Interdomain routing: Autonomy vs. expressiveness

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Outline

- Problem motivation
- Autonomy: ARC functions
- An “impossibility” theorem
- Steps forward

Who owns the Internet?

The Internet is independently owned and operated by 1000s of ISPs.

These providers use BGP to implement routing policy goals.

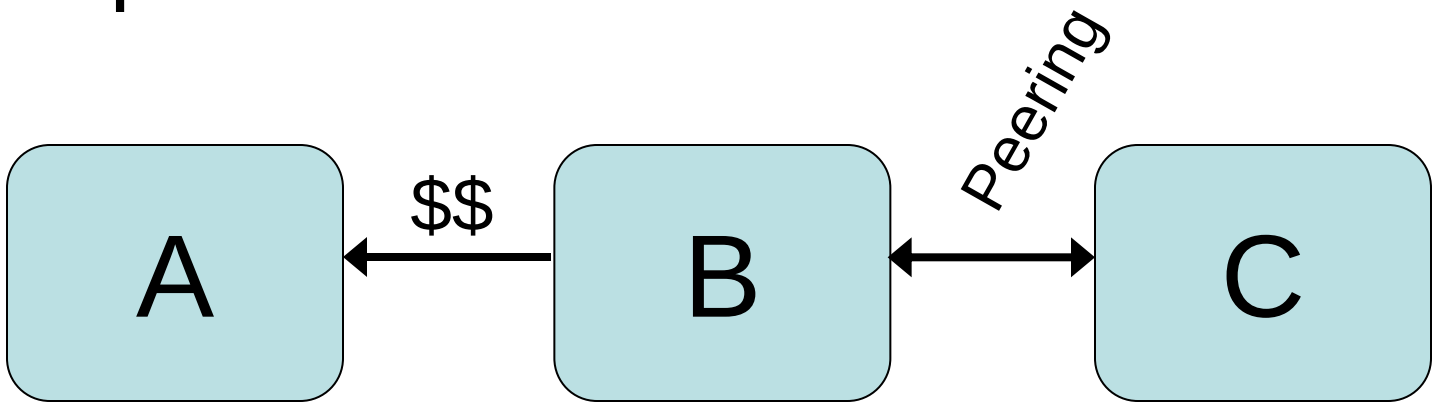
Question:

What are the implications of this autonomy?

Policy

Why is policy needed?

