Abstractions for Network Routing

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Abstractions for Network Routing

Impressions of Network Routing

Neo-Dadaisms for Network Routing

Absurdisms for Network Routing

See also: Postmodern Routing

[Bhattacharjee, Calvert, Griffioen, Spring, & Sterbenz]

What routing abstractions facilitate flexibility and evolvability?

How can we quantitatively compare architectures and abstractions?

rather than just

performance of an implementation

Setting the Stage

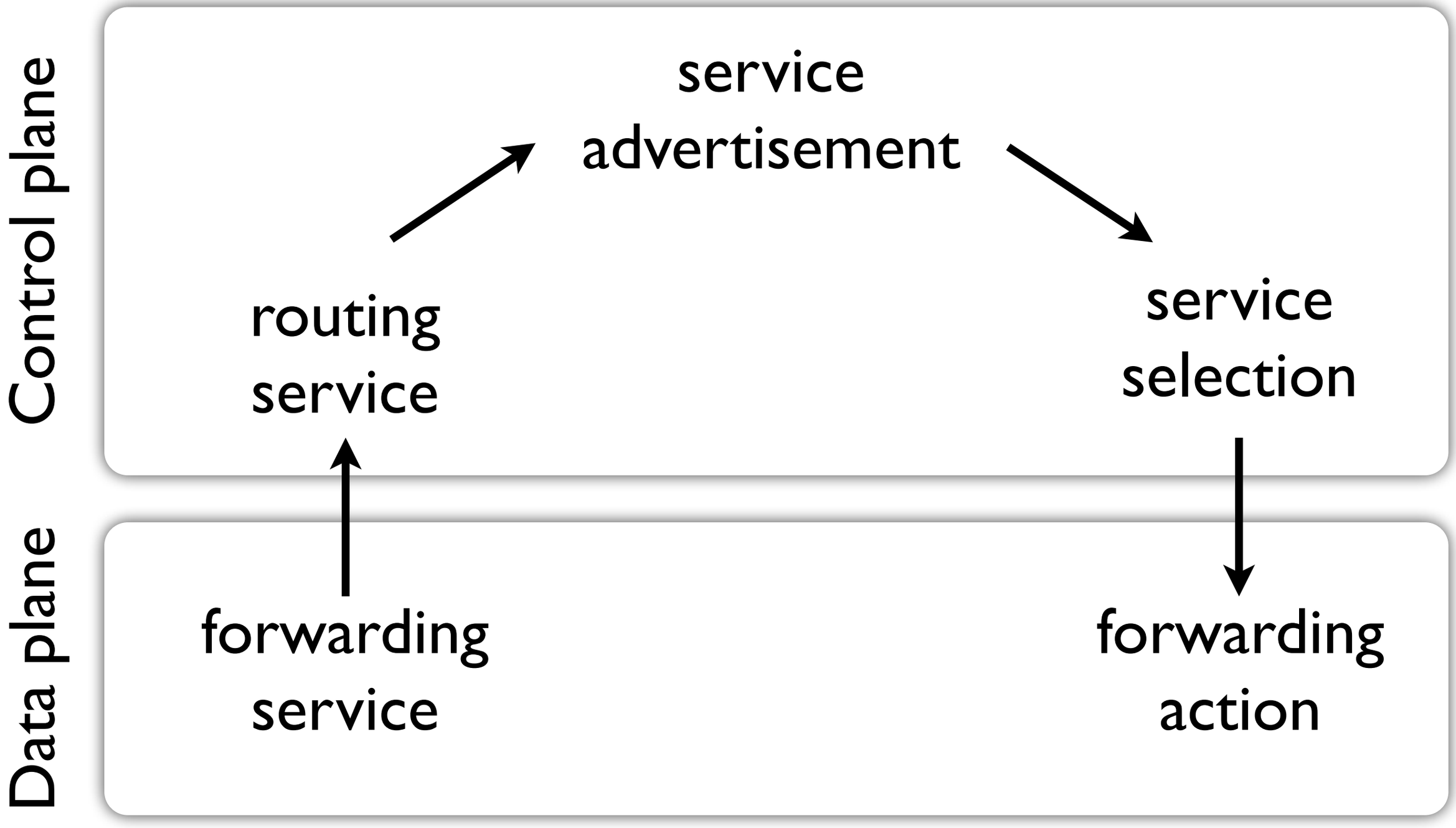
Routing Defined

Selection of path in network
along which to send message

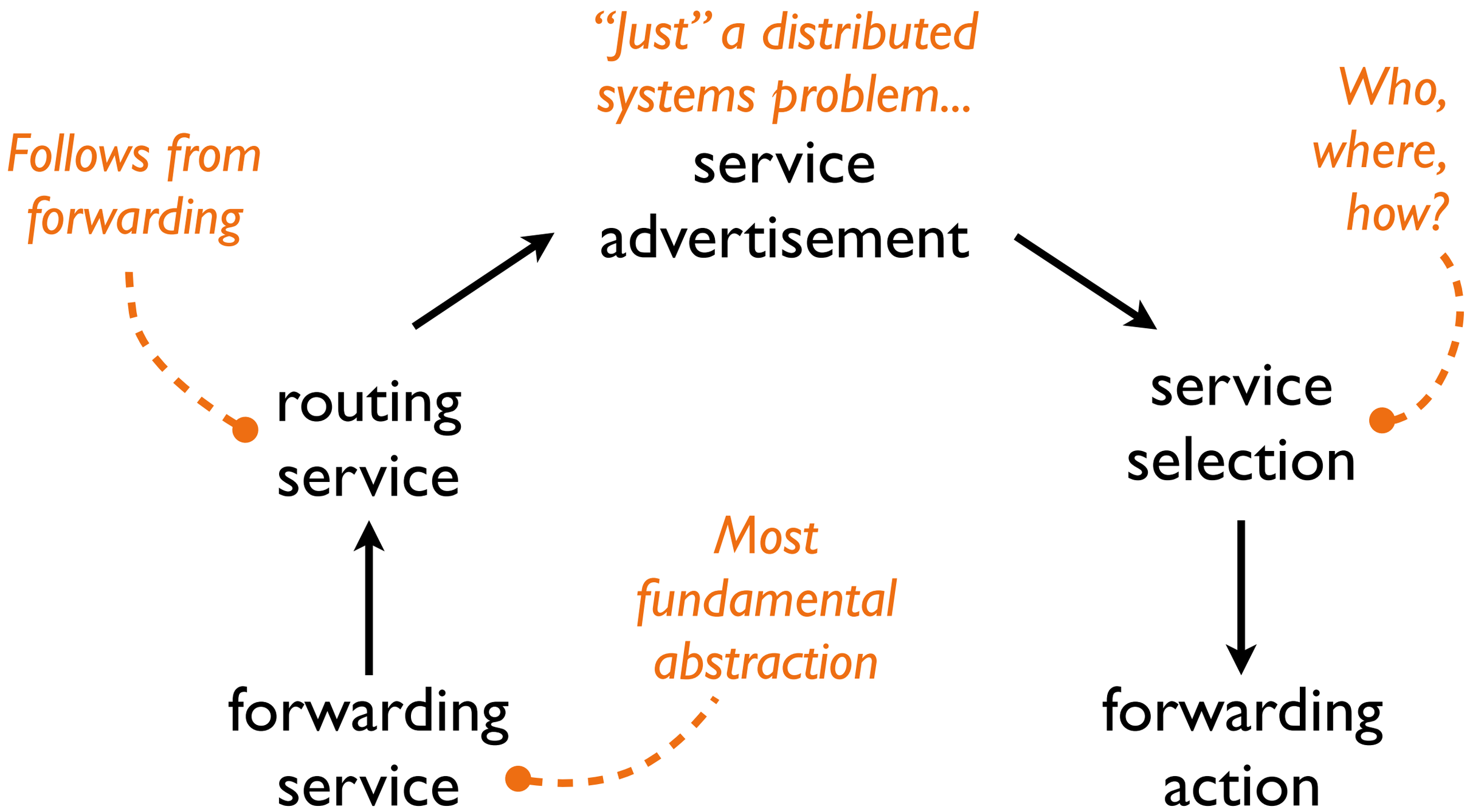
Routing Defined

Selection of services in network along which to send message

Components of Routing

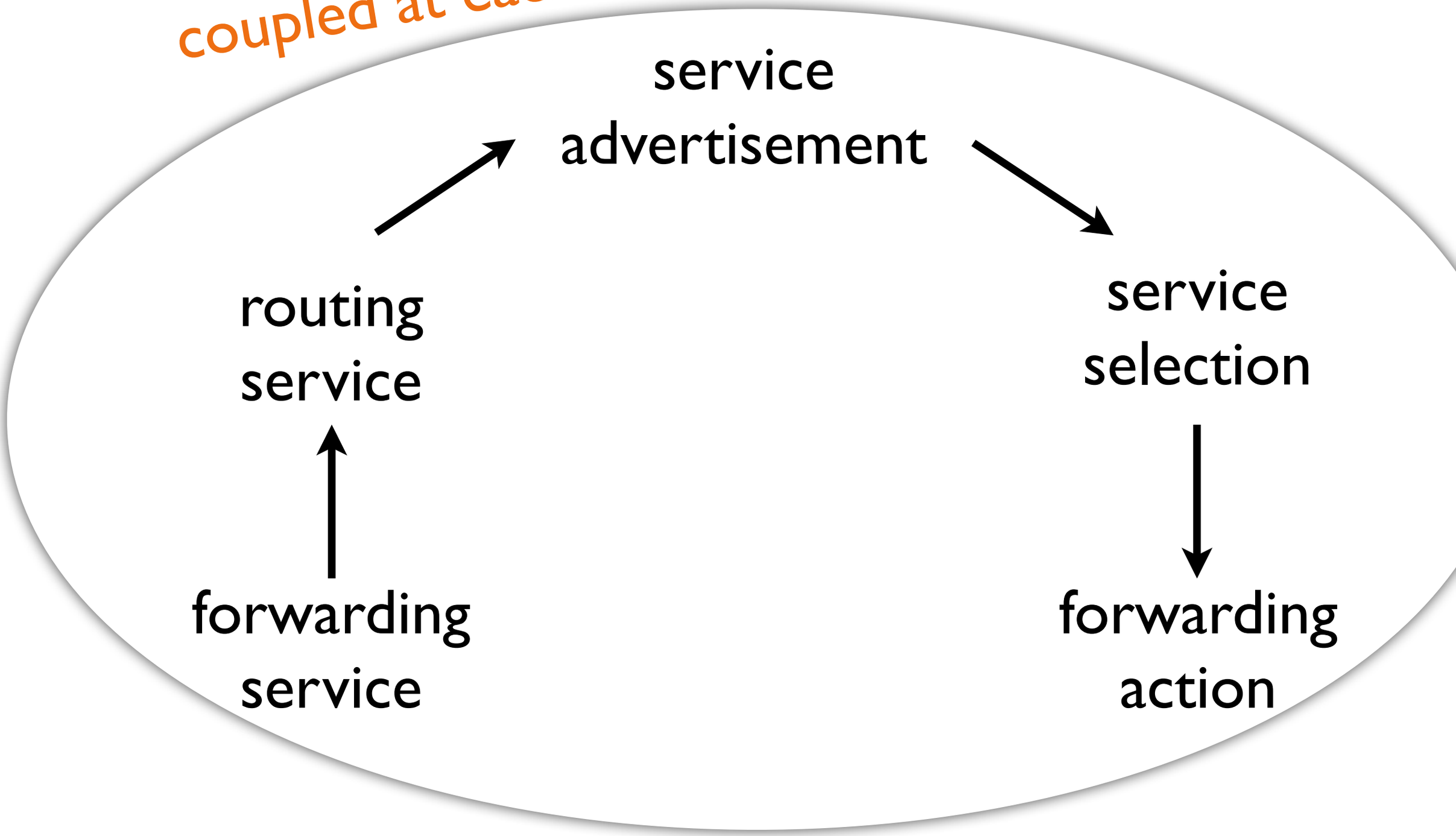


Components of Routing



Components of Routing

Today: all components coupled at each router



Summary so far

Key questions:

- What's the right abstraction of forwarding service?
- Who should choose the services and how?

Traditional (next-hop-style) networking: coupled

- Each router locally selects service, installs forwarding service, advertises directly to all recipients (neighbors)

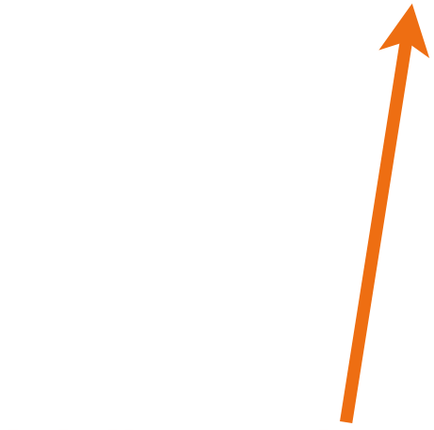
Software Defined Network: decoupled

