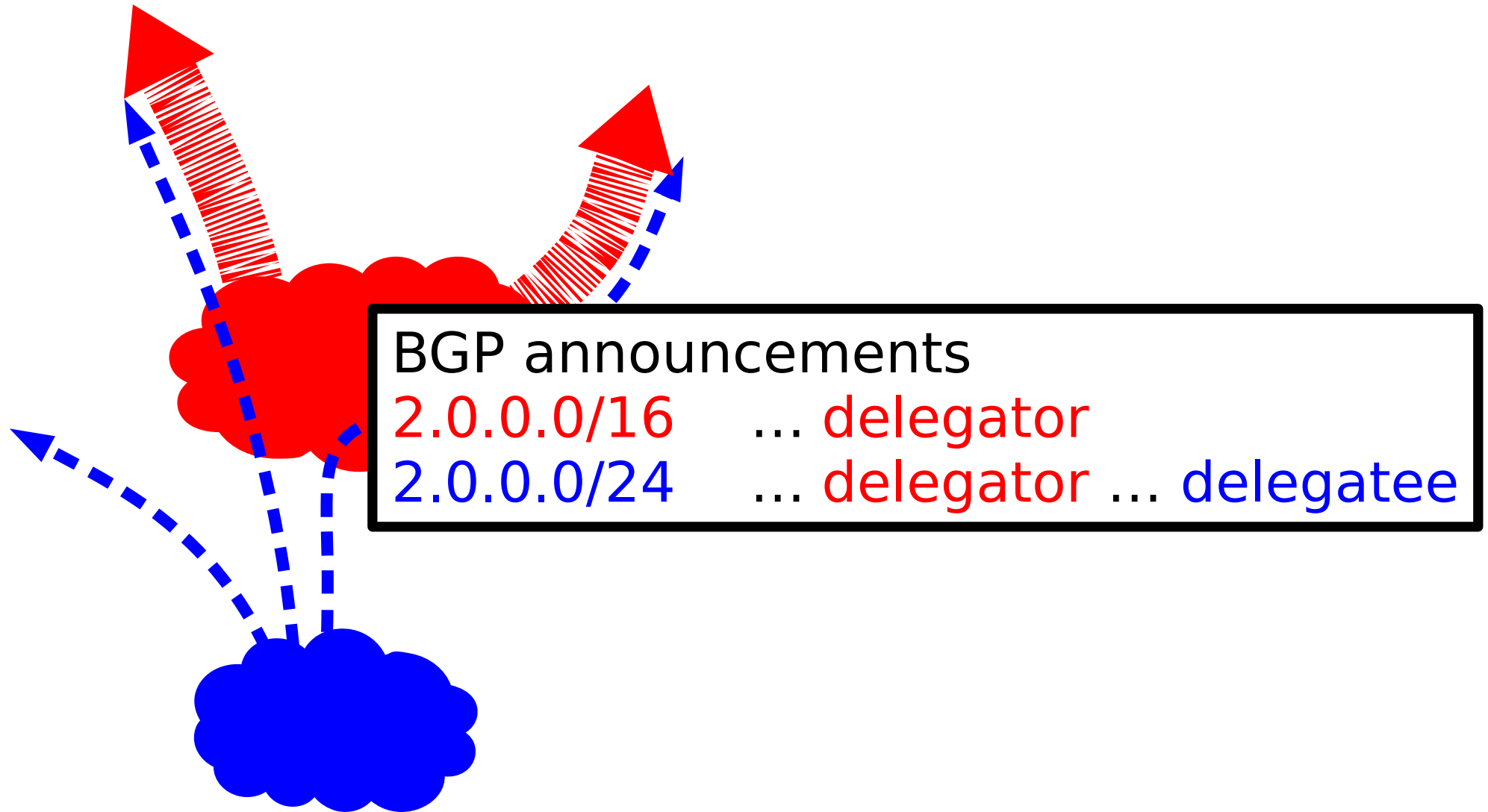
- Based on AS path information

Delegation Classification

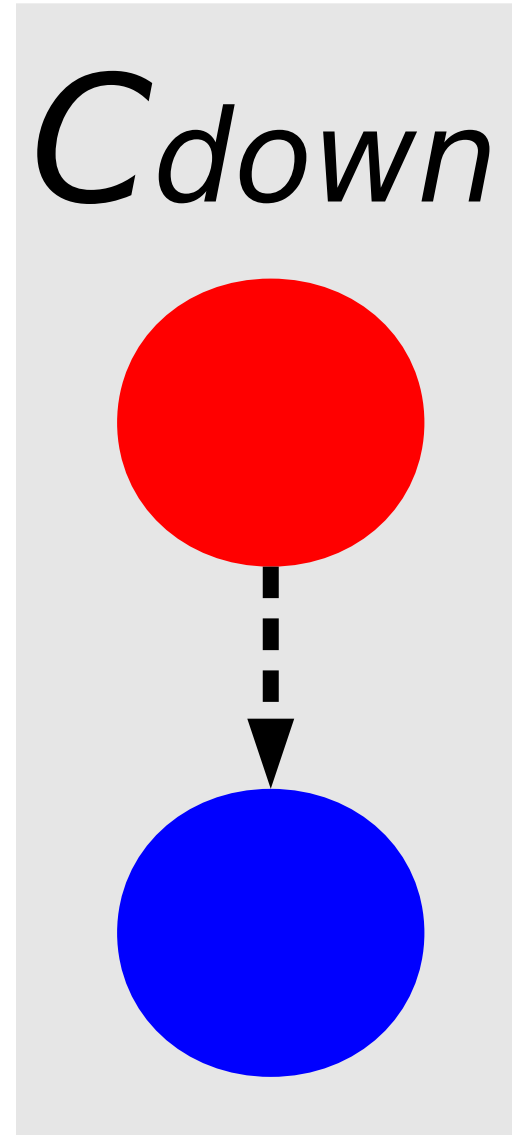
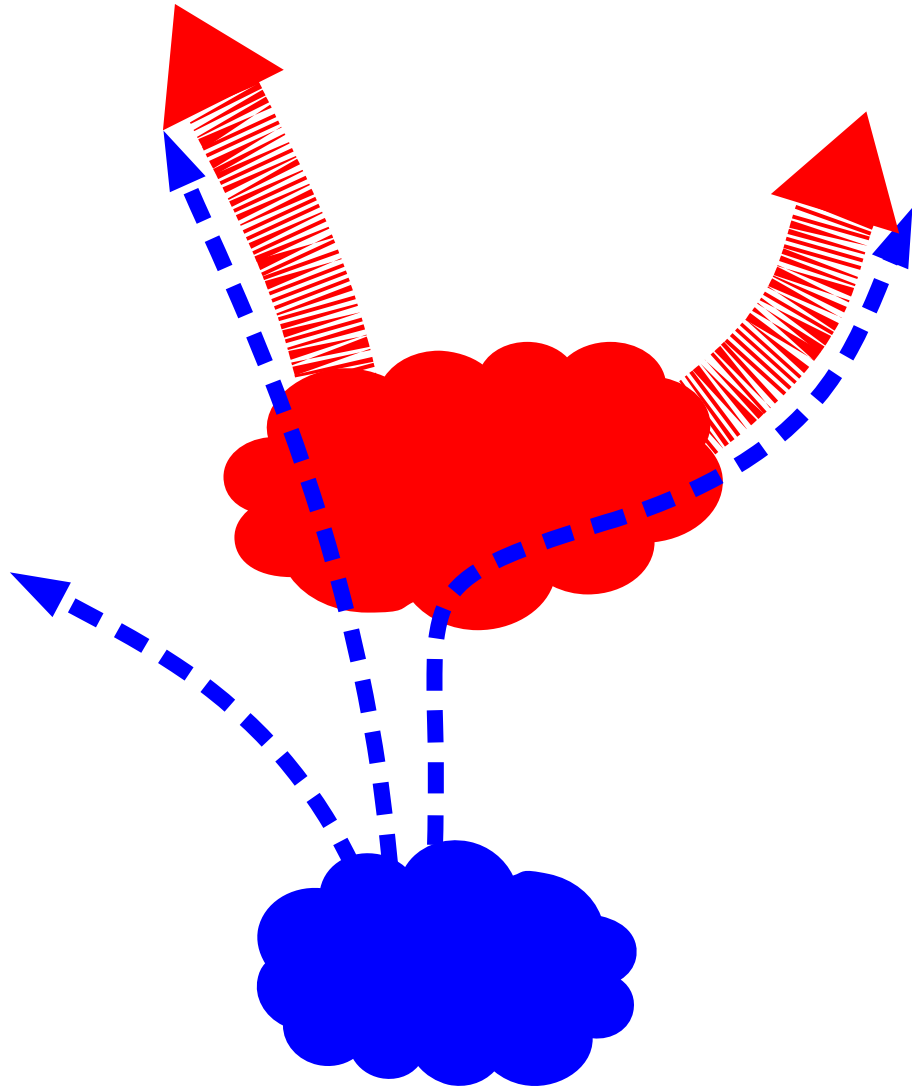


- Based on AS path information
- Agnostic to business relationships between delegator and delegatee