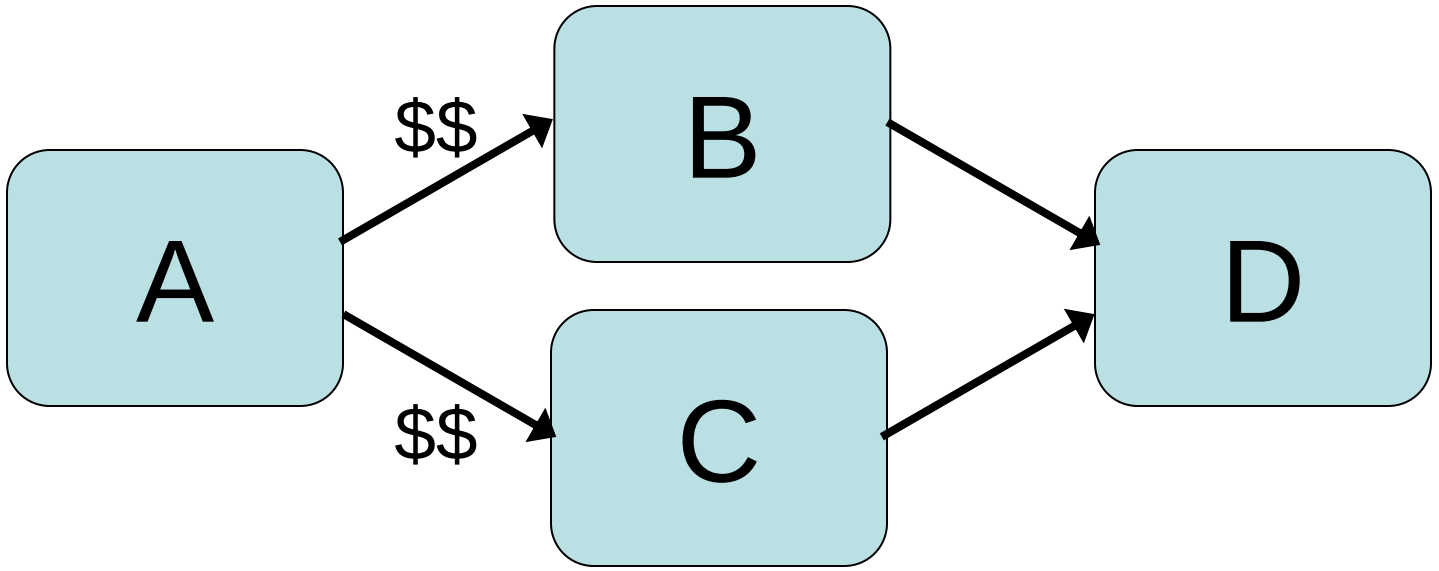
Example 1: Contracts



B and C are peers. B pays A. ⇒
B filters the route B→A from C.

Policy

Example 2: traffic optimization



A pays B and C to reach D. B costs less.

⇒ A prefers A→B→D to A→C→D.

Ranking and filtering

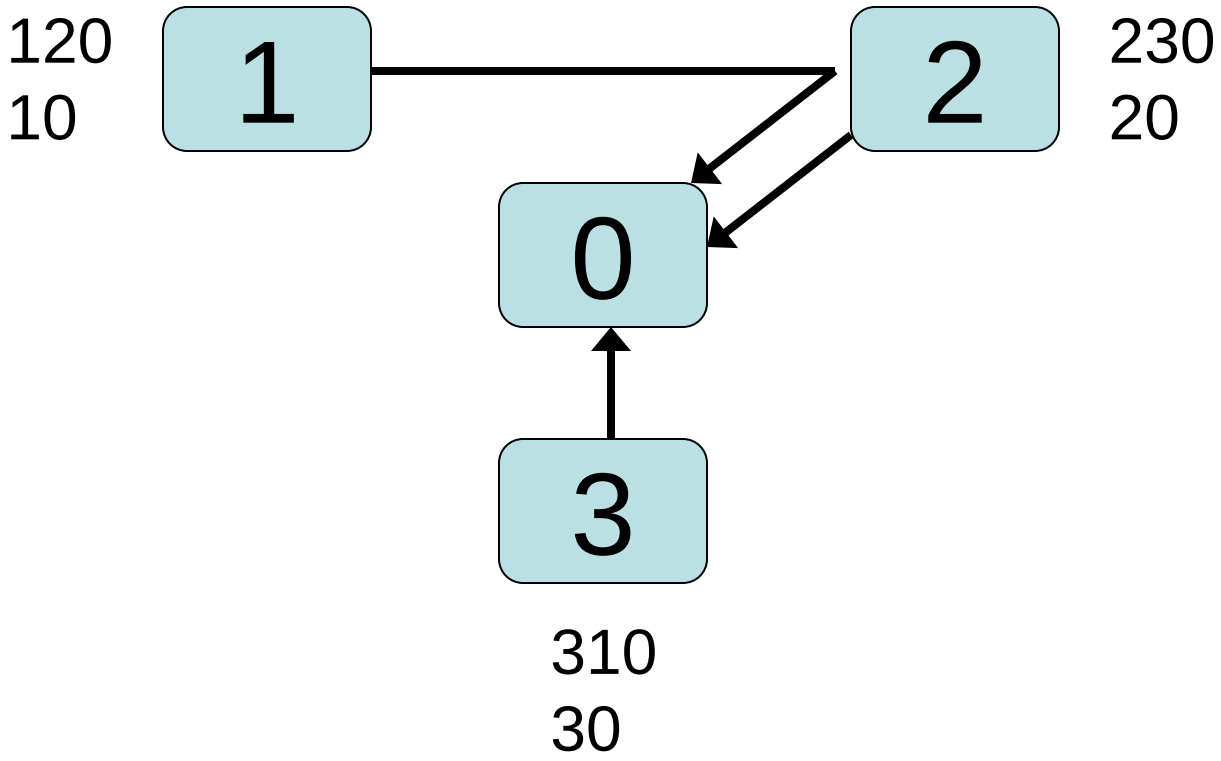
How do ASes implement policy?