- [forwarding] [service advertisement] [service selection]

Interdomain: ???

What problem are we solving?

- What's the right abstraction of forwarding service?
- Who should choose the services and how?



What do these this mean??

“Flexibility”

Today's inflexible routing: BGP

Routing fixed within the network, leading to:

- Unreliability (long convergence)
- Inefficient resource allocation (prefix-level load balancing)
- Insecurity
  - Even with Secure BGP, traffic attraction attacks
  - Each domain's security is dependent on the actions of many other domains between it and the destination

You get one path to each IP prefix, and this path may be broken, inefficient, or insecure.

Source routing for flexibility

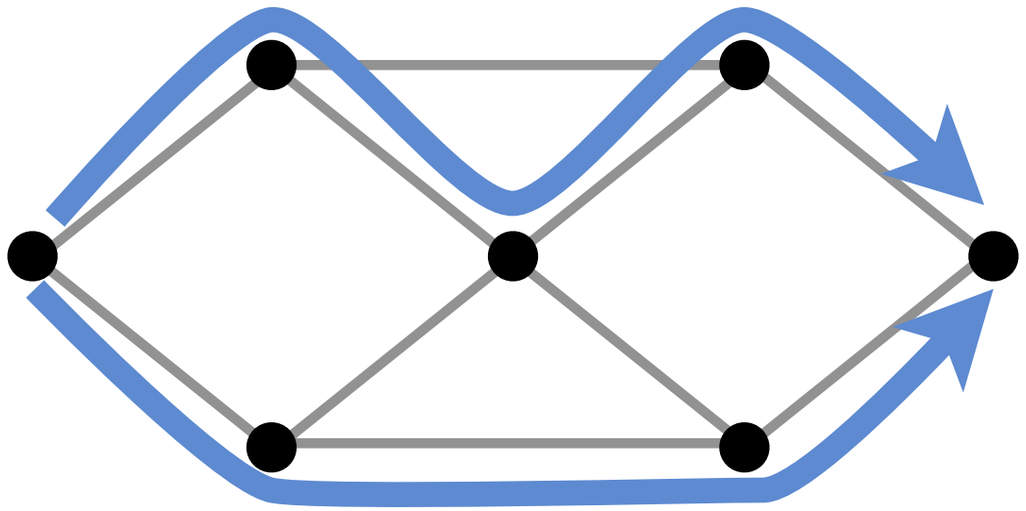
Separate route computation from the network

- Route (i.e., selected services) is parameter given to the network

Source routing for flexibility

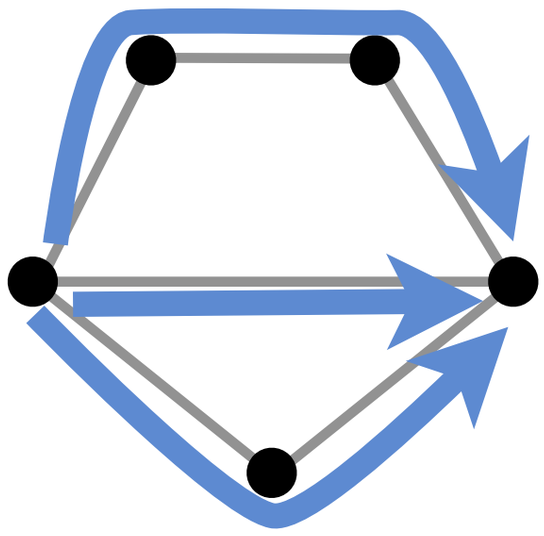
Reliability

source can
switch quickly
or use many



Path quality

source knows
what it wants



Lowest latency path

Highest bandwidth path

Path the network
would have picked for you

Security

Each domain can independently protect itself

Source routing challenges

Security

- Can attackers exploit route control? (Can defenders?)