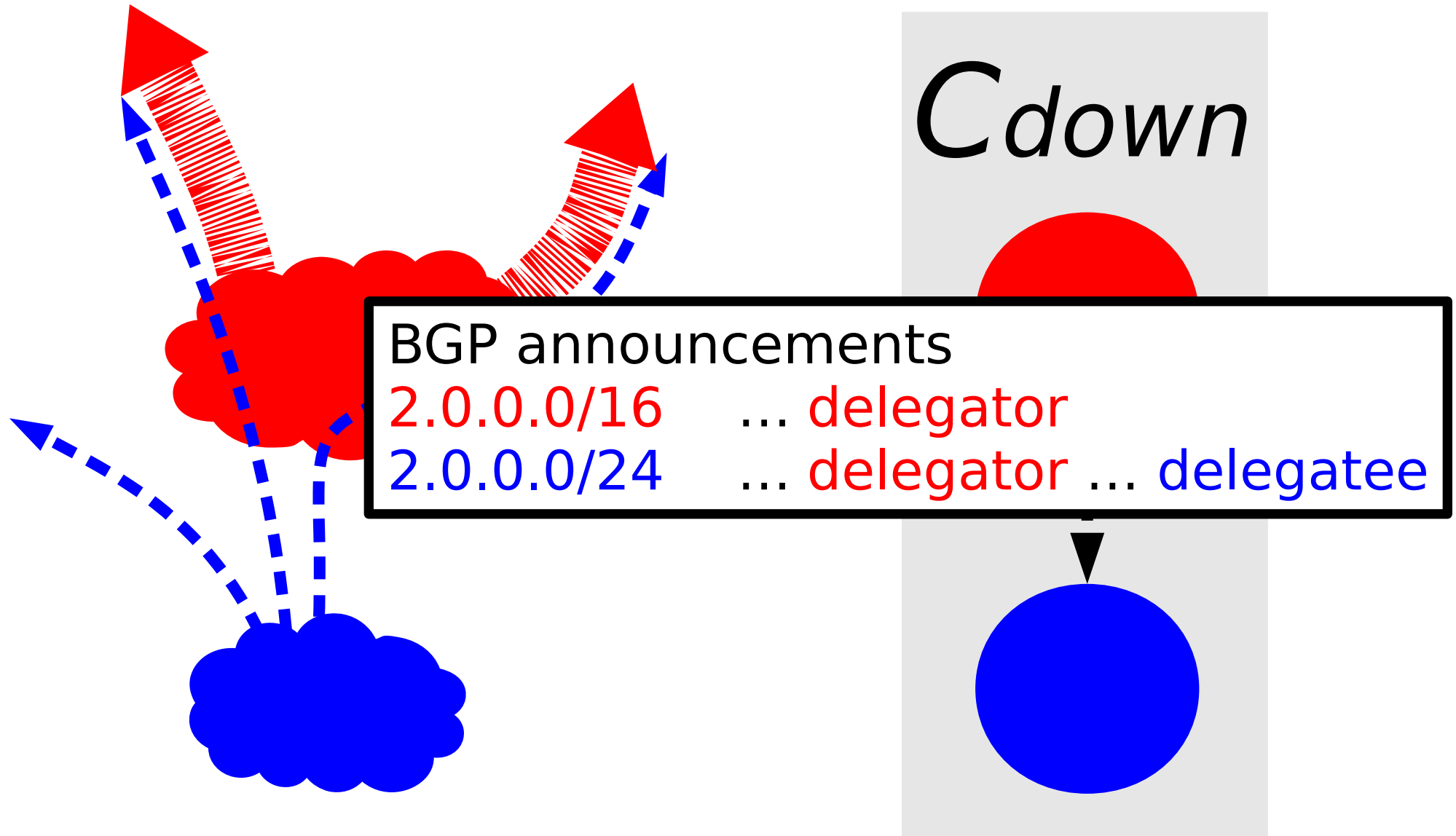
Delegation Classification



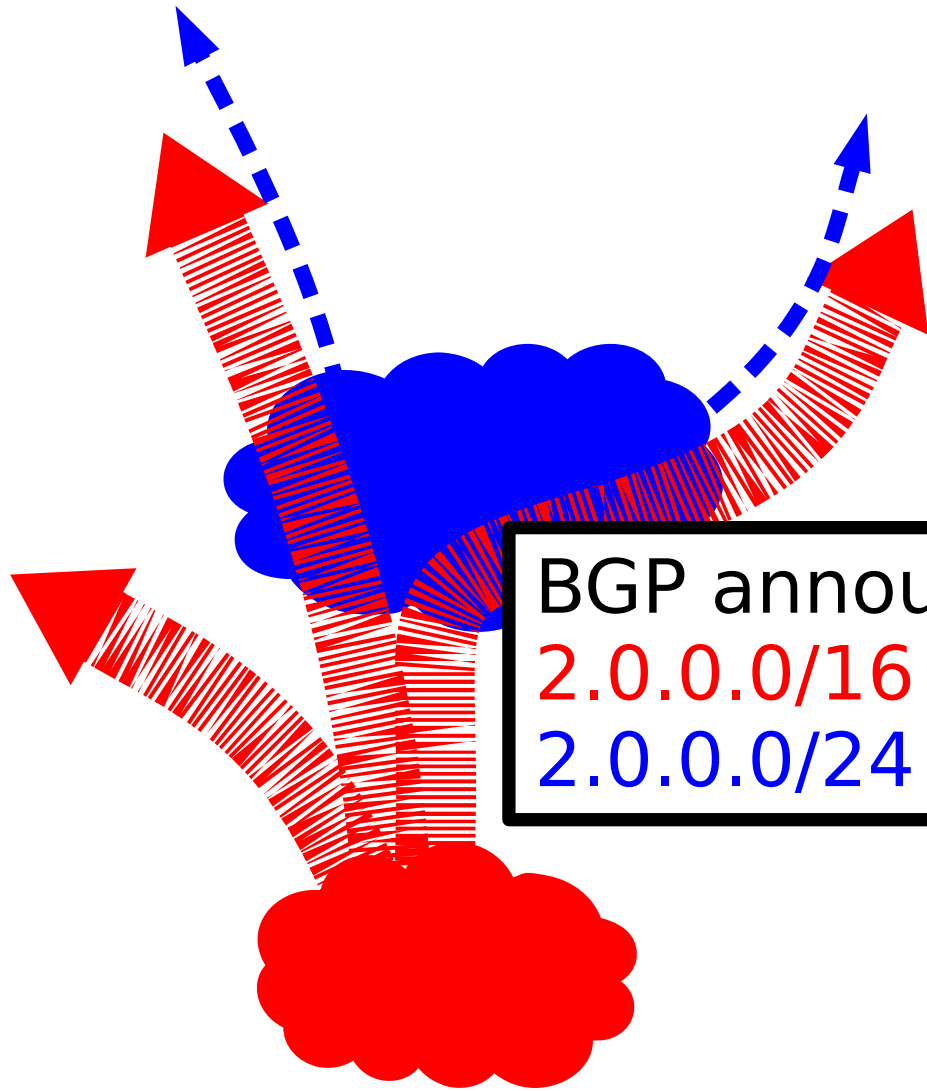
Delegation Classification



Delegation Classification



Delegation Classification

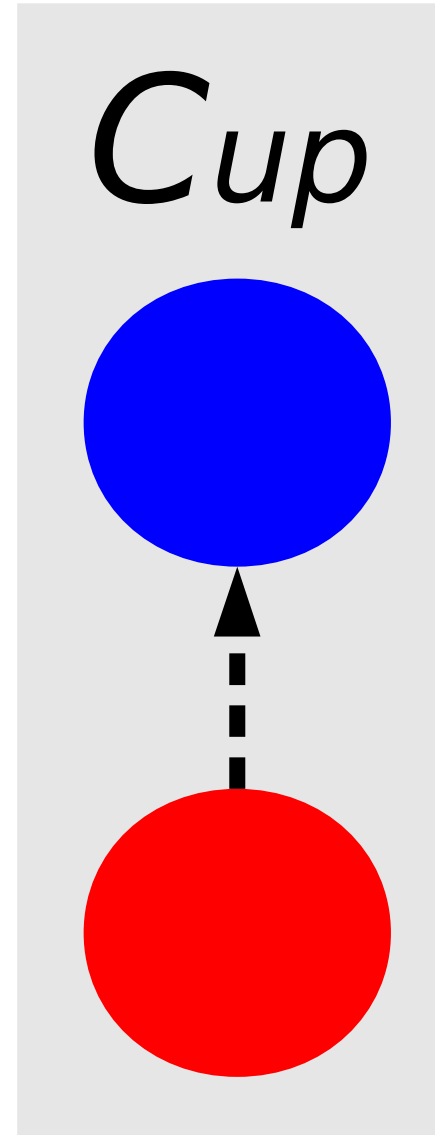
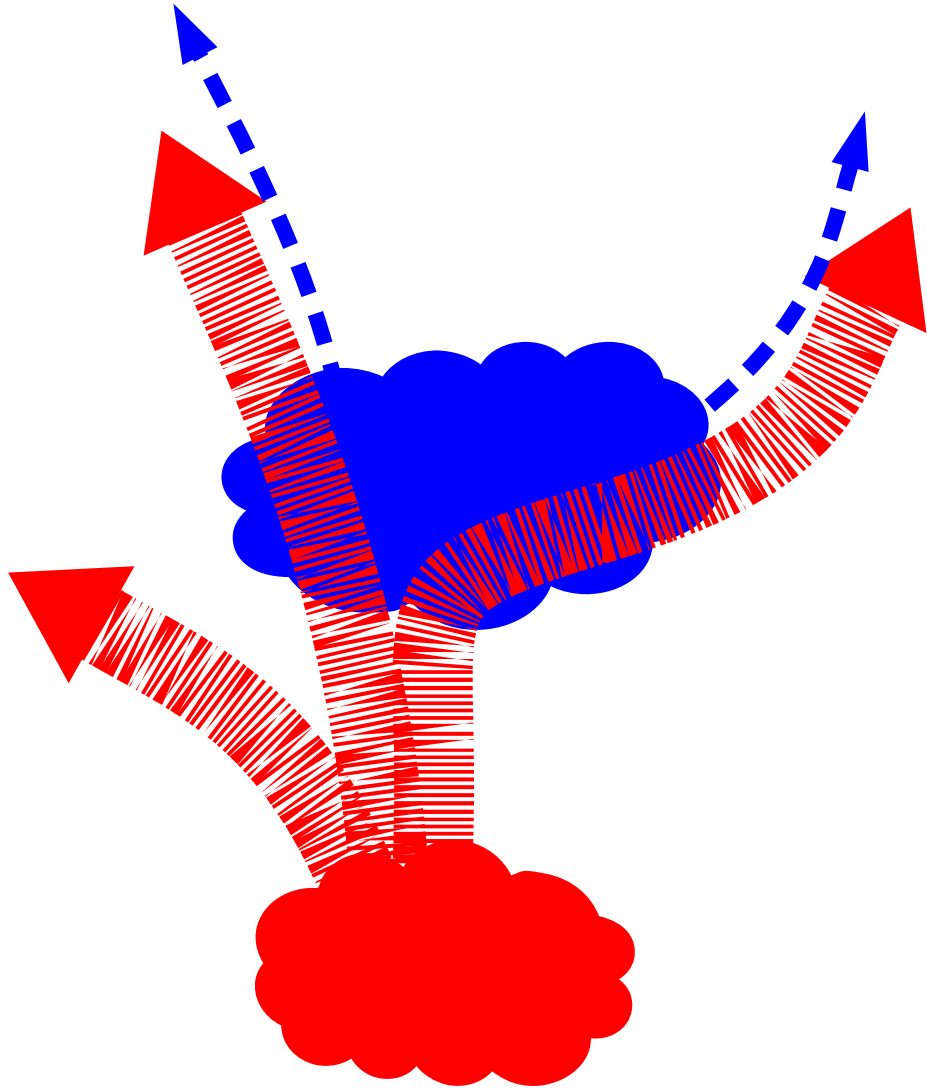