1. Ranking the routes that outbound traffic will use
2. Filtering routes that inbound traffic will use

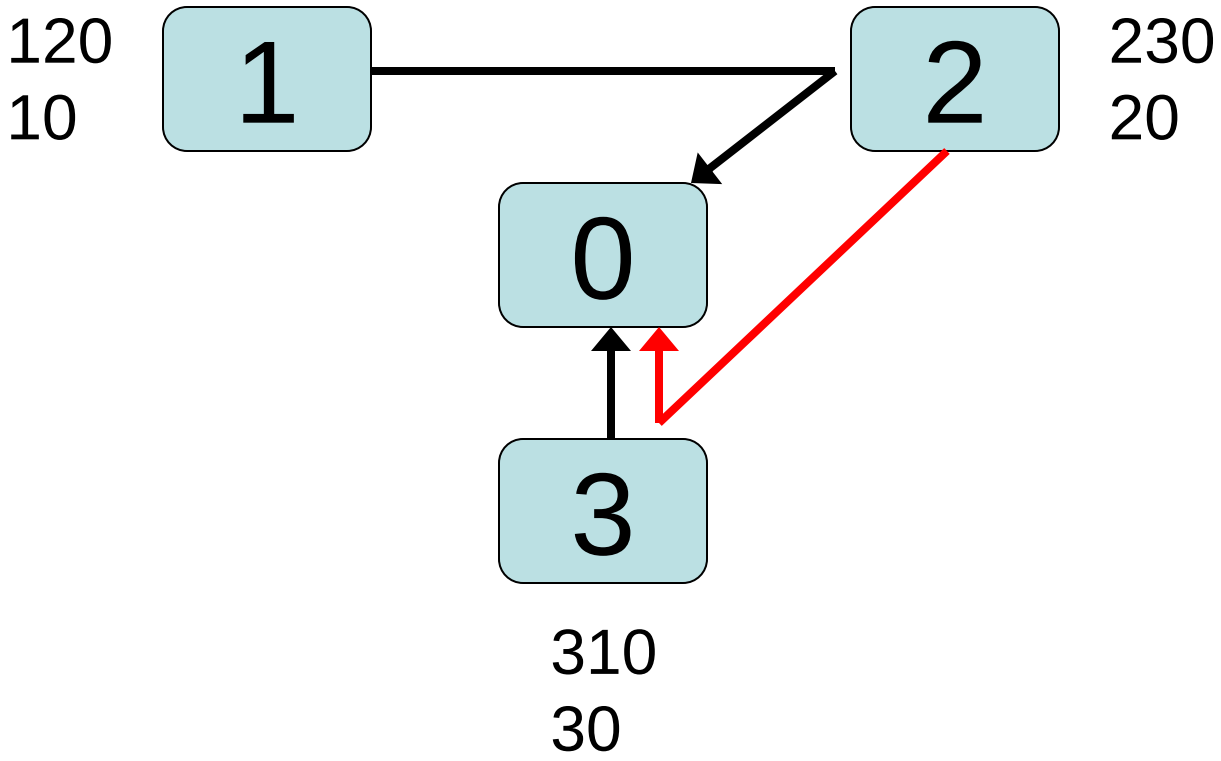
We view filtering as an inalienable right needed to implement contracts.