Scalability

- How do sources quickly pick good paths without huge amounts of dynamic state distribution?
- "Eh."

Route control tussle

- How can an architecture enable source control yet still provide sufficient network owner control of routing?

Solving the route control tussle

Pick one "reasonable" tradeoff between source and network control?

- then get everyone to agree...
- then standardize it...

Better solution: design for variation

> *“Design for variation in outcome, so that the outcome can be different in different places, and the tussle takes place within the design, not by distorting or violating it.”*

— Clark, Wroclawski, Sollins & Braden, 2002
“Tussle in Cyberspace”

Pathlet routing

[Godfrey, Ganichev, Shenker, Stoica, SIGCOMM 2009]

vnode virtual node

pathlet fragment of a path:
a sequence of vnodes

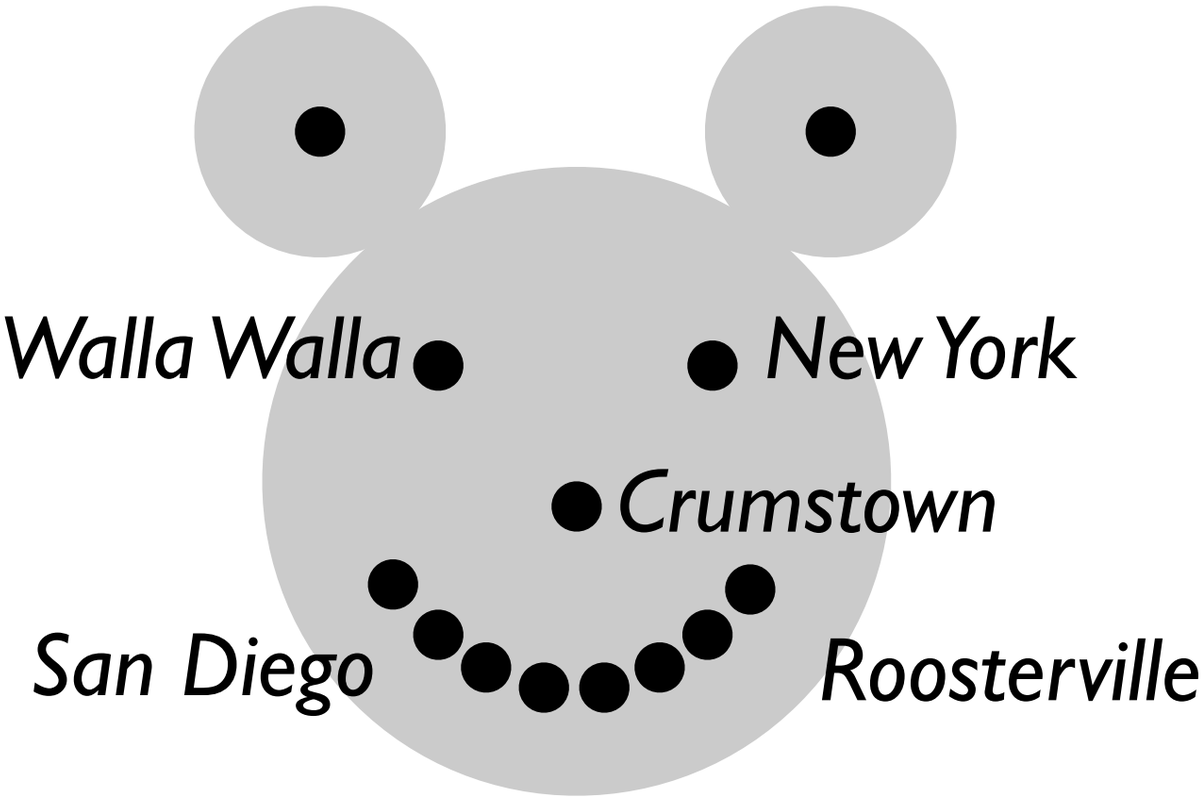
Source routing over pathlets.