BGP announcements

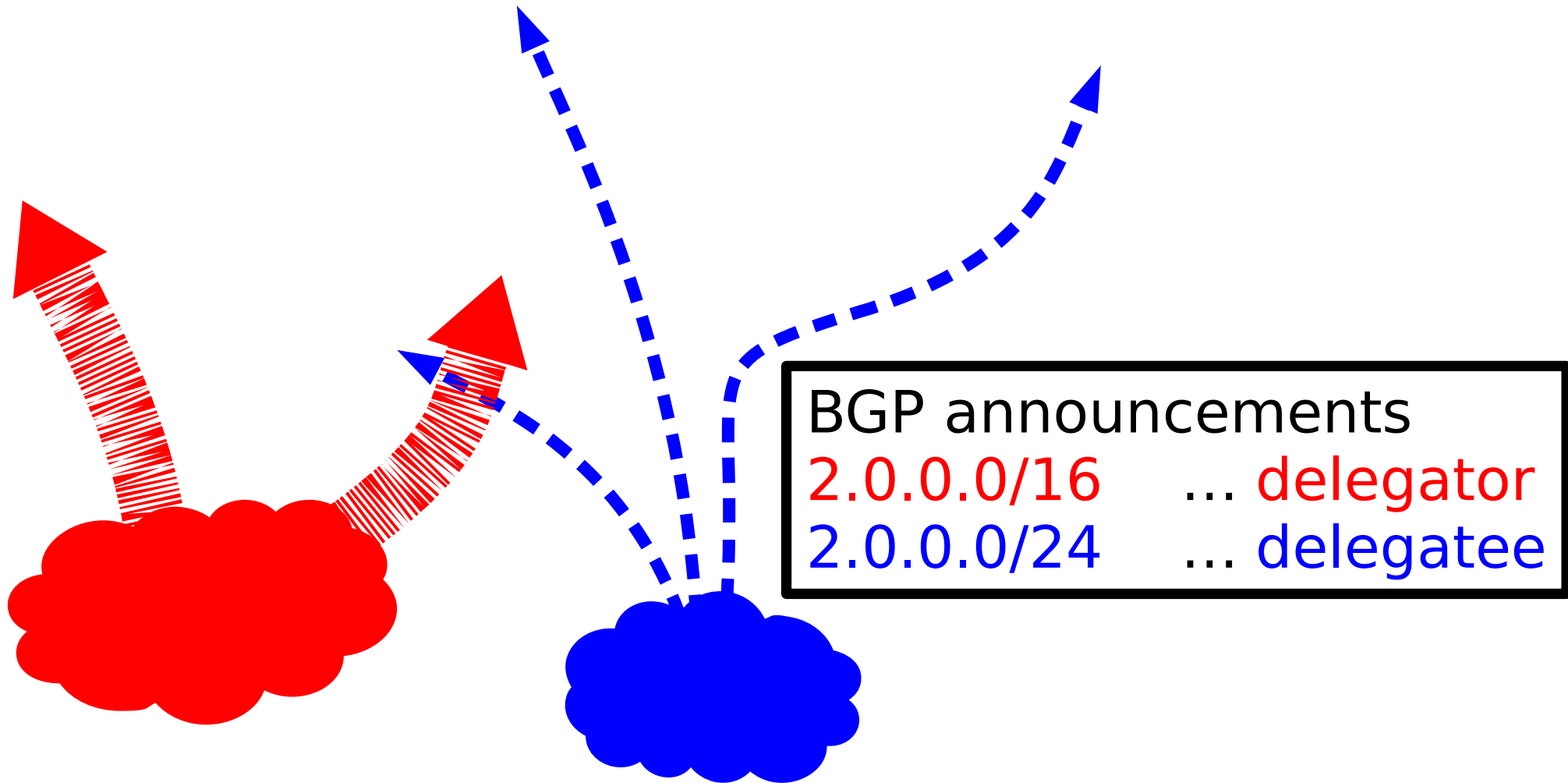
2.0.0.0/16 ... delegatee ... delegator

2.0.0.0/24 ... delegatee

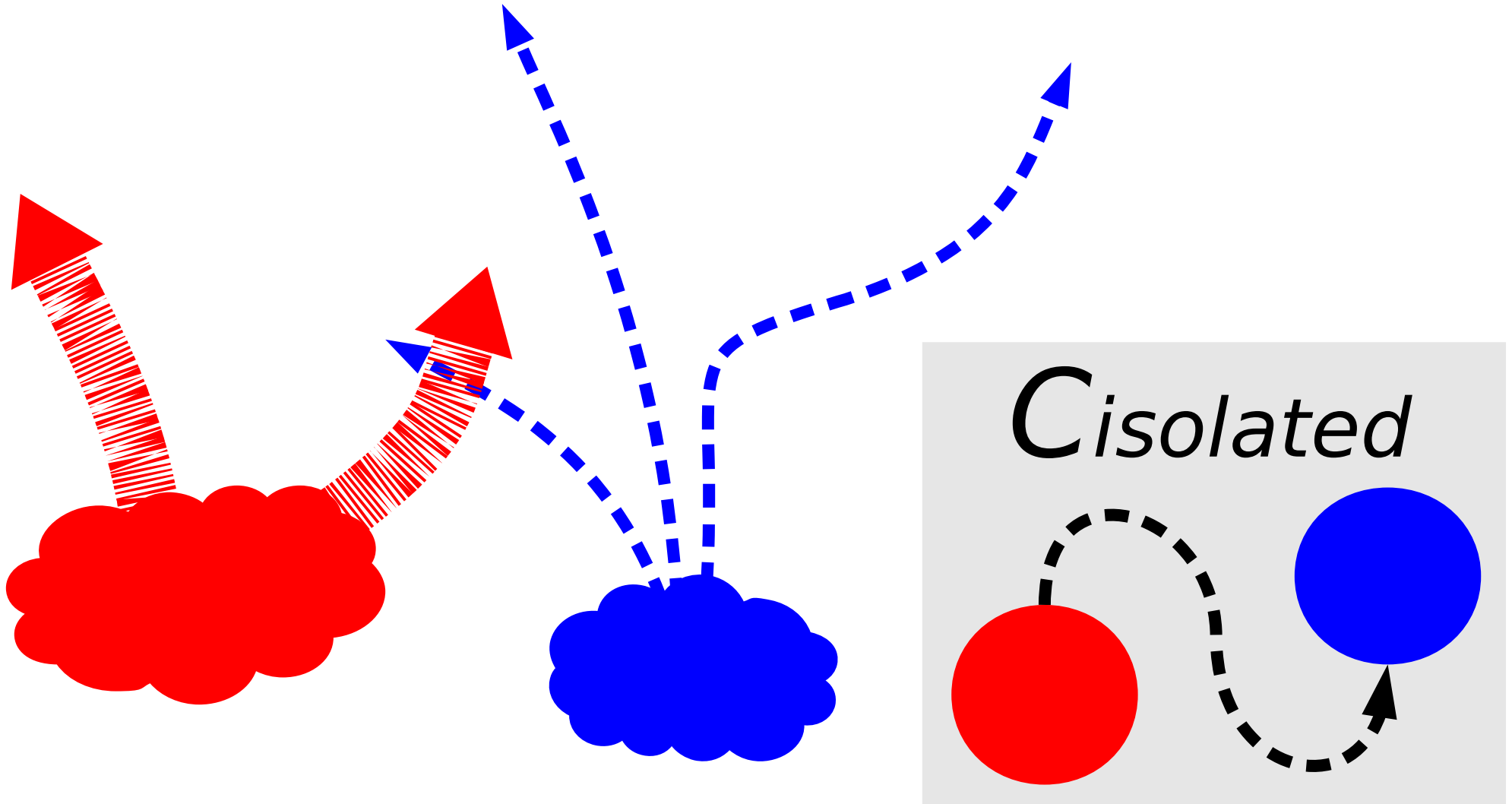
Delegation Classification



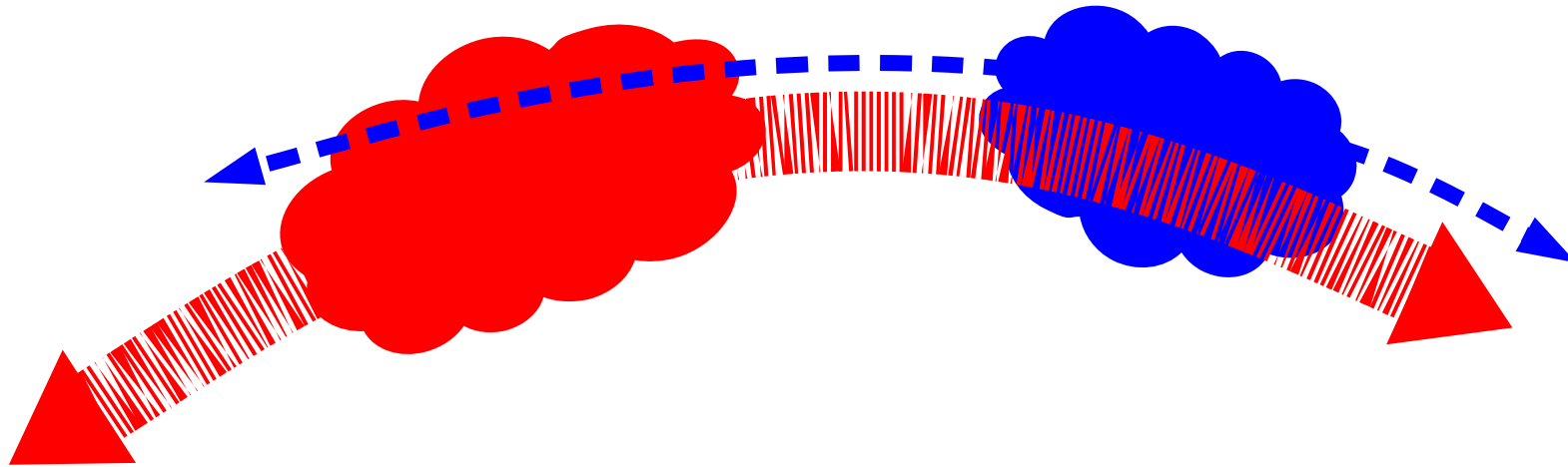
Delegation Classification



Delegation Classification



Delegation Classification

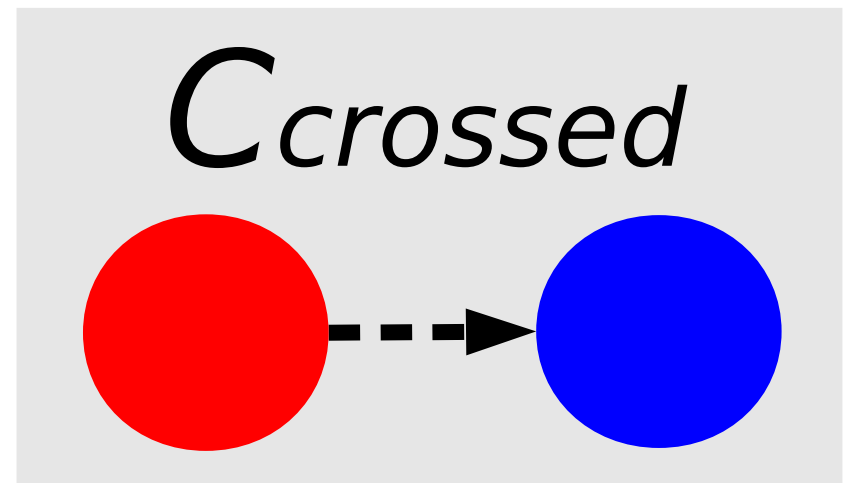
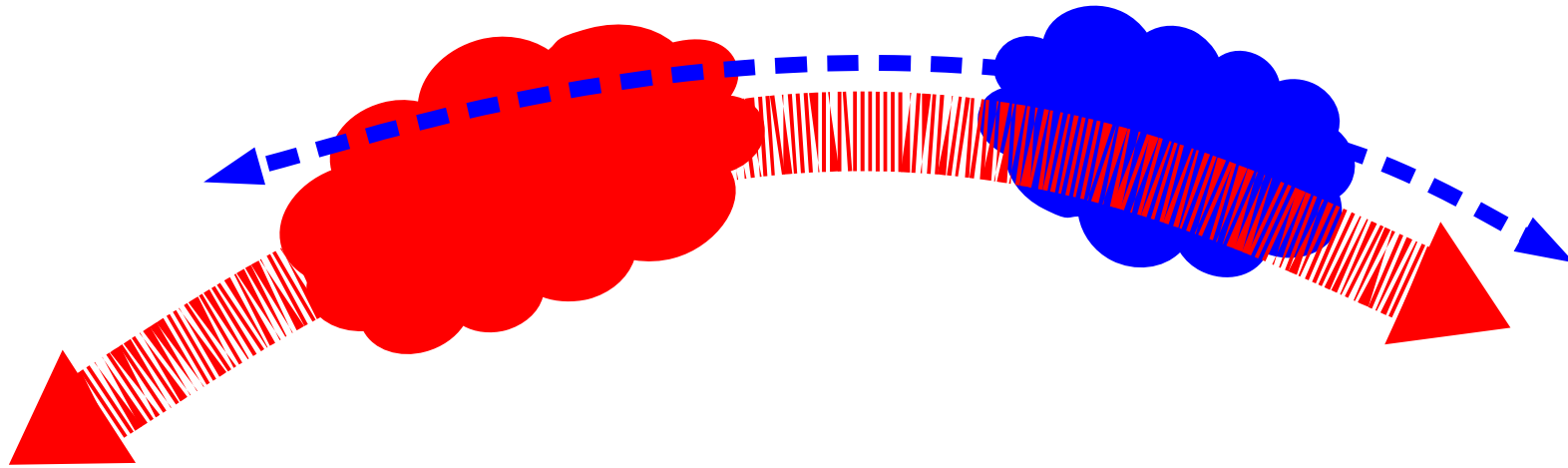


BGP announcements

2.0.0.0/16 ... delegatee ... delegator

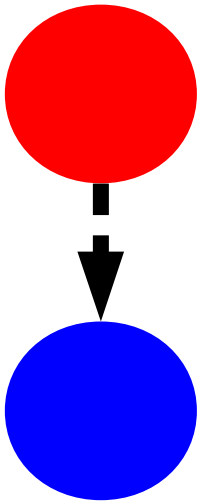
2.0.0.0/24 ... delegator ... delegatee

Delegation Classification

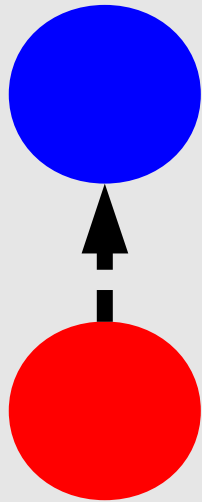


Delegation Classes

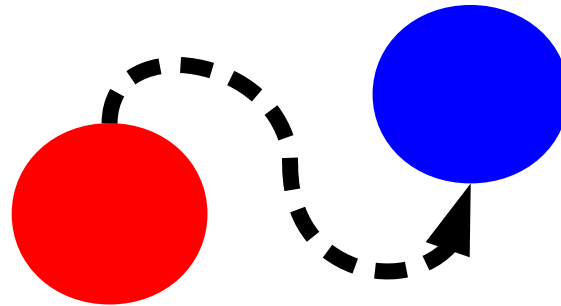
C_{down}



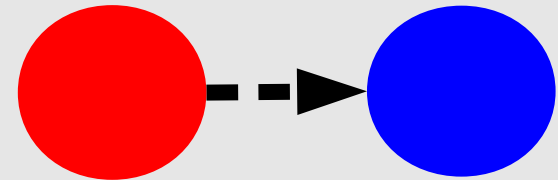
C_{up}



C_{isolated}

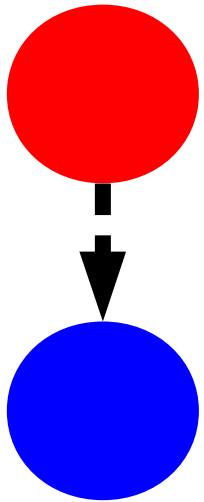


C_{crossed}

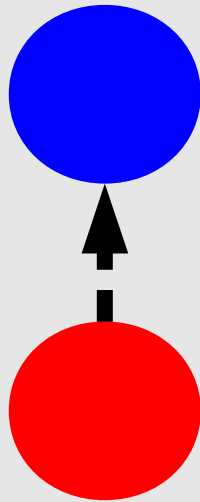


Delegation Classes

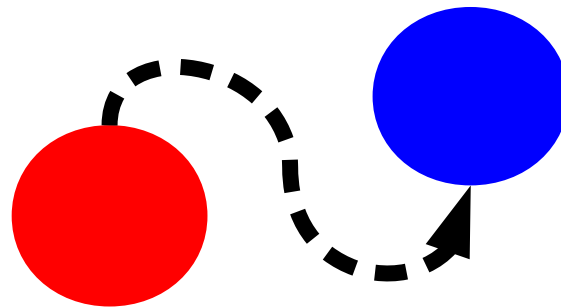
C_{down}



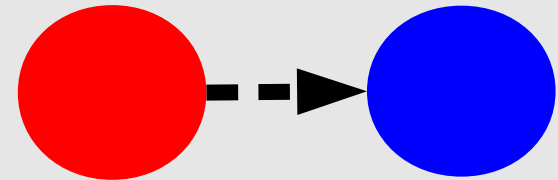
C_{up}



C_{isolated}



C_{crossed}



Share of all delegations in 2016:

60%

10%

29%

1%

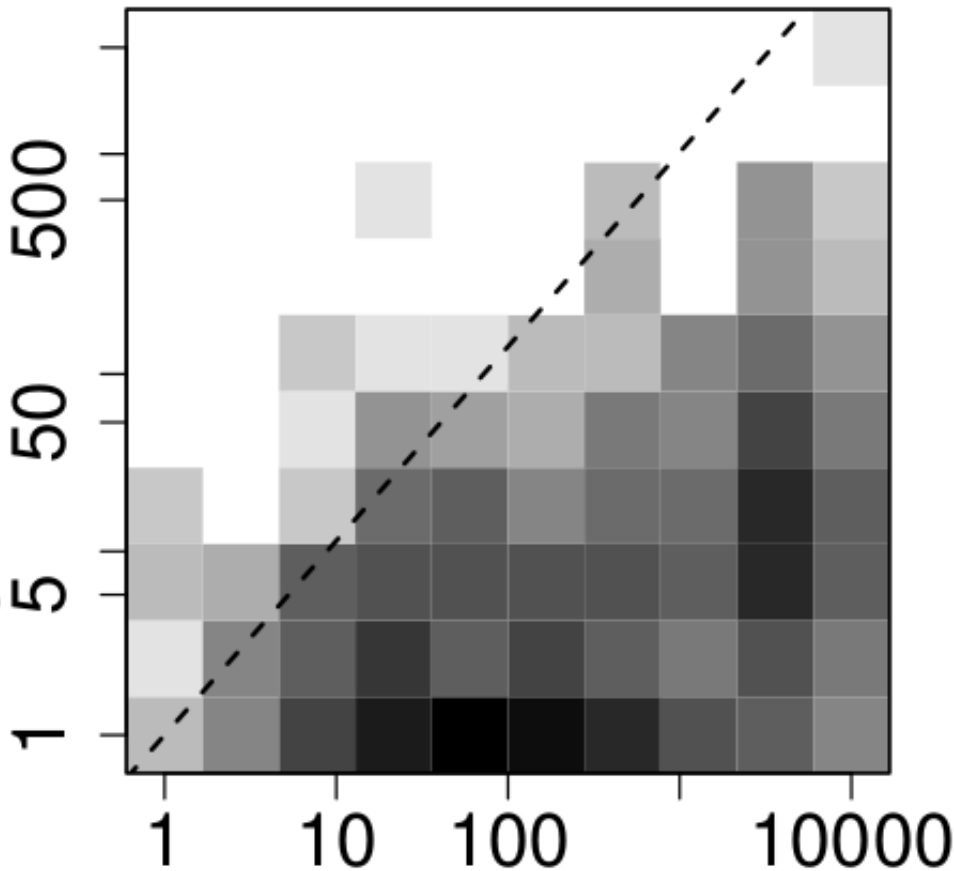
Agenda

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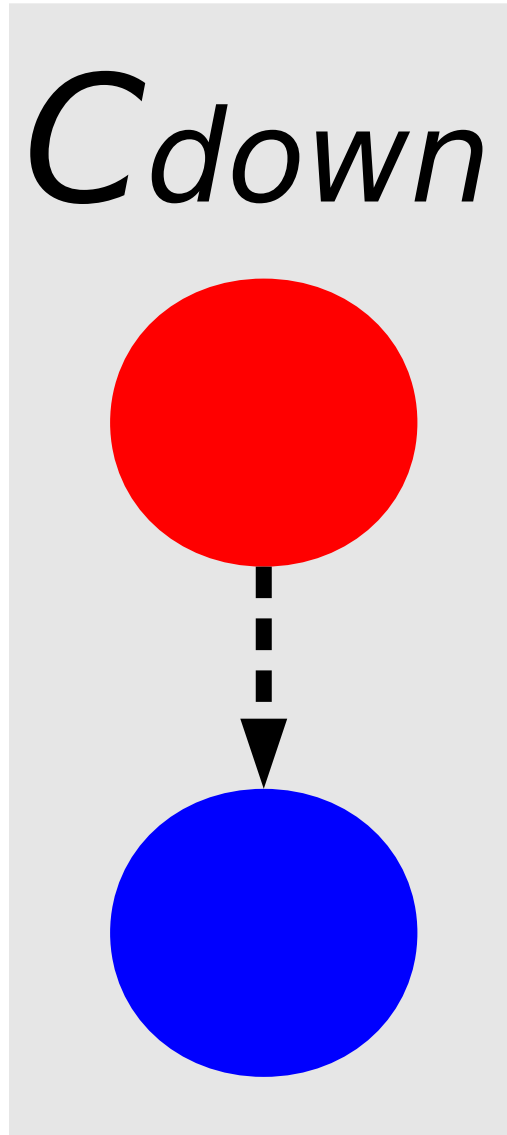
Delegator vs. Deegatee