Safety

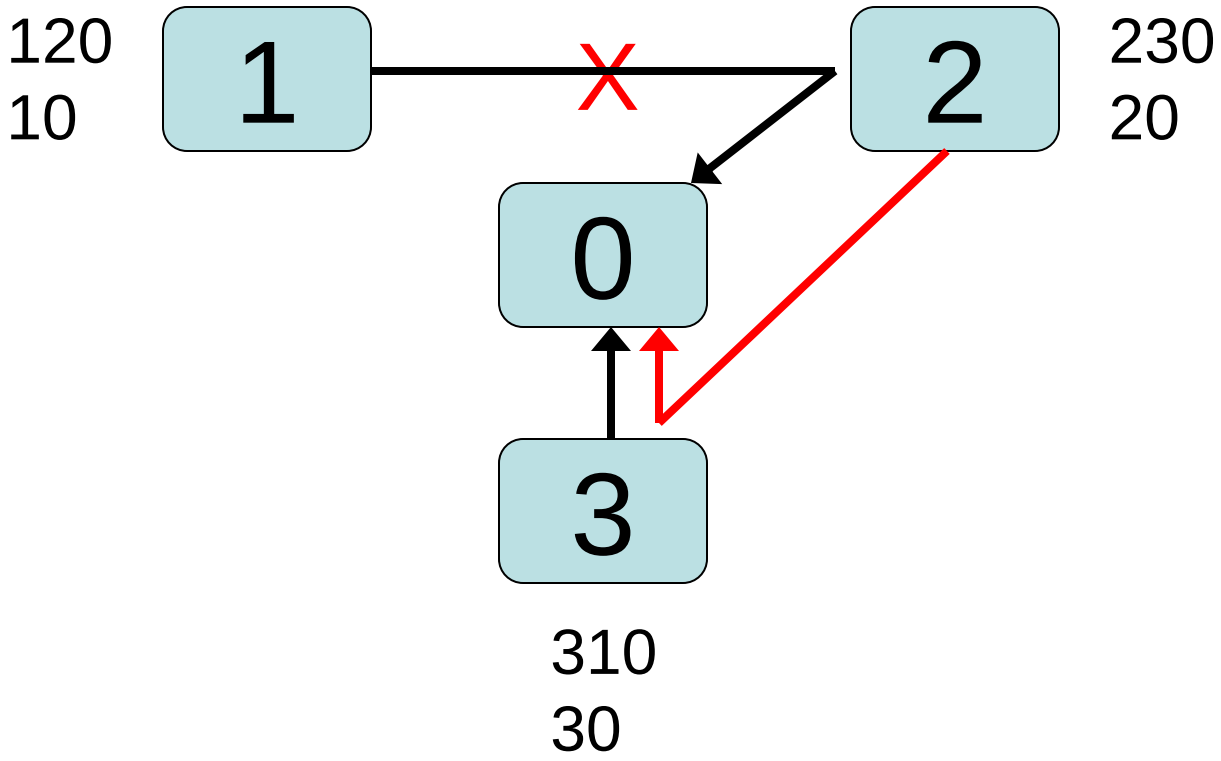
Policy expressiveness ⇒ oscillations.