virtual graph:
flexible way to define
policy constraints

provides many path
choices for senders

vnodes

vnode: virtual node within an AS

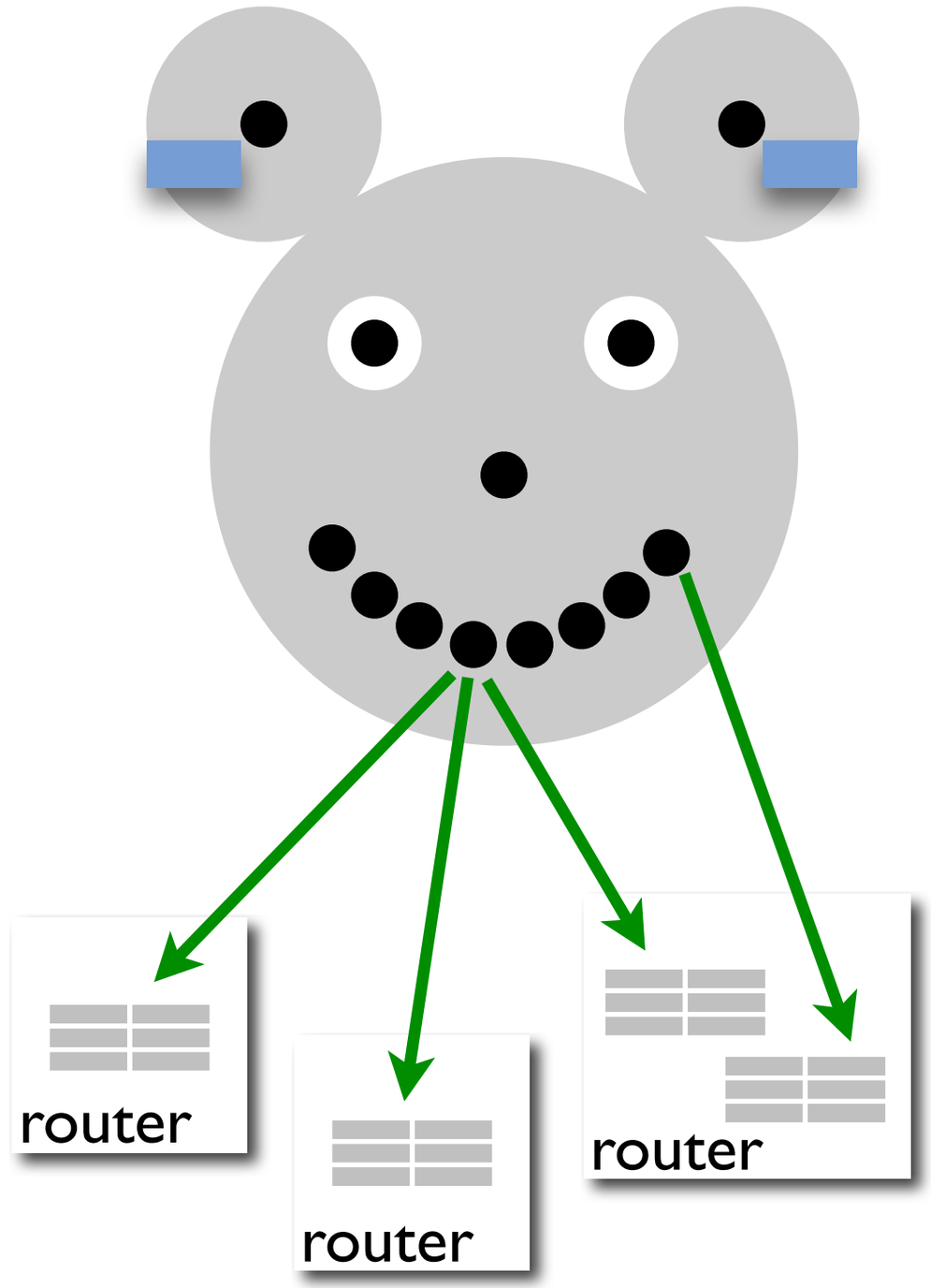


vnodes

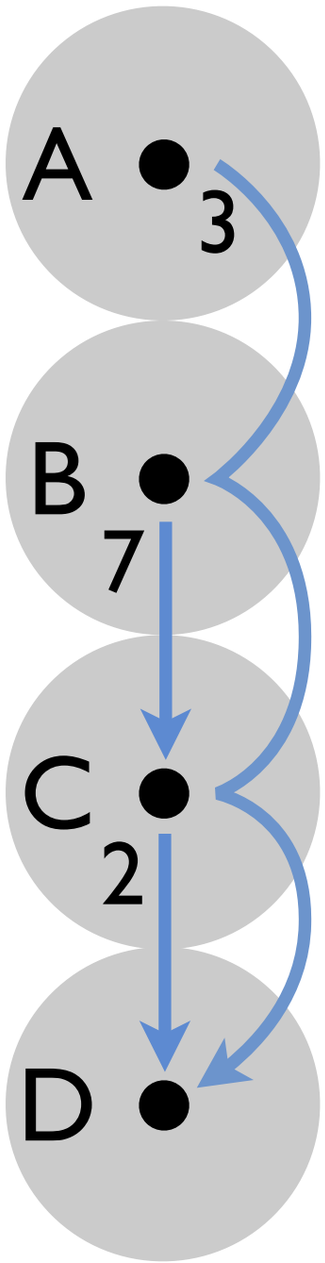
vnode: virtual node within an AS

designated ingress vnode for each neighbor

Internally: a forwarding table at one or more routers



Pathlets



Packet route field

Forwarding table

...	...
3	push 7,2; fwd to B

...	...
7	fwd to C

...	...
2	fwd to D

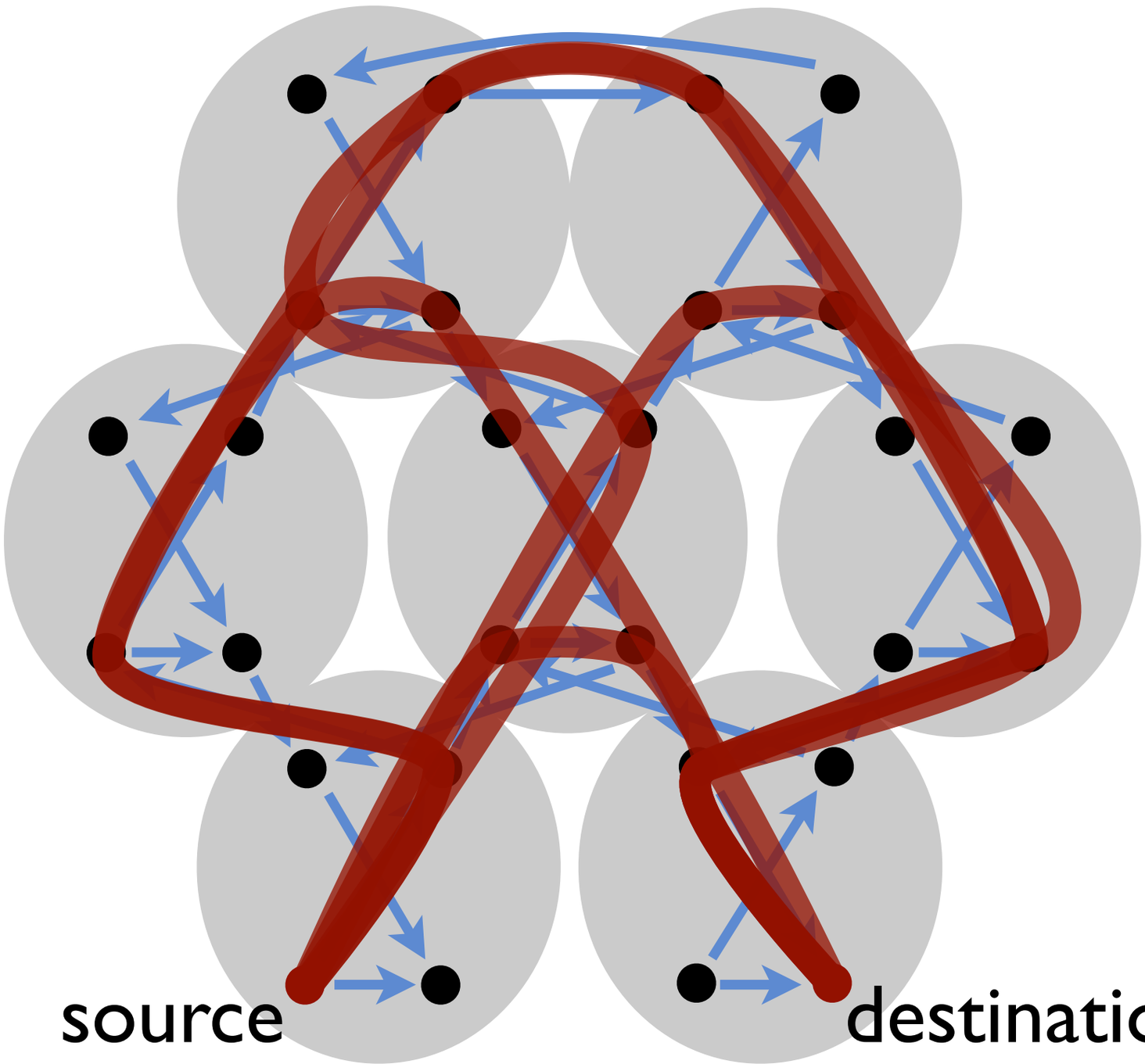
delivered!

So what?

For network owners,
flexibility to define
how the network
can be used.

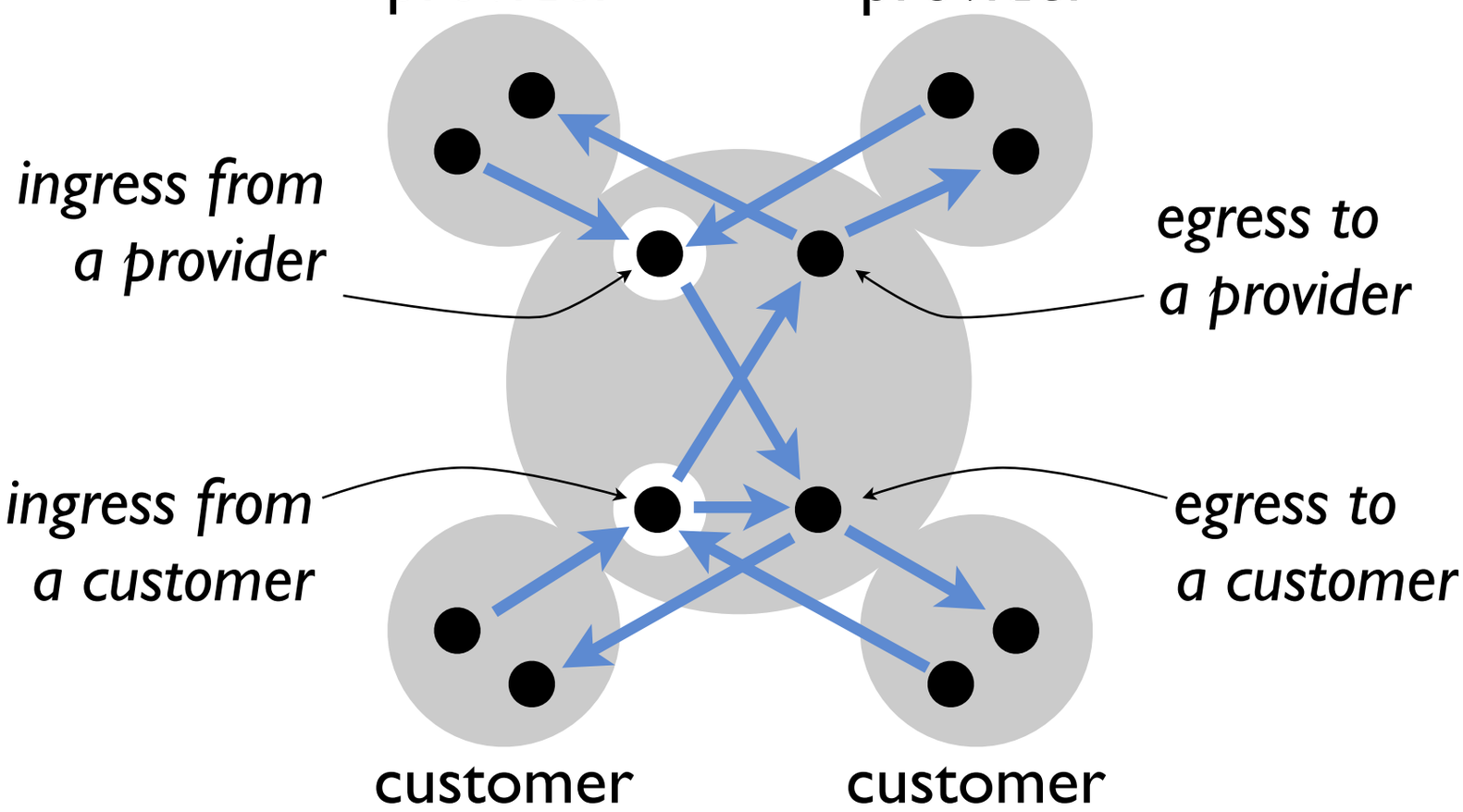
For users,
flexibility to choose
paths or services.

