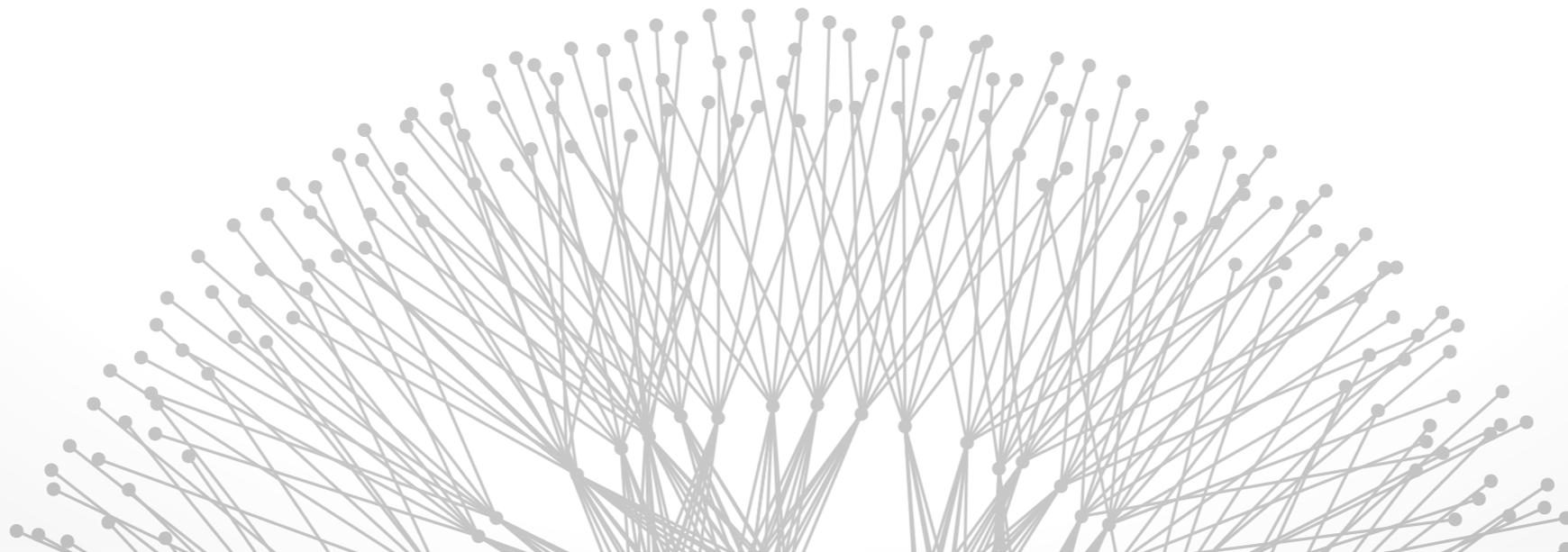


Future Internet Architectures

Matthew Caesar
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“Tussle in Cyberspace”



[Clark, Wroclawski, Sollens, Braden, ToN'05]

Tussle: process of “contention among parties with conflicting interests”

What tussles have we studied this semester?

"Tussle in Cyberspace"



What tussles have we studied this semester?

- **Congestion:** selfish user behavior; ISPs block apps; etc.
- **Content access:** countries & ISPs censor & block for security; users circumvent with Tor
- **Routing policy:** conflicting preferences cause divergence
- ...

Key point: Design of protocols shapes how tussles play out in the running system

Example 1: Control of routes



Current Internet: routes fixed within the network

- Each router makes part of the route choice
- Picks one route per destination & advertises that one

Technical problems

- Single offered path may be broken, congested, insecure
- Decision-makers (in the network) may not have useful information (at end-hosts)

Tussle problems

- Parties disagree on what is a “good” path
- Lack of choice discourages competition



Architecture exacerbates tussle: no way to enable choice even if involved parties want it

- In IP, typically just get to specify destination
- No infrastructure for exposing extant choices

One solution: **separate routing from the network** by letting sender specify a route in packet

- Switch quickly in response to end-to-end failures
- Use multiple routes simultaneously
- Better load balance, more efficient use of capacity
- Competition among providers

Pathlet routing



[Godfrey, Ganichev, Shenker Stoica, SIGCOMM '09]

Idea: separate route computation from the network

Refined idea: route in a **virtual topology** which can flexibly represent policy constraints

- For network owners: **flexibility** to define how the network can be used, via what virtual links (pathlets) are advertised
- For users: **flexibility** to choose paths or services defined by any concatenated sequence of advertised pathlets

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

Example 2: Naming & Addressing

Naming & addressing



Originally “just” technical problems...

- **Address:** indicates location, convenient for routing
- **Name:** location-independent, convenient for human

...all wrapped up in tussle

- Names tied to trademarks
- Addresses difficult to change (and now scarce for IPv4!)

How would you fix this?

Modularize to protect the system



Principle: Modularize along tussle boundaries

- Separate task of location independent identification of endpoints (hosts/services) from tussle spaces

Possible implementation: flat names

- Endpoint identifier (EID): Just a bag of bits
- Human-readable name maps to location-indep. EID
- Location-independent EID maps to address

Or, can we route directly on flat names?

- VRR, ROFL [Caesar et al, SIGCOMM'06]
- Disco [Singla et al, CoNEXT'10]

**Architecture:
not just about tussle**

Architecture beyond tussle



Security / accountability

Privacy

Mobility

Scalability

Content-awareness

- Next up!

Evolvability of the architecture itself

...

Discussion (1)



Paper's approach: “design for variation” to accommodate tussle

Alternate approach: ossify the architecture to take a moral stand and make it hard for tussle to change it.

When might the second choice be a good thing?

Discussion (2)



Game theory models tussle but **assumes rationality**.
What are examples of when rationality is a good or bad assumption?

How would you fix the model?

Discussion (3)



We're told that the Internet architecture has "ossified". But given competition and ongoing tussle, isn't it always evolving?

Announcements



Homework due Thursday 11:59 p.m.

Office hour Wednesday 5:30 - 6:30 p.m.

Thursday: Wireless

- **They can hear your heartbeats** (Gollakota, Hassanieh, Ransford, Katabi, Fu, SIGCOMM 2011)