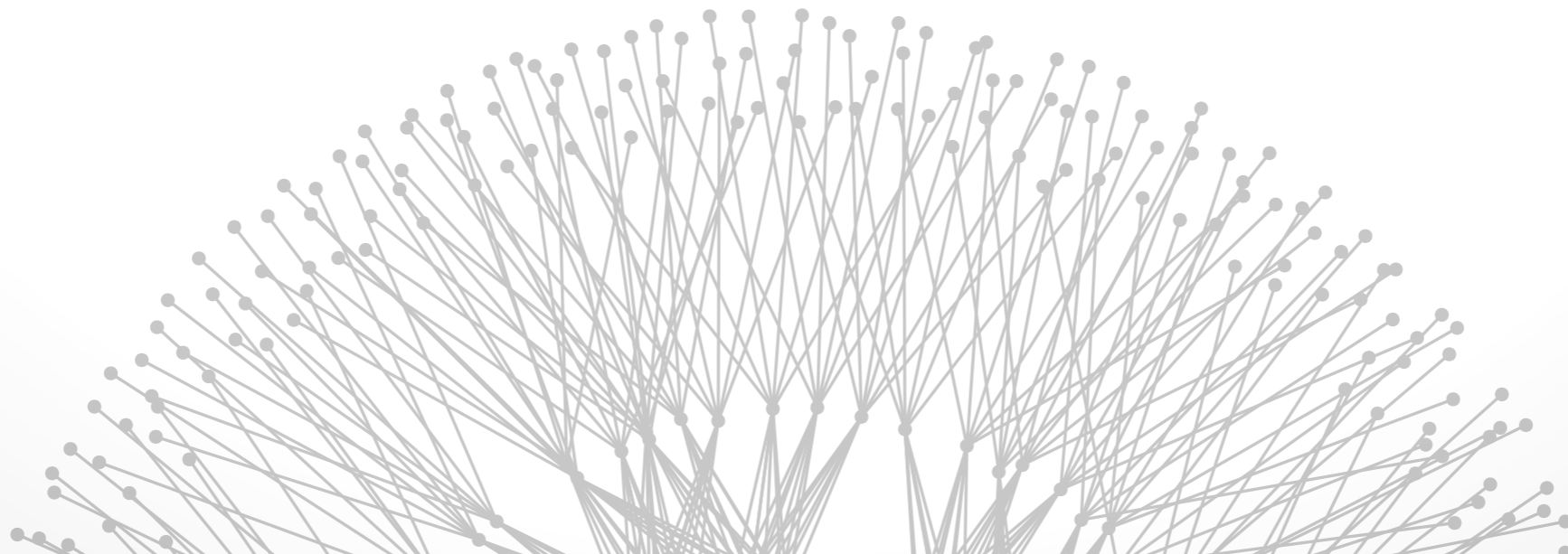


# Future Internet Architectures

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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)