Choice for senders



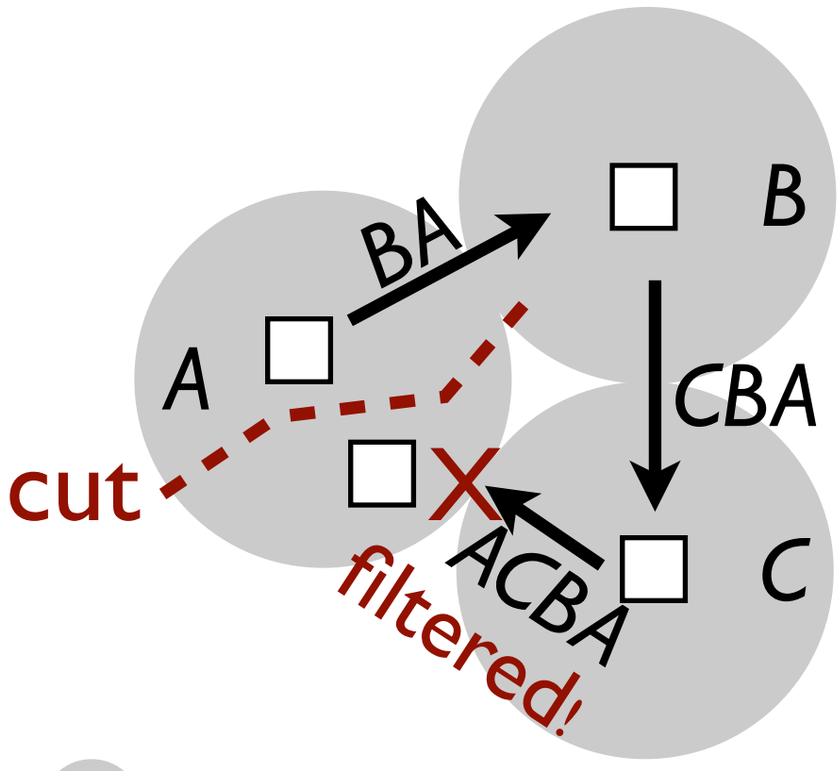
Example: allow all valley free routes

e.g., all valley free routes
("customers can go anywhere;
anyone can route to customer")