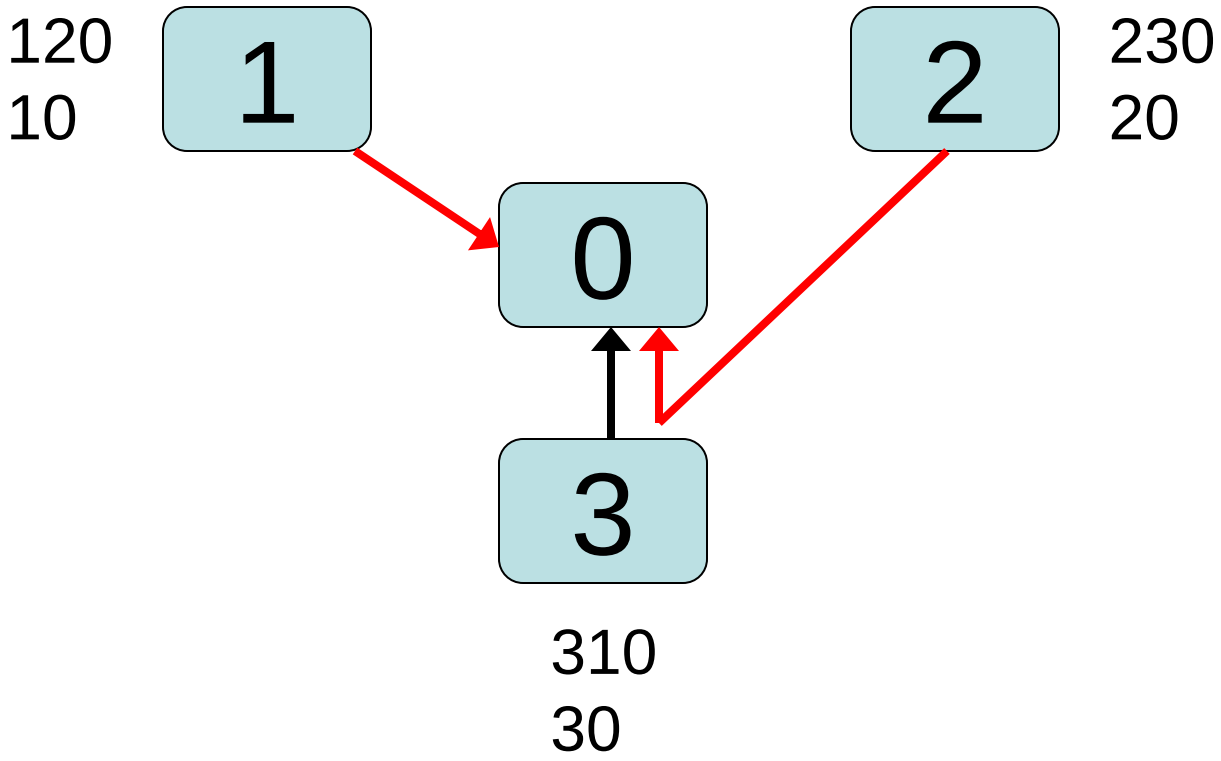
Safety



Safety

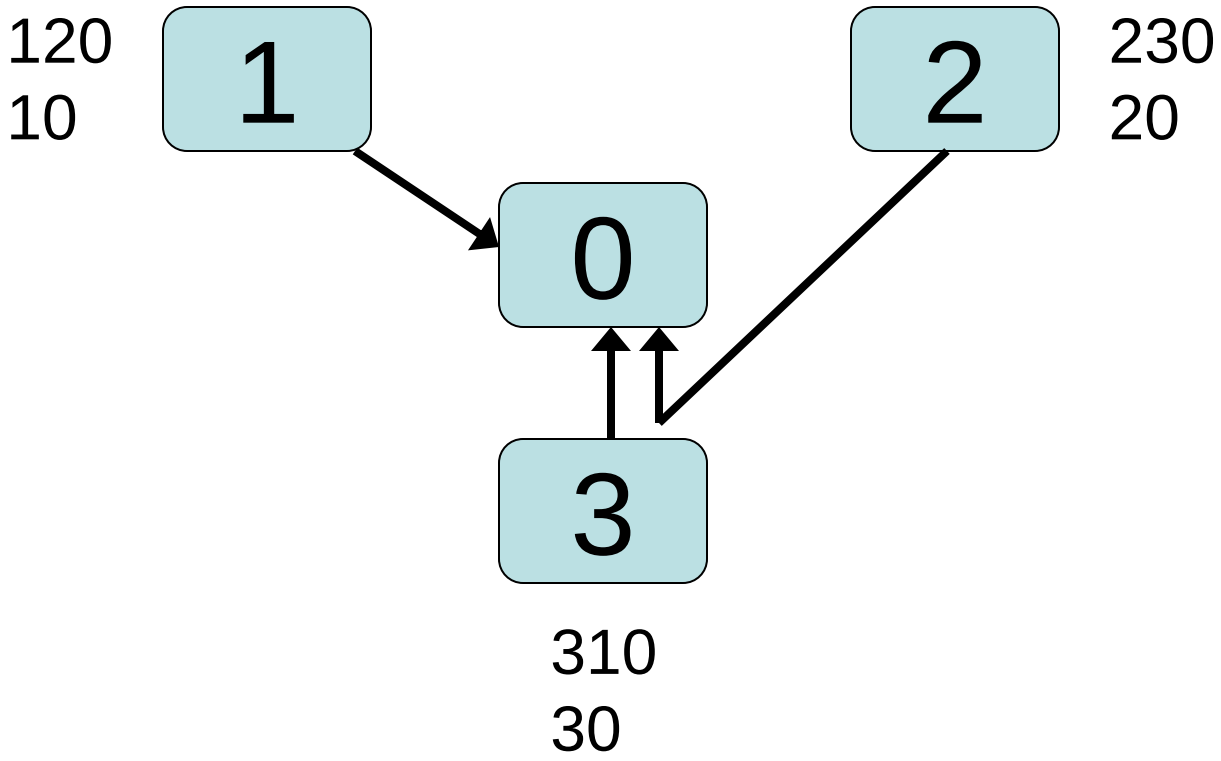


Safety



Safety

Now: permutation of initial condition.



Problem statement

We want:

1. Safety
2. Autonomy of policy choice
3. Unrestricted filtering