Customer cone

deegatee size

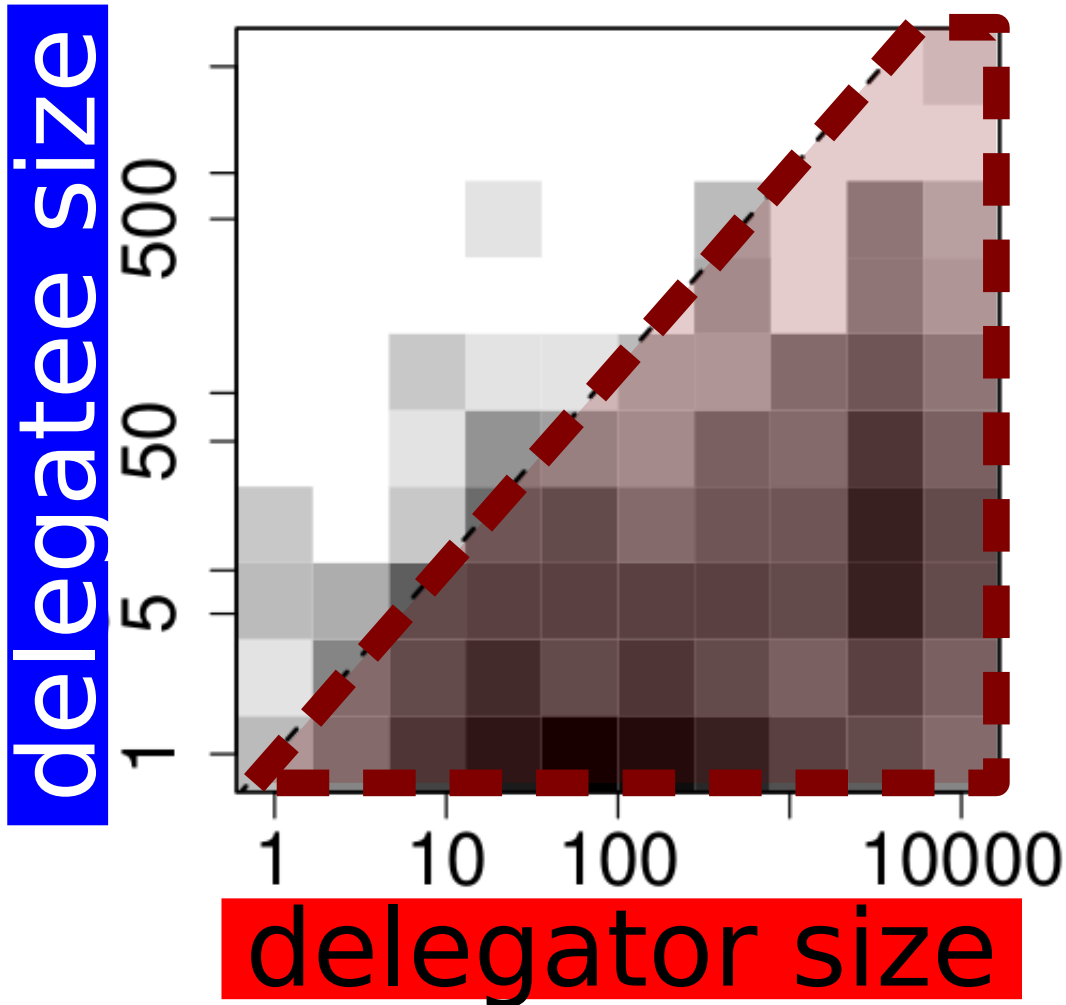


delegator size



Delegator vs. Deegatee

Customer cone



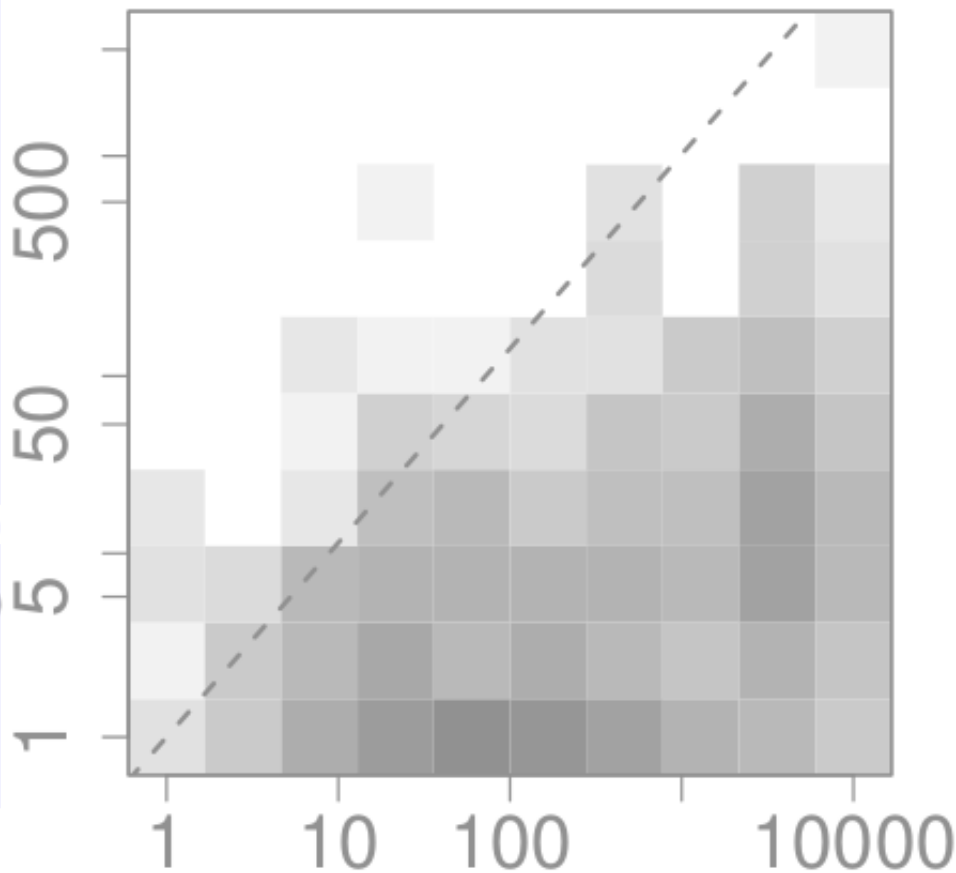
- **ASes of any size**
- **For 99.5% of AS pairs:** ● > ●

Delegator vs. Deegatee

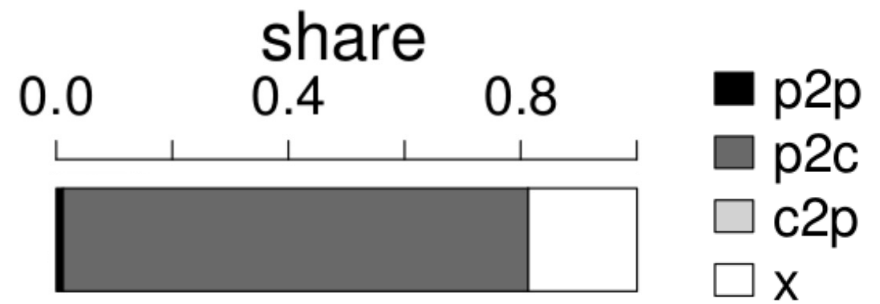
Customer cone

Business relation:

deegatee size



delegator size

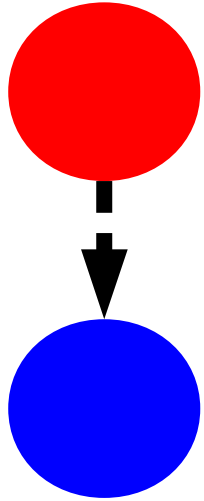


- **For 80% of AS pairs: P2C**

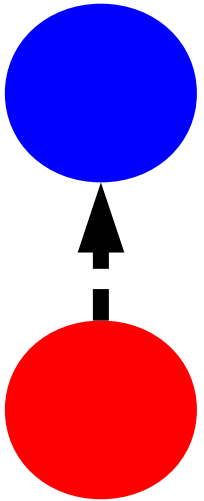
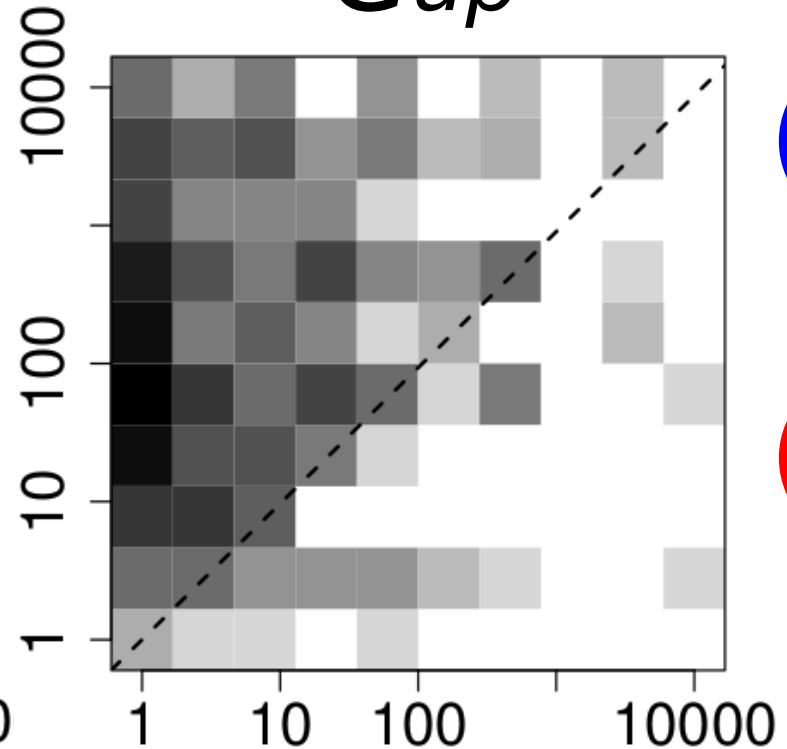
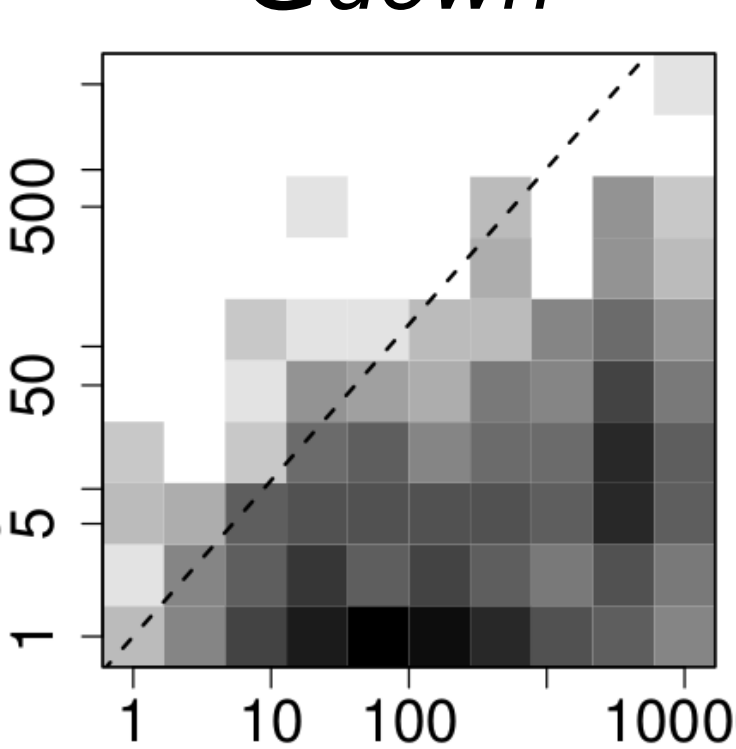
Delegator vs. Deegatee

C_{down}

C_{up}



deegatee size

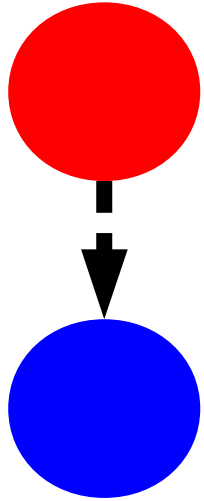


delegator size

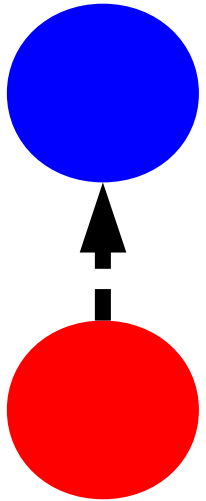
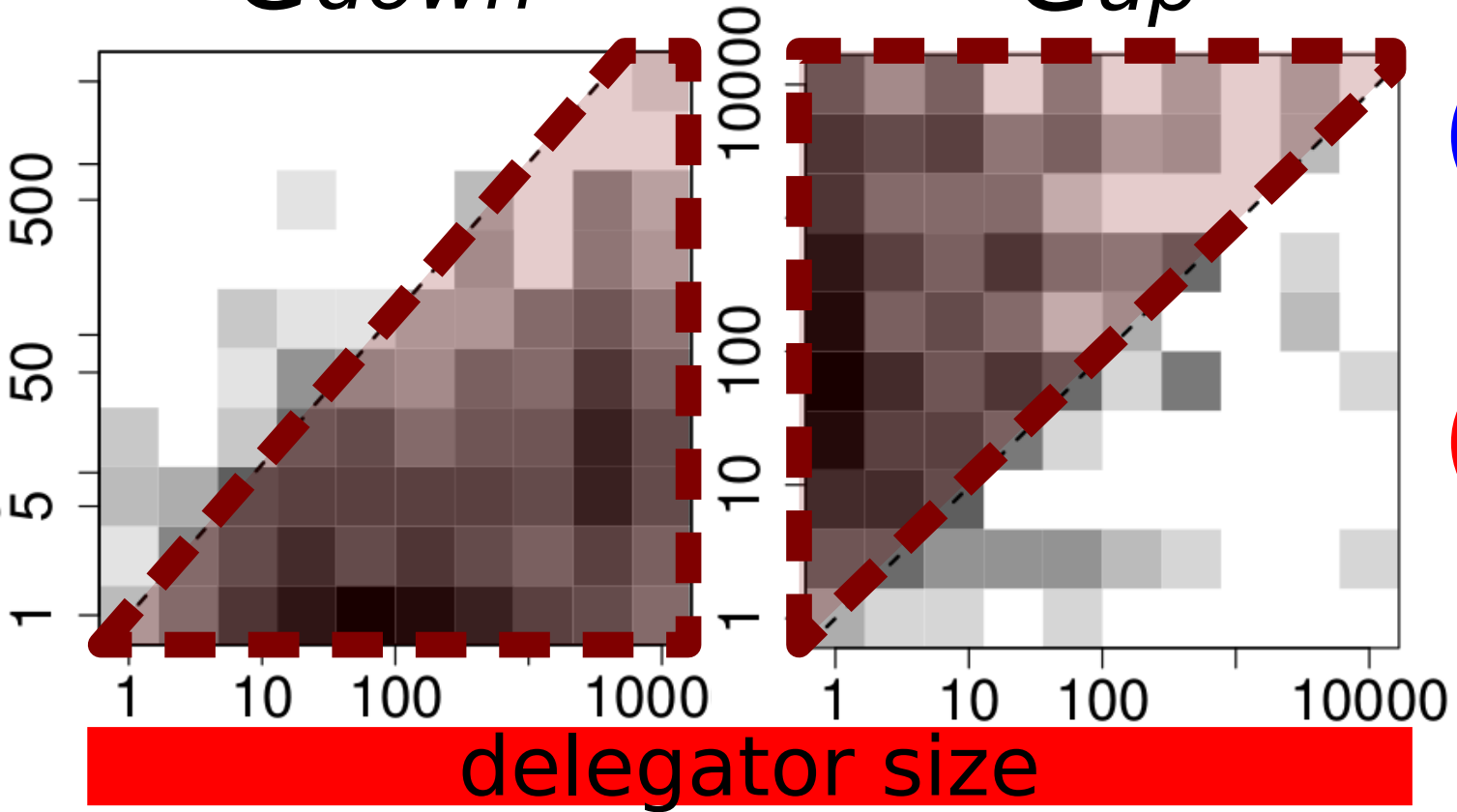
Delegator vs. Deegatee