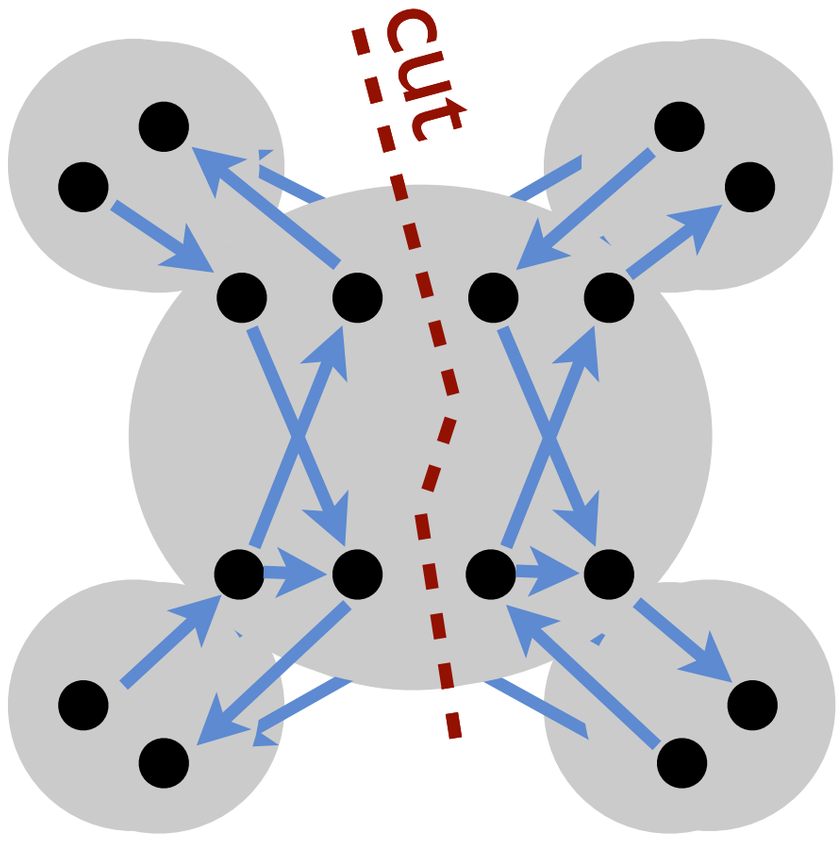


Example: flexible granularity

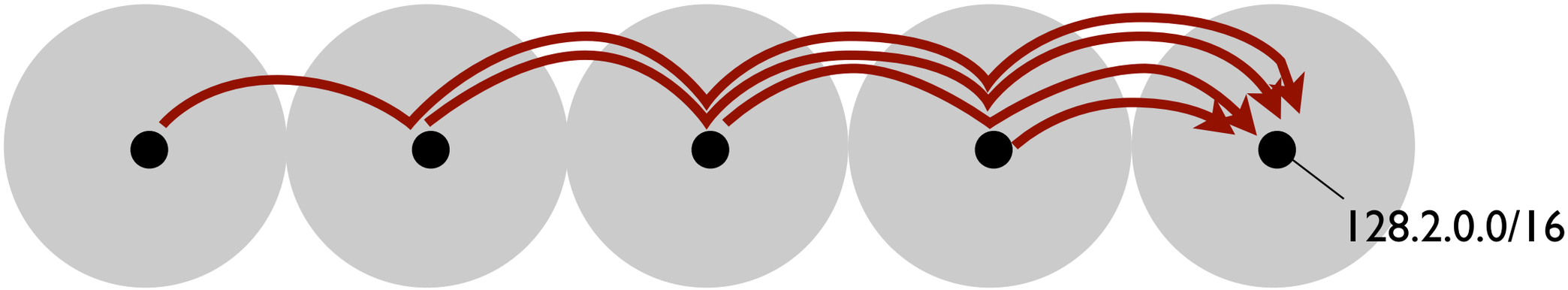
BGP



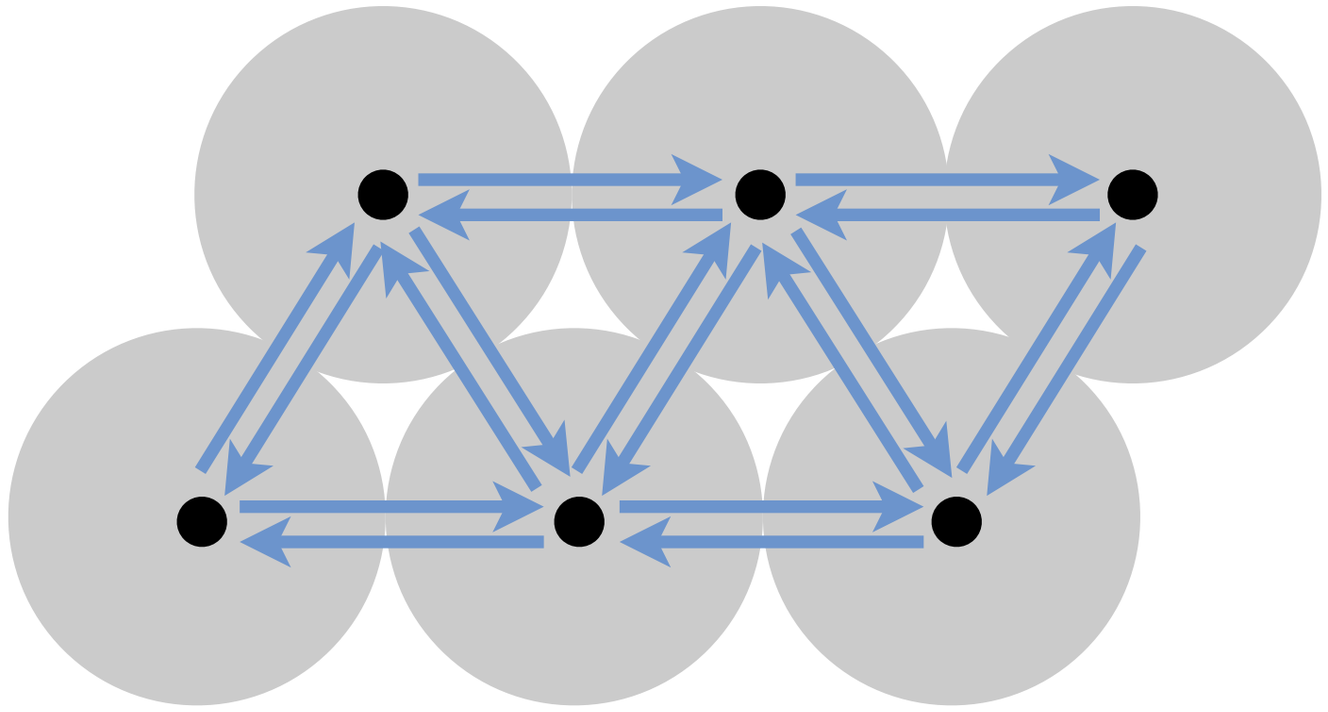
Pathlet routing



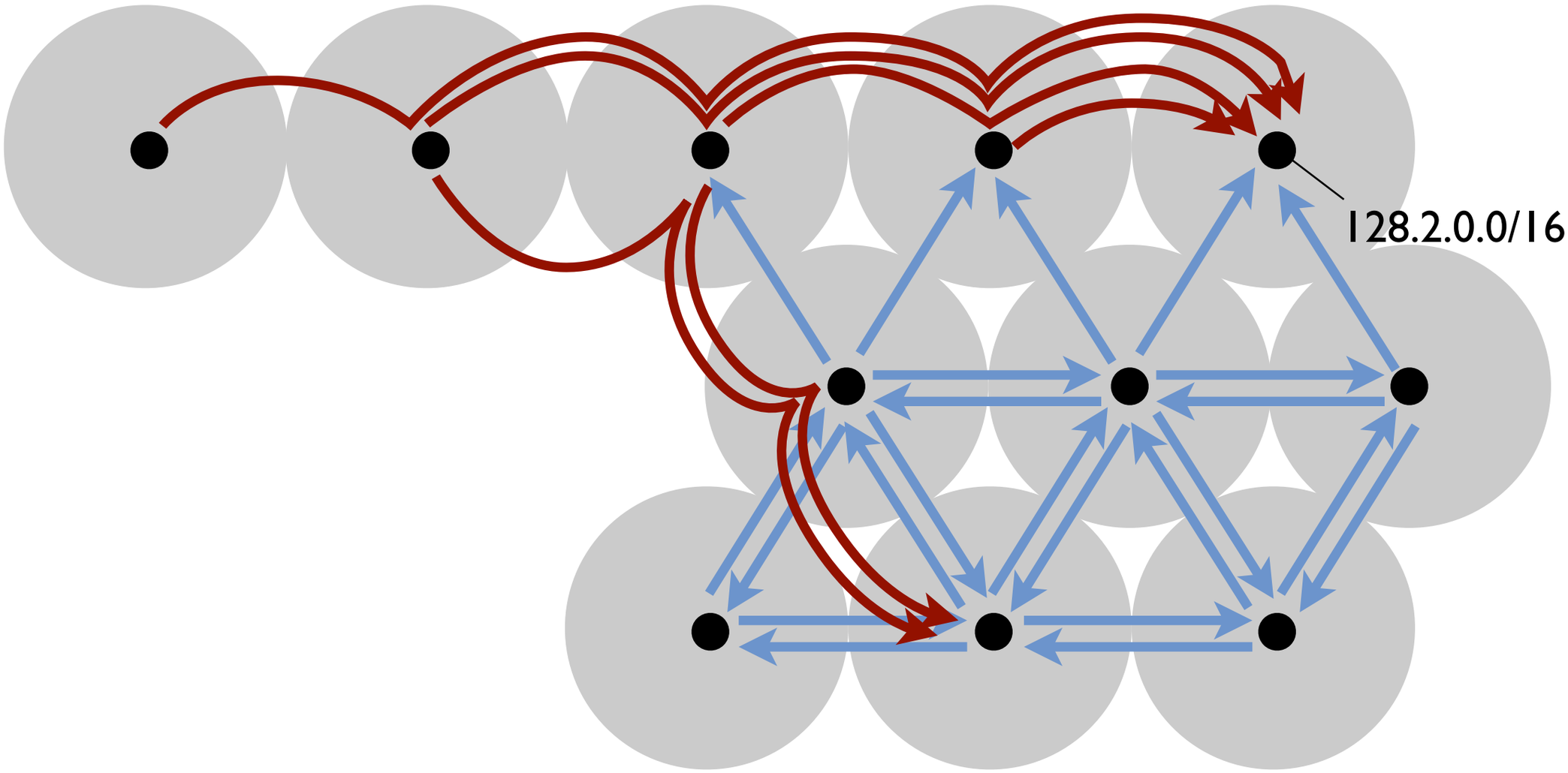
Flexible policies



Flexible policies



Flexible policies



Quantifying policy flexibility

“We don’t know how to figure out whether one of our ideas is better than another.”