How must such a protocol constrain ranking expressiveness?

Main result

If providers choose rankings,
a protocol satisfying (1)–(3)
must (essentially) only allow
shortest hop count rankings.

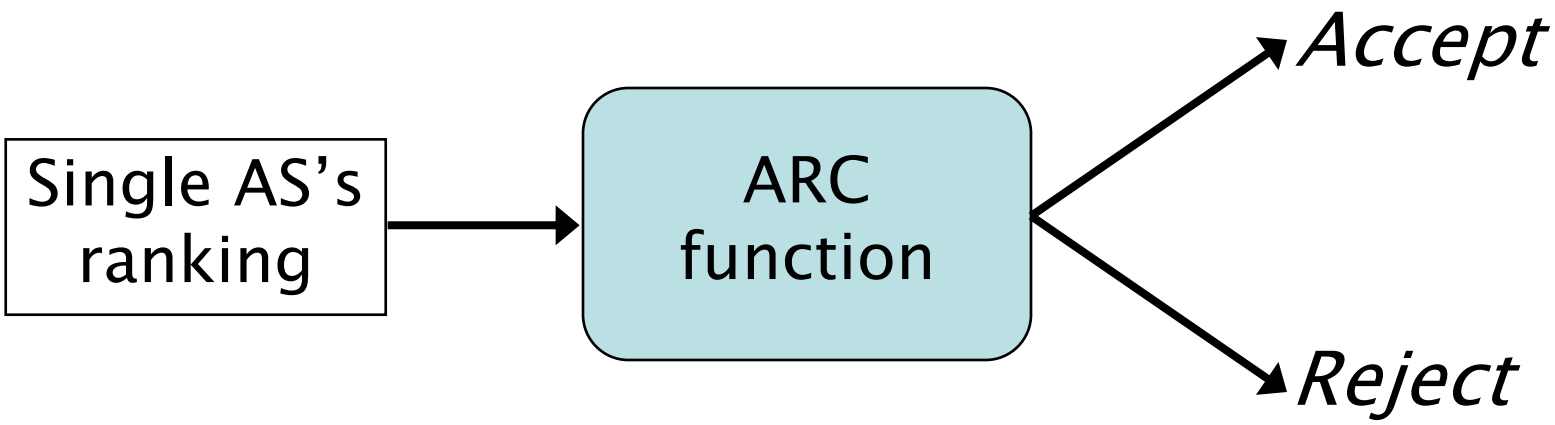
Global to local

Autonomy: providers locally choose policies.