C_{down}

C_{up}



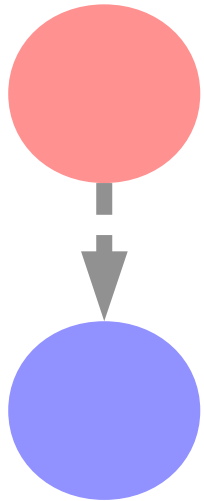
deegatee size



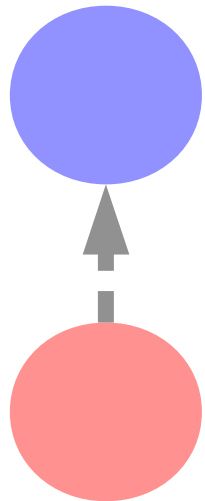
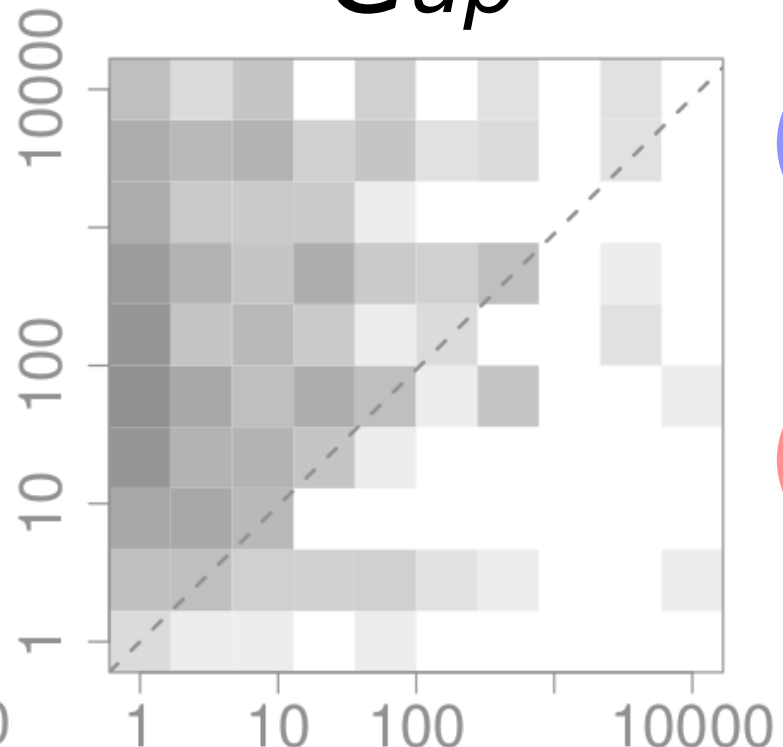
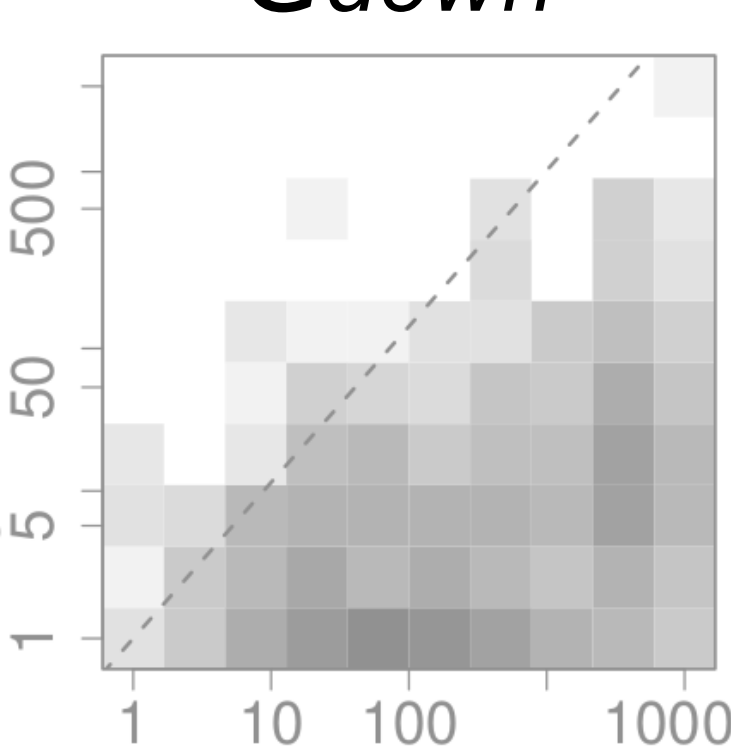
Delegator vs. Delegatee

C_{down}

C_{up}

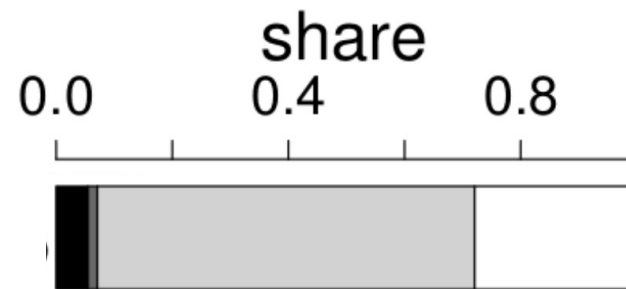
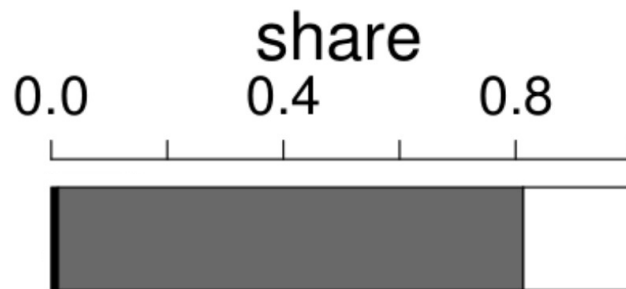


delegatee size



delegator size

- p2p
- p2c
- c2p
- x

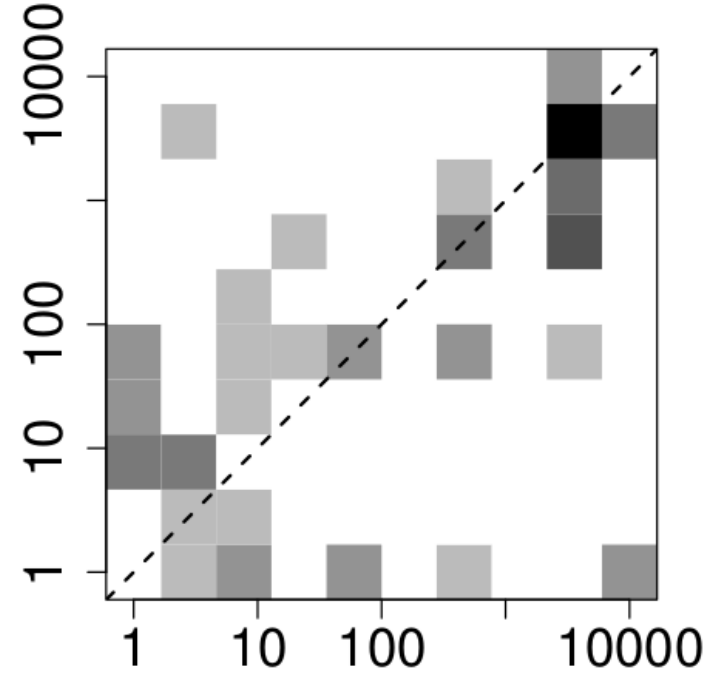
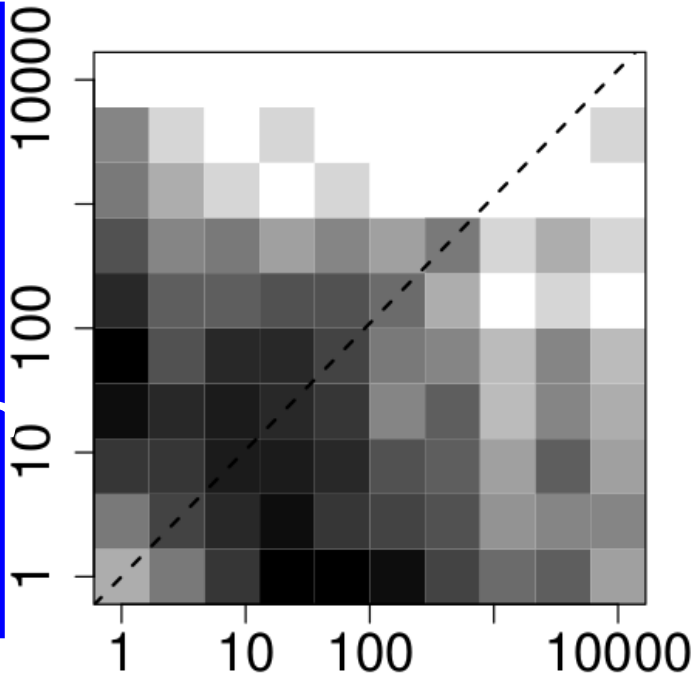


Delegator vs. Deegatee

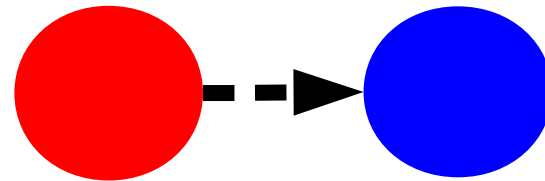
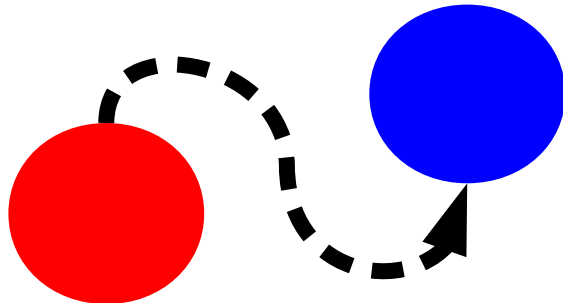
Cisolated

Ccrossed

delegatee size

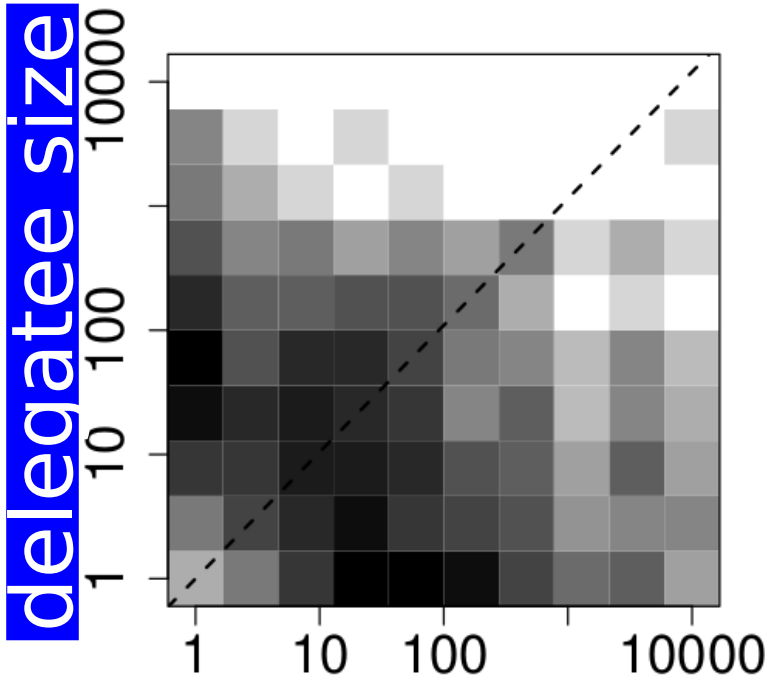


delegator size

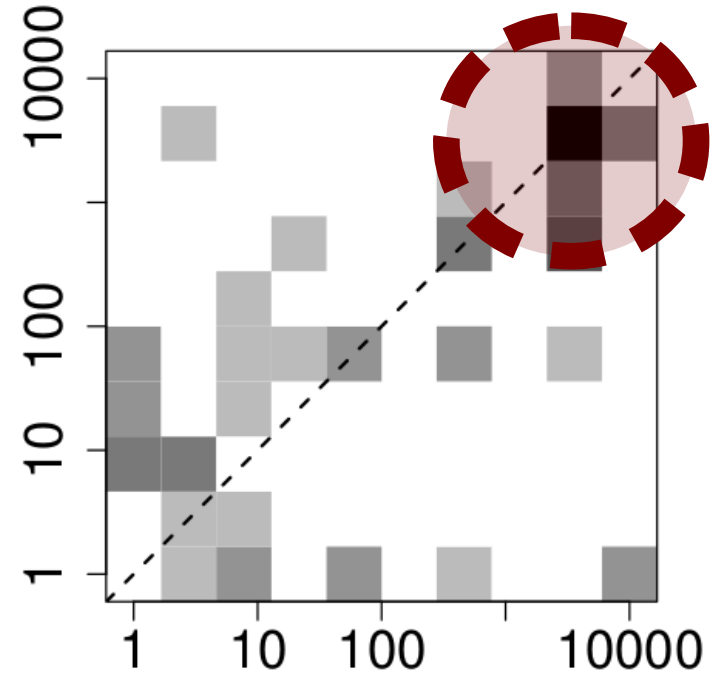


Delegator vs. Deegatee

Cisolated

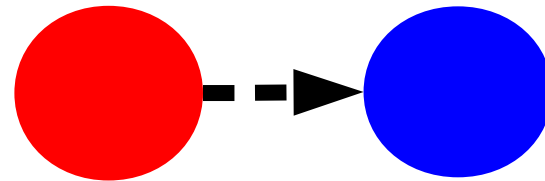
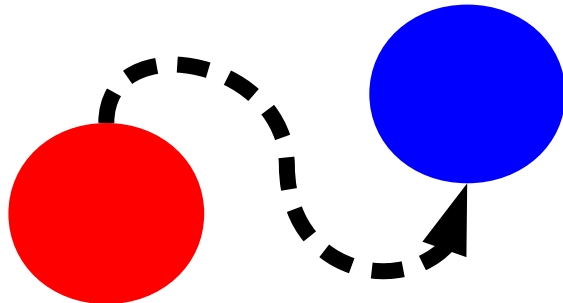