— David Clark

Quantifying policy flexibility

Pathlet routing

Feedback-based routing

NIRA

MIRO

Loose source routing

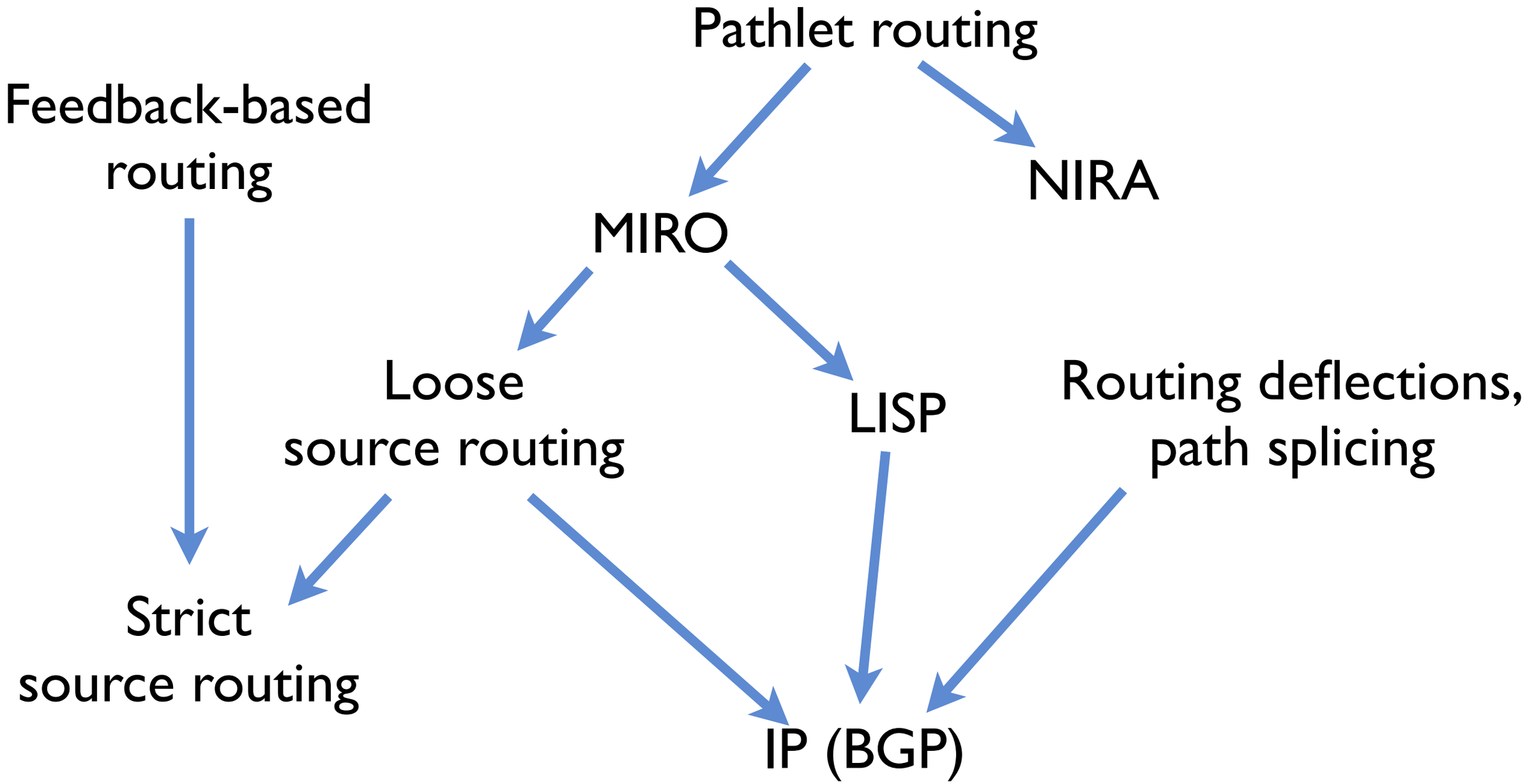
LISP

Routing deflections, path splicing

Strict source routing

IP (BGP)

Quantifying policy flexibility



“Evolvability”

Evolvability

Goal:

- Communication infrastructure for all of humanity

Only hope: evolve across time

- Ratnasamy, Shenker, McCanne [SIGCOMM'05]
- FII [CCR'11]
- OPAE [Ghodsi, Koponen, Raghavan, Shenker, Singla, Wilcox, HotNets'11]
- XIA [Anand, Dogar, Han, Li, Lim, Machado, Wu, Akella, Andersen, Byers, Seshan, Steenkiste, HotNets'11 & NSDI'12]

What is an evolvable architecture?

Our history: Not Good

IP options? Usually dropped

UDP? Sometimes dropped

Not HTTP? Sometimes dropped

...

Attacks on evolution

Useful frame of mind: Some parties will act to hinder evolution

- Apathy
- Security
- Government control

Therefore, should design architecture to defend against evolution attacks

- What abstraction yields "defensive evolvability"?

Quantifying evolvability (Toy Model)

Node state

- Legacy
- Attacker
- Deployed New Protocol

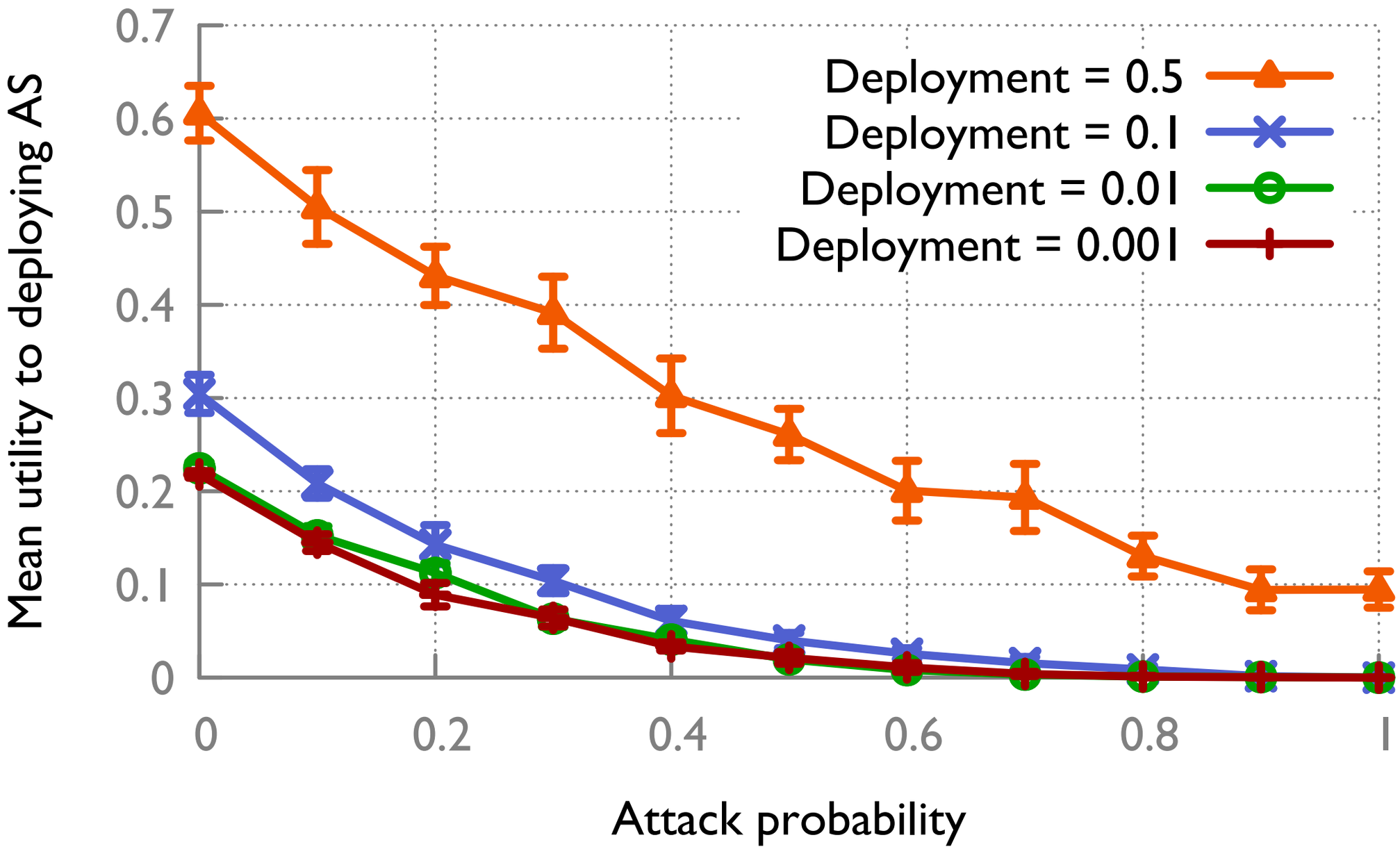
When can we run the New Protocol along a path?

- Source runs N.P. and no attacker on path

Utility of a path to source

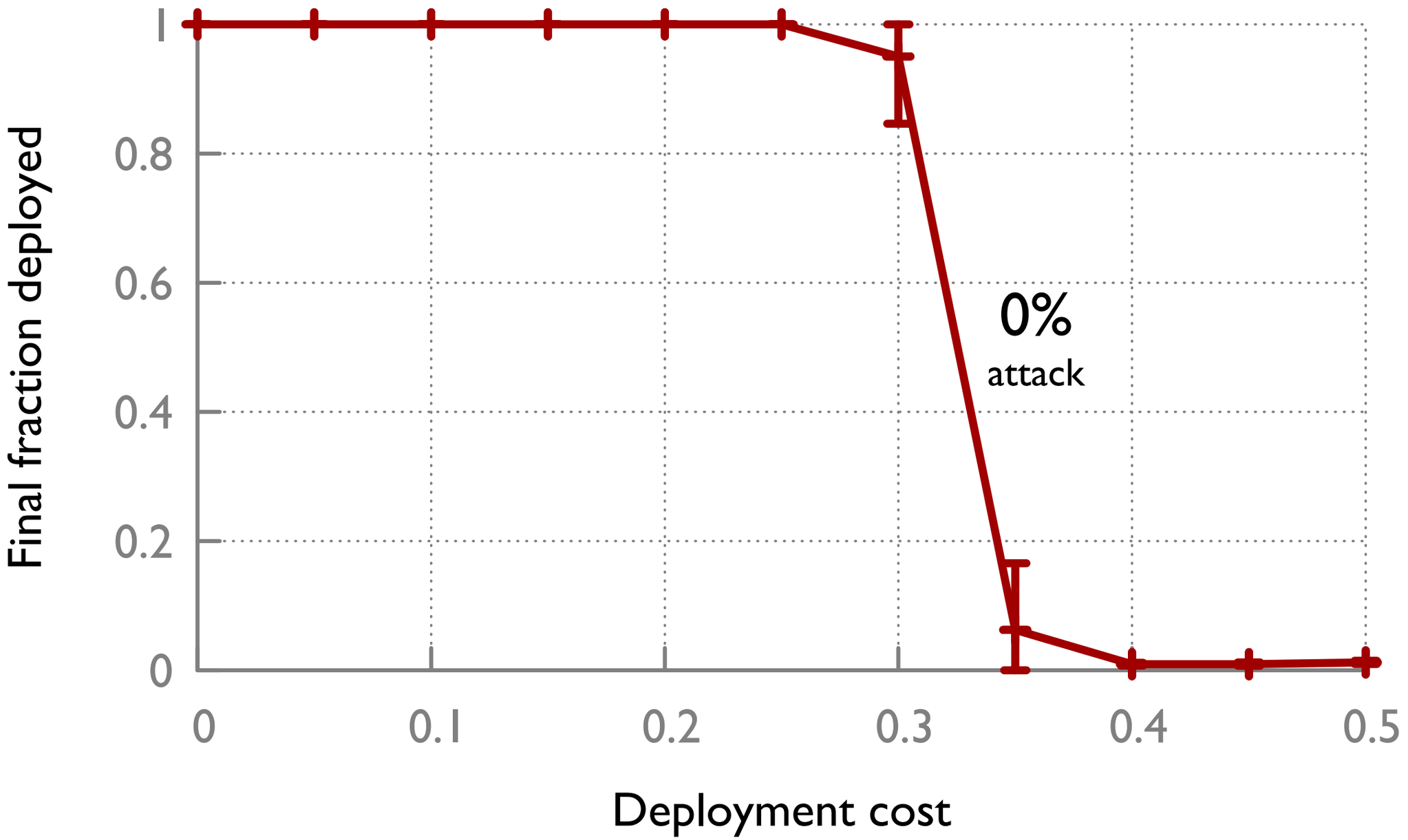
- 0 for old protocol
- ~ (#new hops) for new protocol