ARC (autonomous ranking constraint) function:

An abstraction of a protocol that respects autonomy.

ARC functions

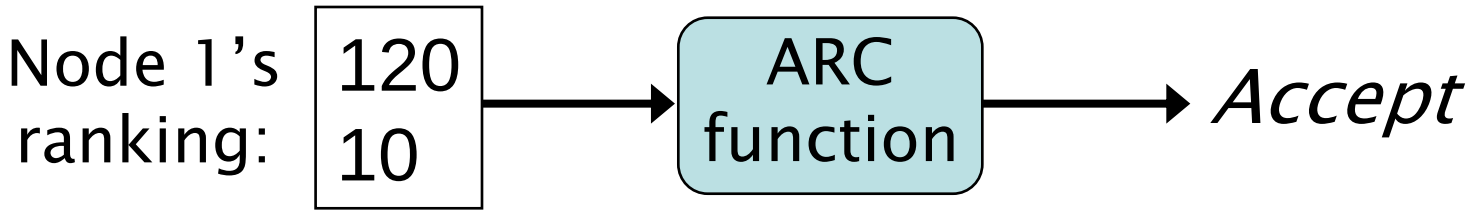


Note: acts on only a single ranking

ARC function properties

Permutation invariance

Node labels don't matter



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Permutation invariance

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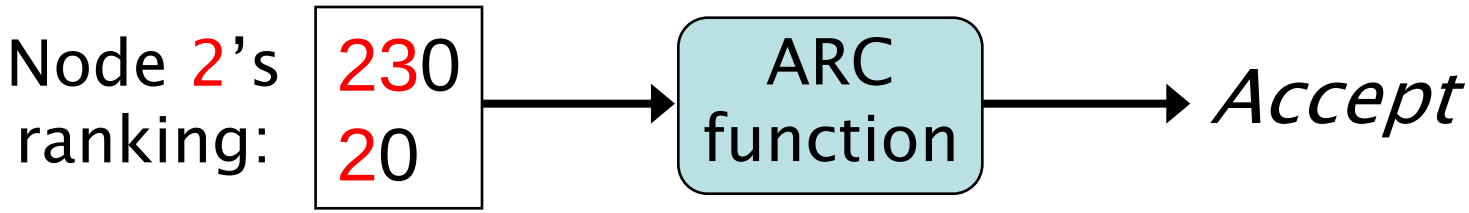

ARC function properties

Permutation invariance

Node labels don't matter

Scale invariance

Adding new nodes does not force a node to change its rankings over old paths

Example: Next-hop rankings

ARC function:

"Accept if providers rank routes based only on first hop."

Good: a fixed point always exists

Bad: May not converge!

"Impossibility" theorem

Consider an ARC function that
ensures convergence
regardless of filters chosen.

Then:

Any accepted ranking cannot prefer
a path longer than $n + 2$ hops
to an n hop path

Possible means of escape

- Derived rankings
- Global constraints

Derived rankings

We only consider protocols where providers directly choose rankings.

Instead, rankings could be derived from locally chosen parameters

Derived rankings

Ex 1: providers choose incident edge weights, protocol is shortest paths

Ex 2: strictly monotonic algebras (metarouting – Griffin & Sobrinho '05)

These are (strong) generalizations of shortest hop count; any others?

Global constraints

Could constrain filtering, ranking, and even topology at a global level

Intrinsically, requires sacrificing some autonomy

Summary

Economics meets engineering!

Tradeoff between

- convergent routing protocol
- expressive policy space
- provider autonomy