Ccrossed



delegatee size

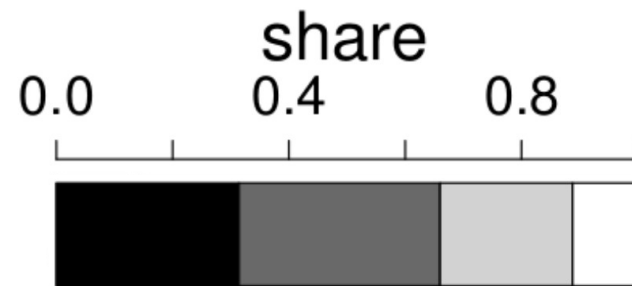
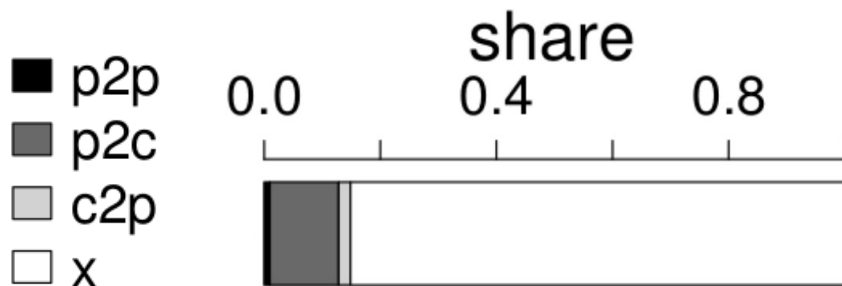
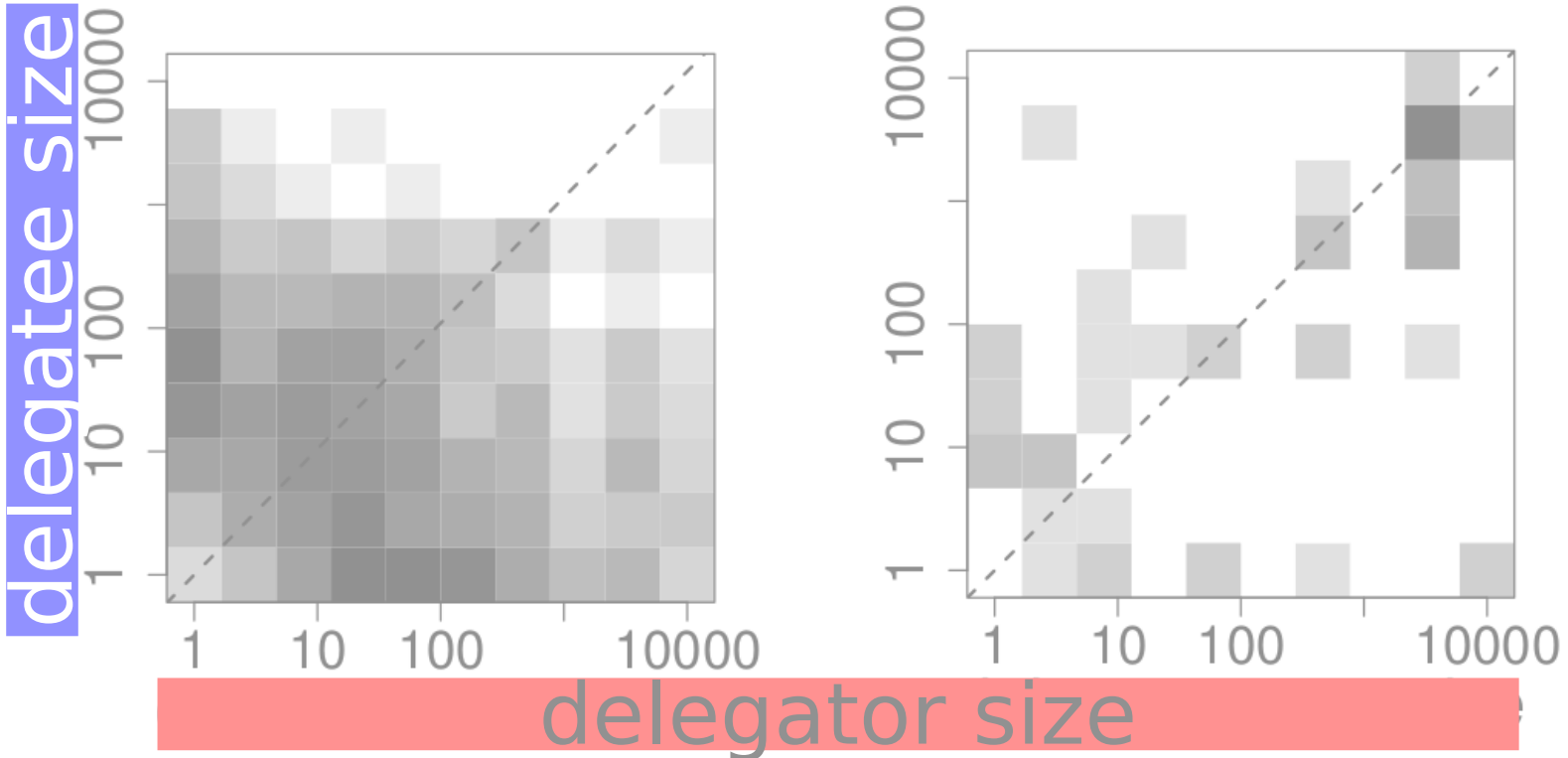
delegator size



Delegator vs. Delegatee

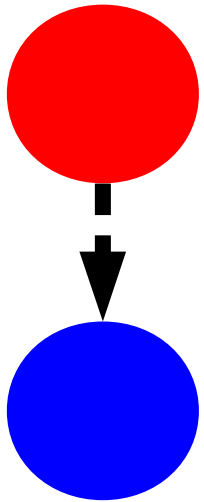
Cisolated

Ccrossed

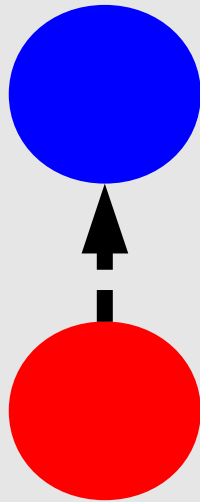


Delegation Classes

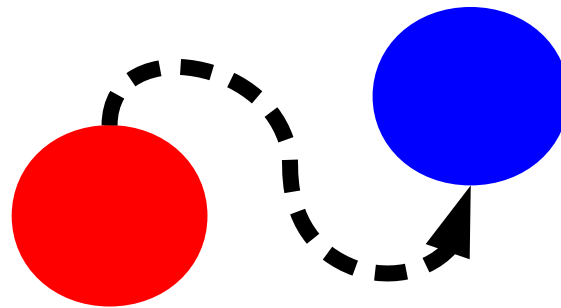
C_{down}



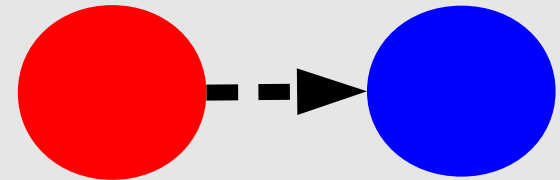
C_{up}



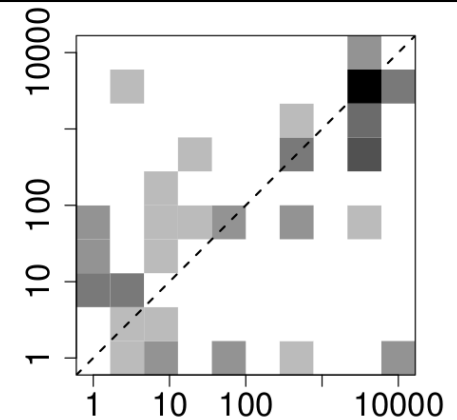
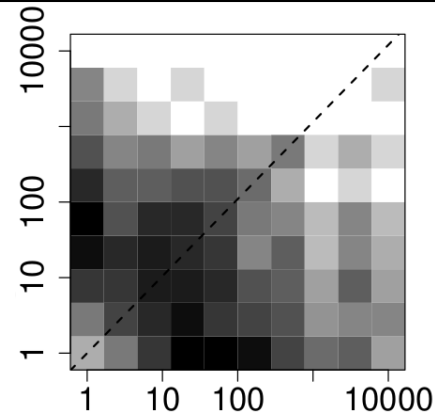
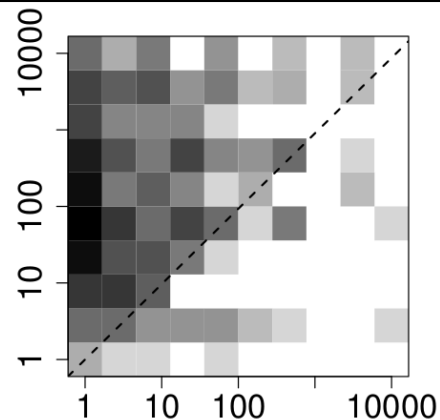
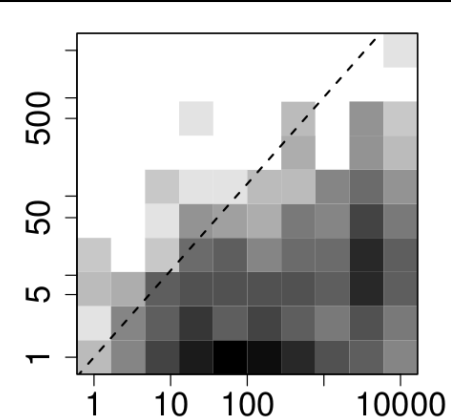
C_{isolated}



C_{crossed}

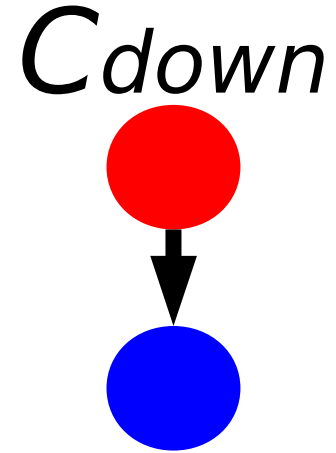


AS size: delegator vs delegatee:



Case Studies

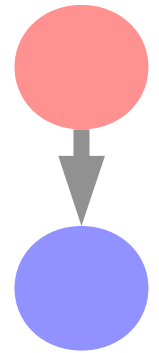
- AS7922 (Comcast, ISP)
 - delegates since 2009; in 2016: 3.5k delegations
 - stable growth
 - almost entirely to small ASes (cone size 1)
 - diverse US companies



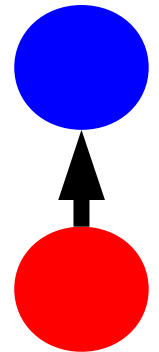
Case Studies

- AS7922 (Comcast, ISP)
 - delegates since 2009; in 2016: 3.5k delegations
 - stable growth
 - almost entirely to small ASes (cone size 1)
 - diverse US companies
- AS31377 (Akamai, CDN)
 - delegated from 2011-2014; up to 3.8k delegations
 - succeeded by AS35994; in 2016: 5.5k delegations!
 - irregular growth
 - to many large ASes incl. Tier-1 (cone size up to 10k)
 - world-wide

C_{down}



C_{up}



Case Studies

- AS7922 (Comcast, ISP)
 - delegates since 2009; in 2016: 3.5k delegations

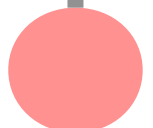
Observed types of delegations depend on the business model of the involved ASes.

- AS
 - irregular growth
 - to many Tier-1 ASes (cone size up to 10k)
 - world-wide