Attacks kill evolution: simulation



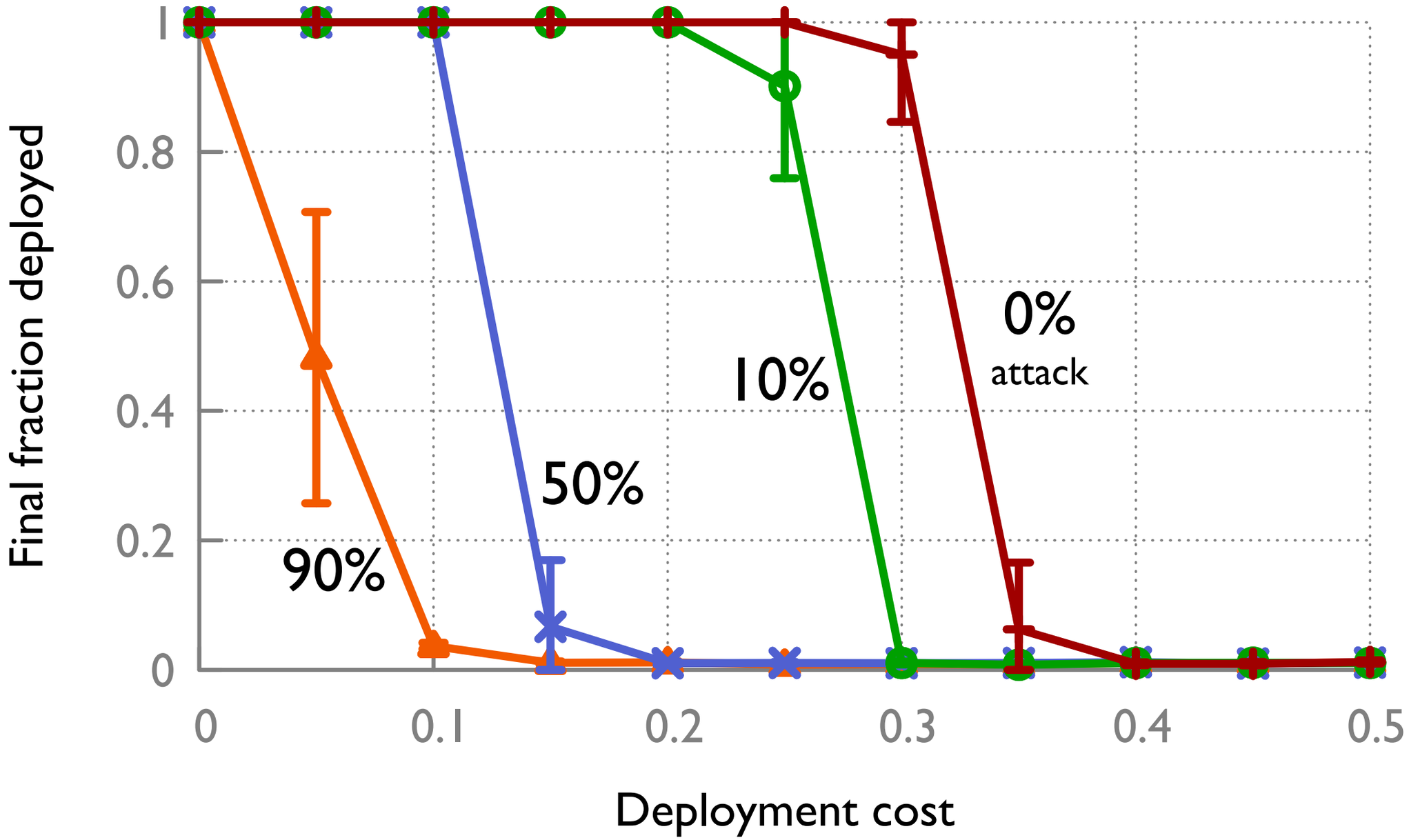
Simplistic simulation on CAIDA AS-level Internet topology (2011)
36,878 nodes, 103,485 edges

Attacks kill evolution: dynamics



Simplistic simulation on 500-node degree-5 random graph
1% initial deployment

Attacks kill evolution: dynamics



Simplistic simulation on 500-node degree-5 random graph
1% initial deployment

Case Study #1: Next-Hop Fwd'ing

Traditional IP routing & forwarding

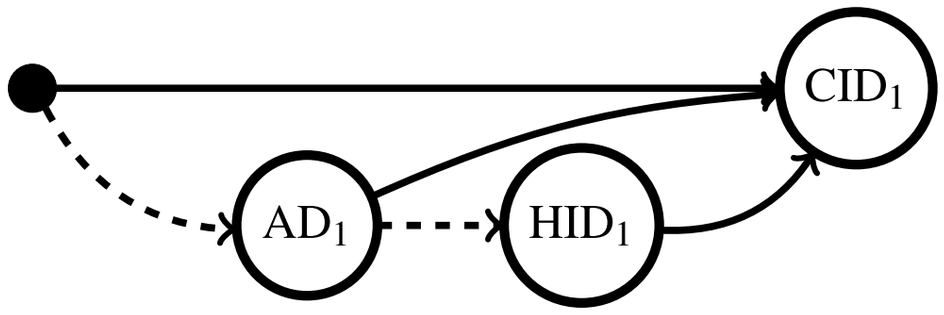
- Each router selects one hop of path (= service)

Result: all routers along path know, agree to, and select the end-to-end service

Case Study #2: XIA

"How should a legacy router in the middle of the network handle a new principal type that it does not recognize?"

- Fallbacks:



Result: Each router is explicitly aware of novel services being deployed

- Analogous to IP options
- Potential result: drop anything "weird" (e.g., security risk)

XIA is flexible, but is it really evolvable?

Defensive Evolvability

Hammer: Modularity

- Hide functionality from those who need not see it

AS/user should be able to unilaterally deploy a new type of connectivity service

- ...without approval of parties used to reach that service
- ...and without them even knowing!

Rough solution: pathlets++

- Each segment is a general "function" rather than just a link between two vnodes

Putting together the pieces

Observations

1. Flexibility and evolvability come from modularity

   - "the degree to which a system's components may be separated and recombined" – wikipedia

2. The principal function of networks is connectivity

3. Need clean abstraction to recombine connectivity

4. Hypothesis: The current architecture lacks such an abstraction

   - Instead of one reusable abstraction, we keep inventing special-purpose tunnels: overlay networks, VPNs, ports, ...

Vasily Kandinsky
"Small Worlds"
1922