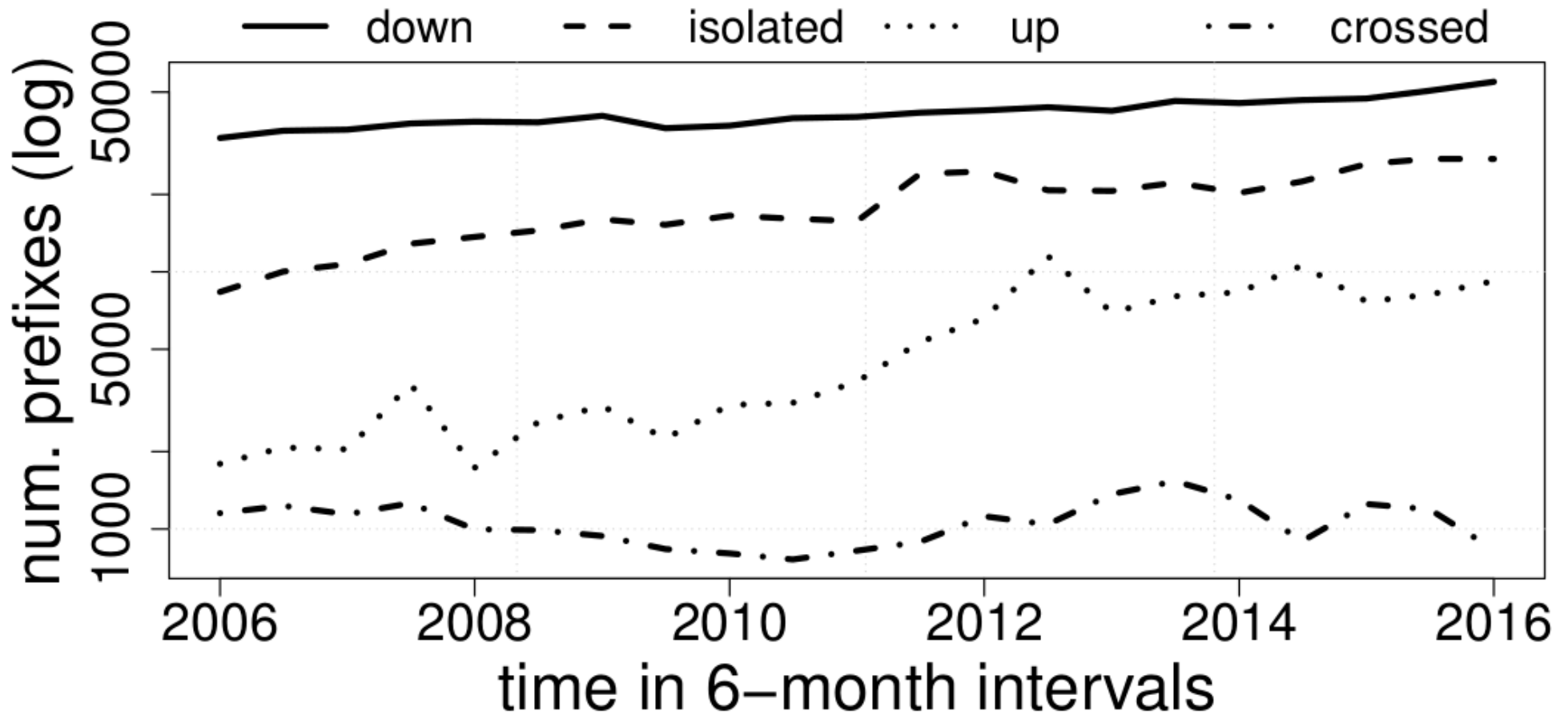
C_{down}



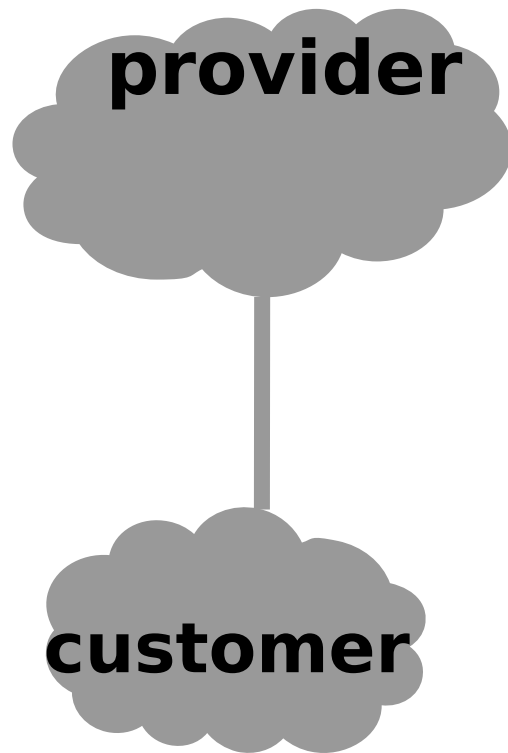
C_{up}



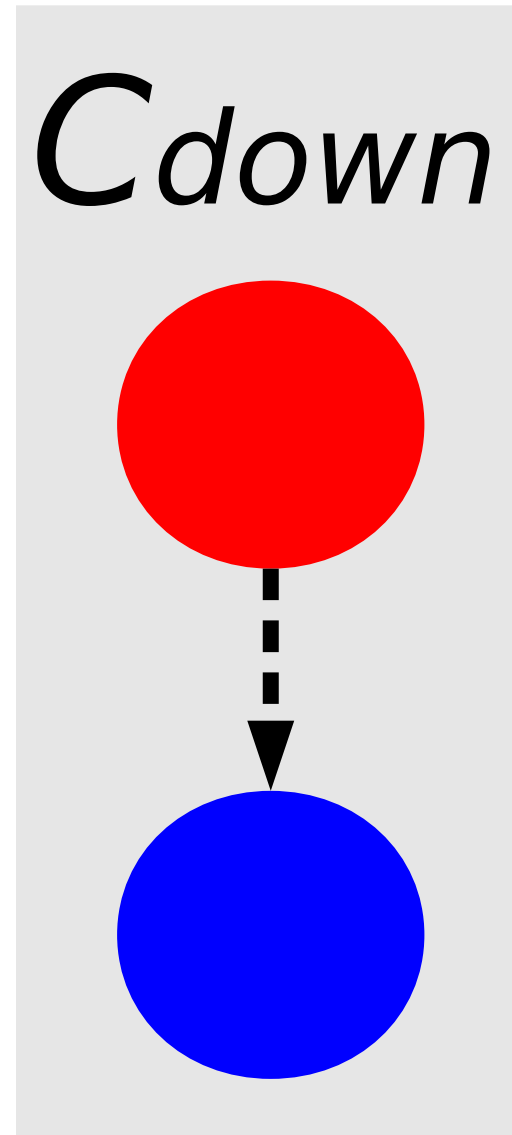
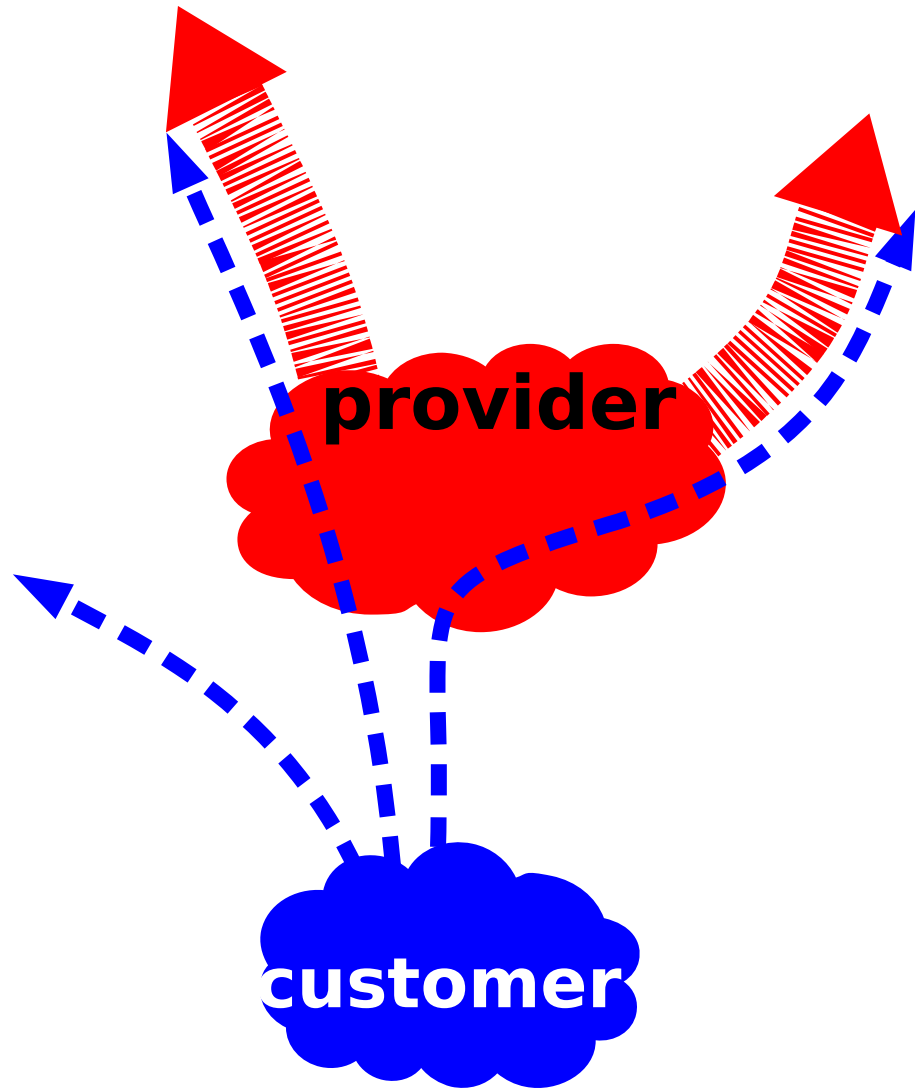
Delegation Classes Over Time



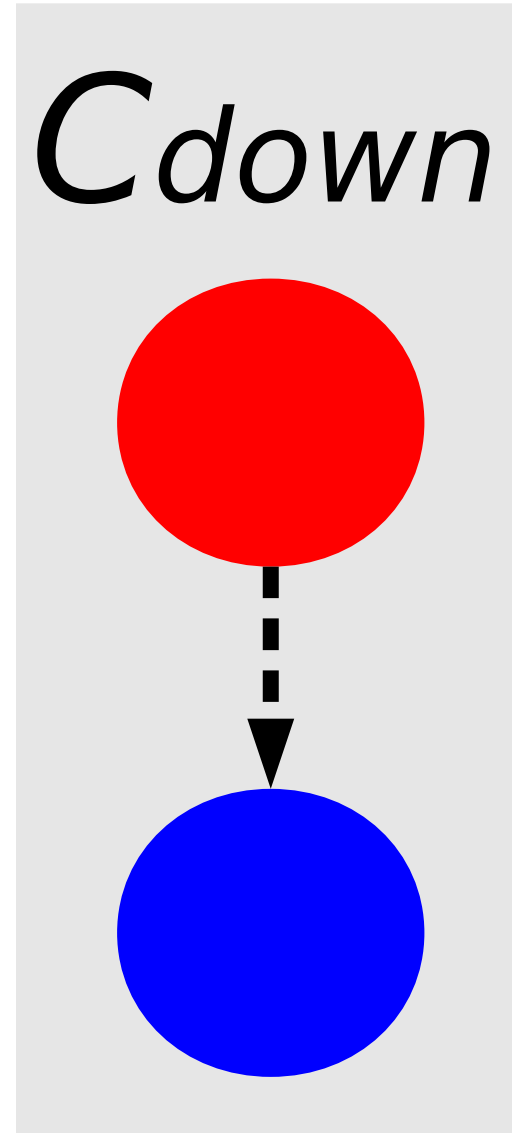
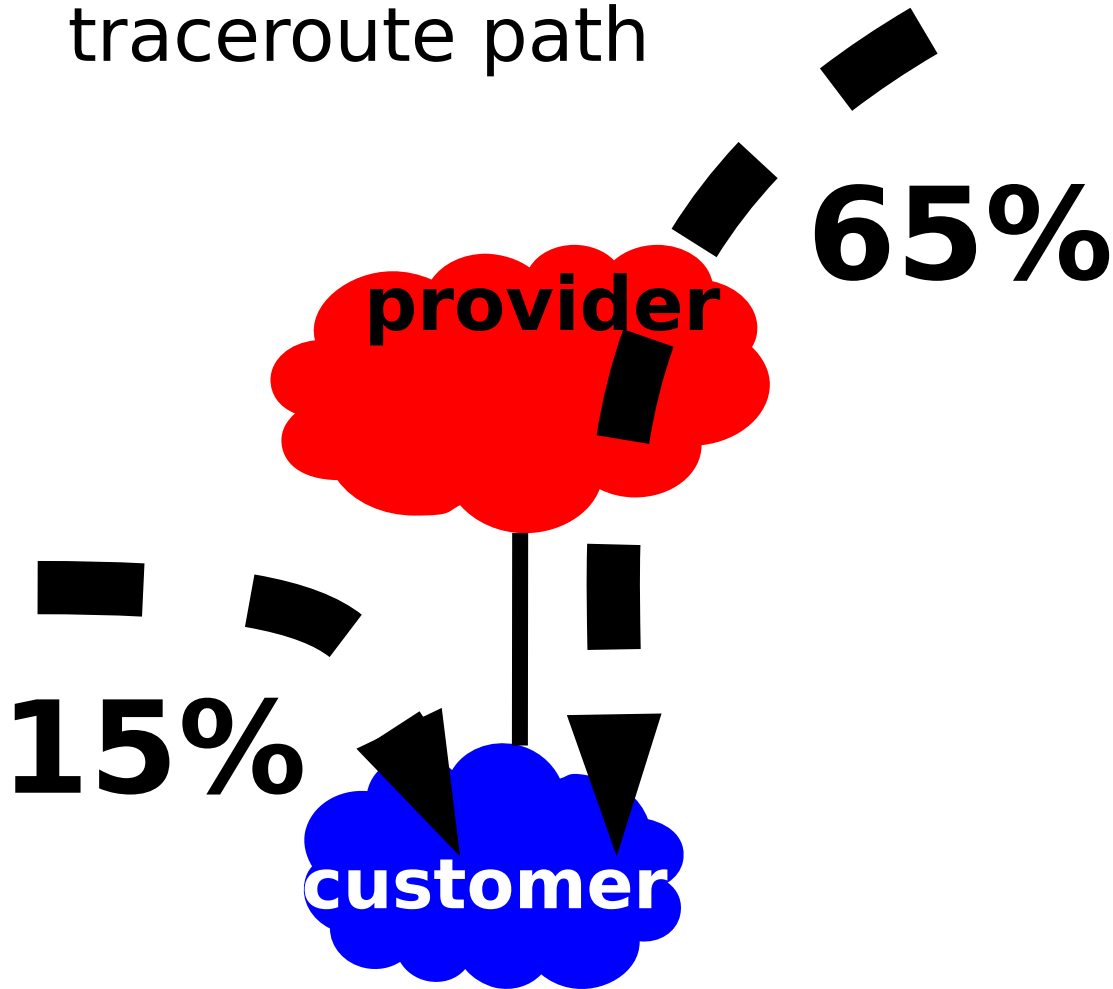
Effects on Path Selection



Effects on Path Selection

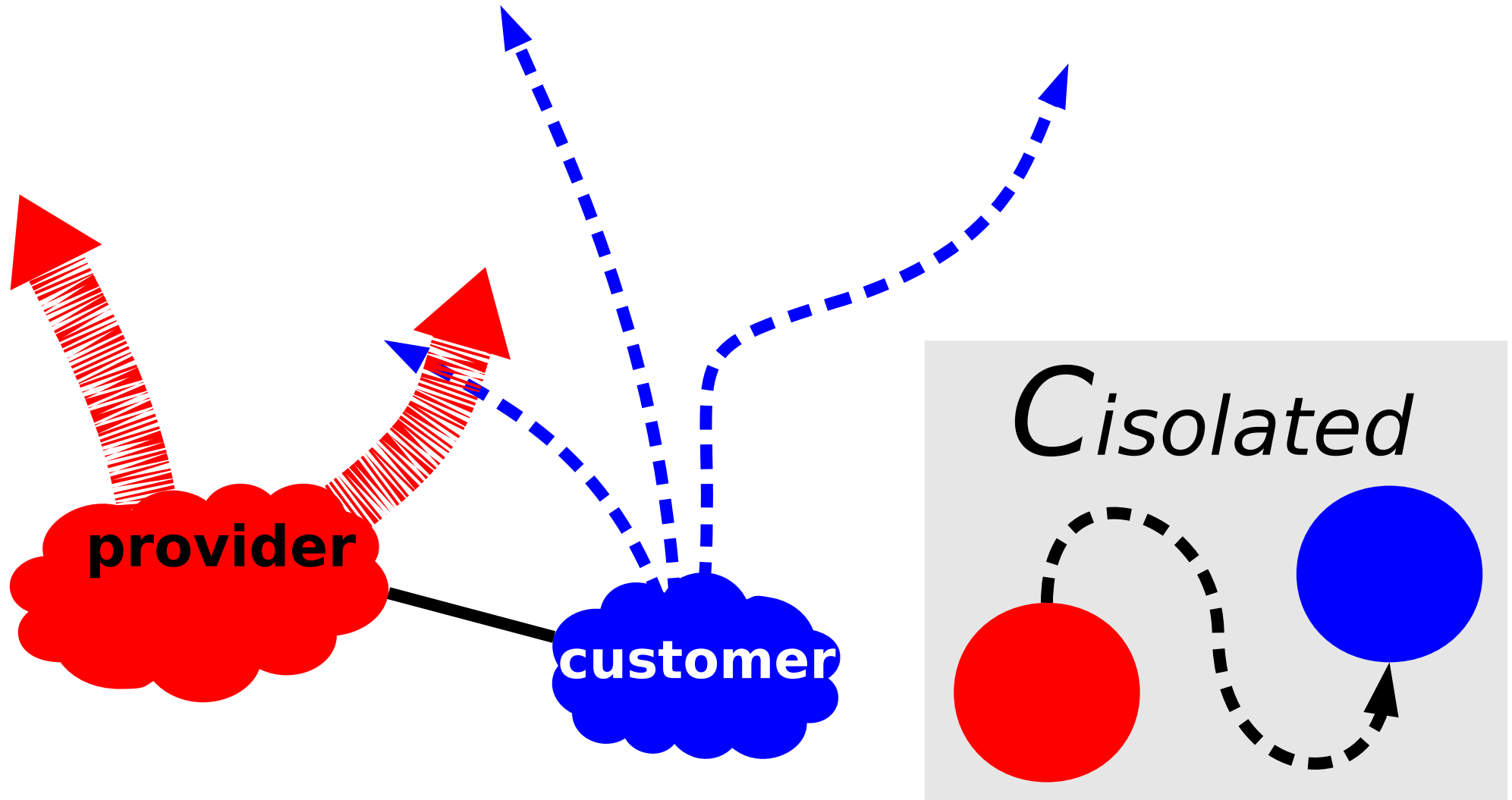


Effects on Path Selection

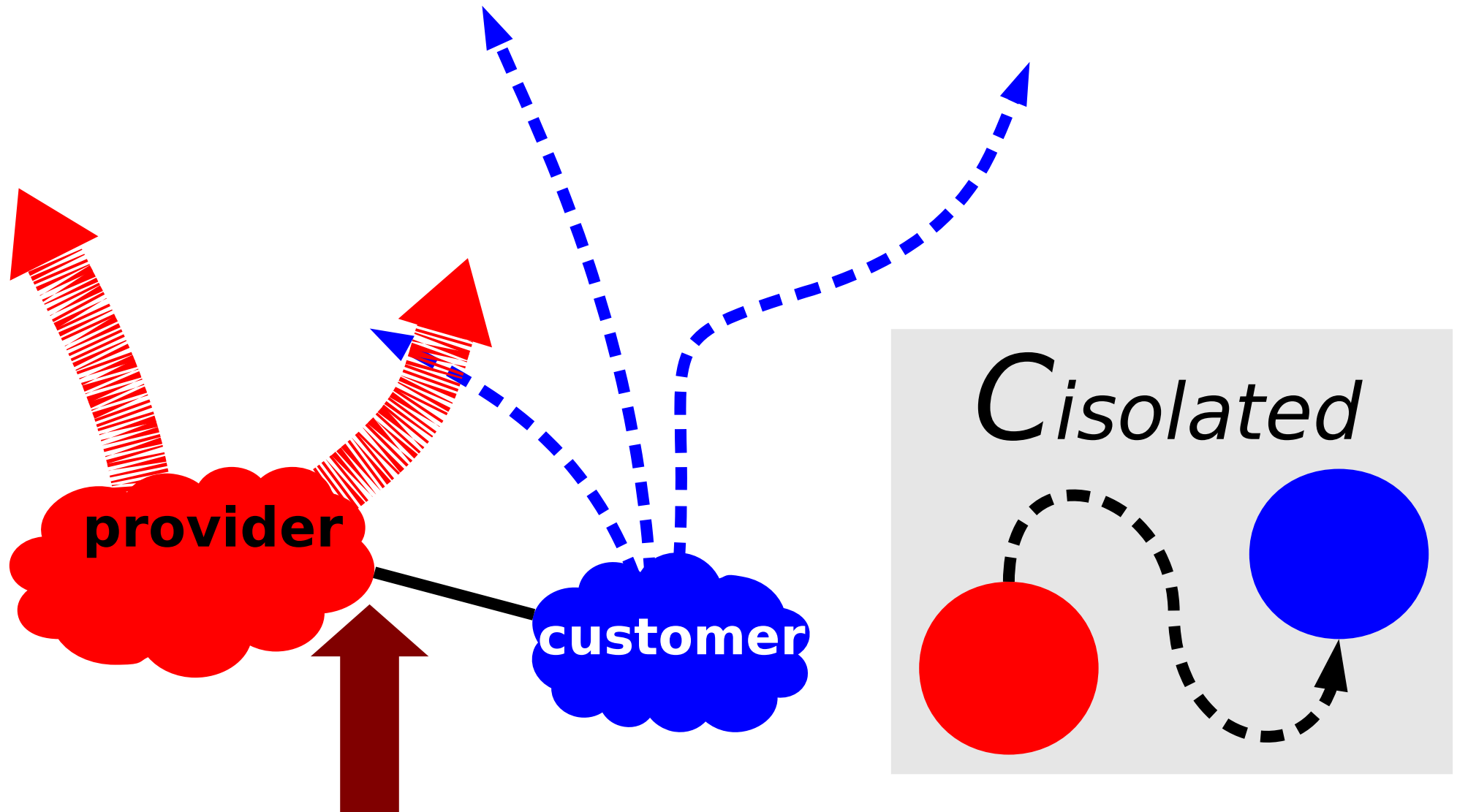


20% of delegations have varying ingress

Effects on Path Selection



Effects on Path Selection



aggregation at the delegating provider ₁₆

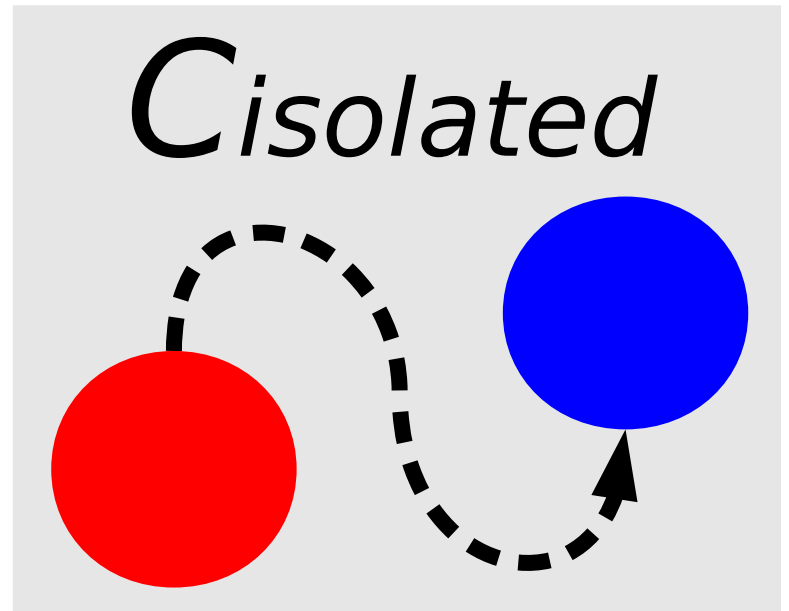
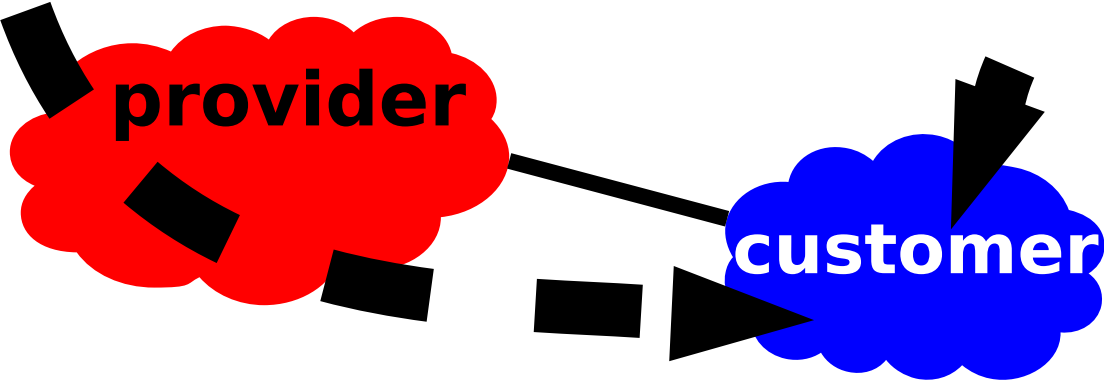
Effects on Path Selection



traceroute path

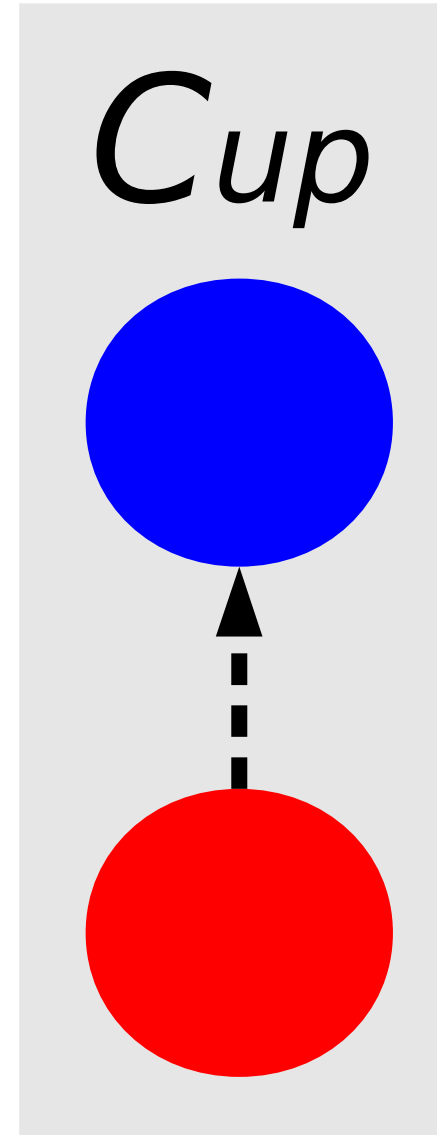
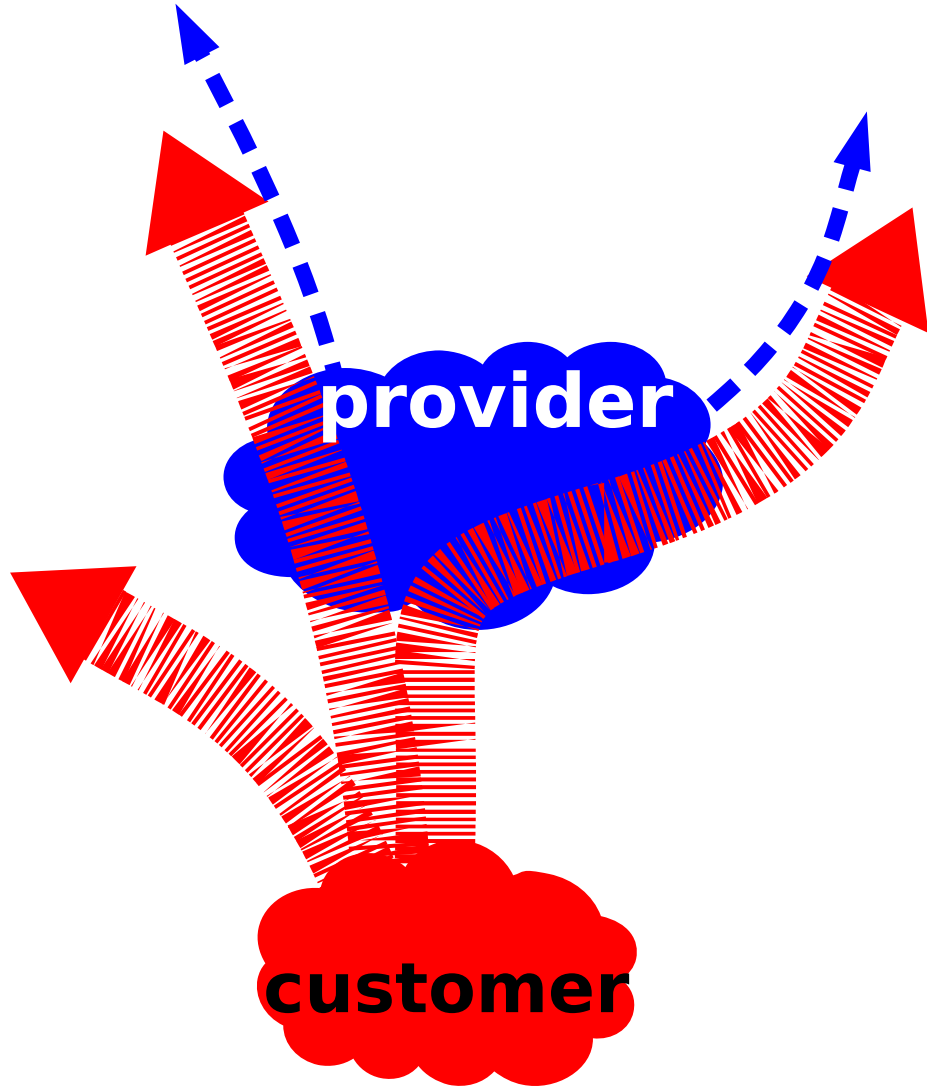
85%

10%



5% of delegations have varying ingress₁₆

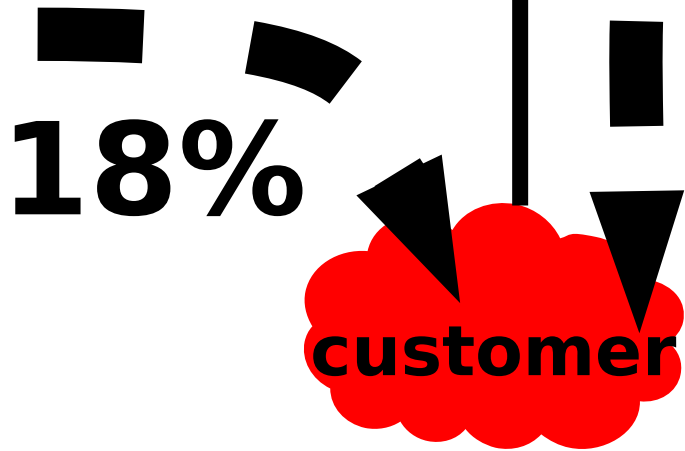
Effects on Path Selection



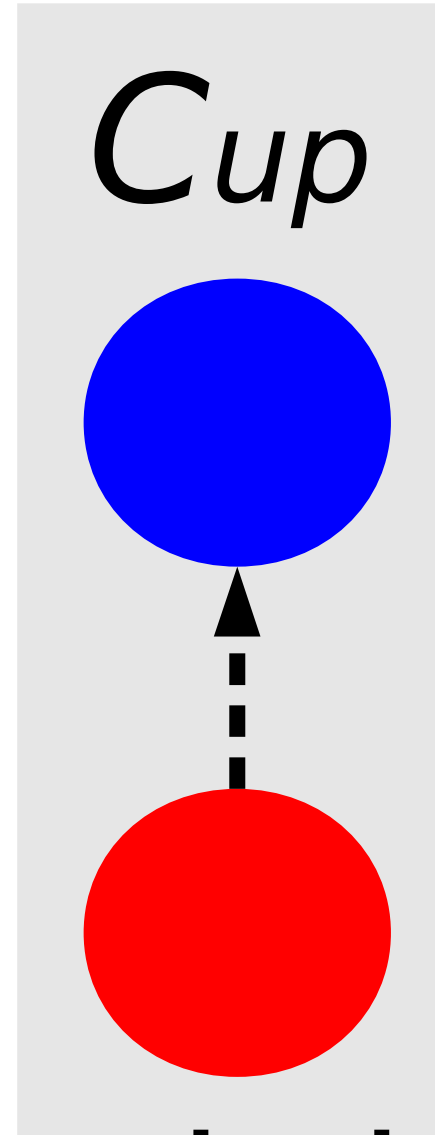
Effects on Path Selection



25%



18%



57% of delegations have varying ingress

Effects on Path Selection

■ ■ →
traceroute path

25%

Cup

**Noticable affect on traffic flow
depending on the delegation type**

18
customer

57% of delegations have varying ingress

Summary + Ongoing Work

- Prefix delegation classification and characterization
 - All kind of ASes involved
 - Delegations up and across AS level hierarchy
 - Type of delegation affects path selection
 - Historical evolution; growth will continue
- Comparison of deaggregation and delegation:
IPv4 vs. IPv6
- Comparison of delegations in different regions
(e.g., RIPE, ARIN)

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