# Software Defined Infrastructure: a direction for networked computing

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# Topics today

- Routing
  - Interdomain name-based networking
  - FIB/RIB Route Lookup
  - Estimation of traffic matrices
- Novel techniques
  - Hiding mobility, multiplexing, and multi-homing from an application
  - Experimentation with IP Multicast
  - AQM experimentation
- Content
  - Caching for content-centric networks
  - Interactions between Youtube video and Facebook users
- Interesting:
  - Some topics relatively far out
    - name-based and content-centric networks
  - Some topics looking to improve today’s network
    - The rest
- Industry perspective
  - That’s good
  - We need help today, and direction for tomorrow

# I’d like to discuss…

- Changes happening in the industry, in data center, enterprise, and service provider networks
- Principles that, if applied, will help research to influence the global network

# Post-Snowdon: pervasive encryption

- Making some waves…
- Today, mobile 3G/4G/LTE networks provide value-added services that insert ads or re-route traffic to cached content
  - Selected by mobile network, not user
- Starting to see http 2.0 (SPDY) proxy networks that prevent that
  - Re-routes all HTTP traffic, TLS encrypted, to Google servers that act as “trusted proxies”
  - Selected by Chrome browser, not user
- “Don’t be evil”…

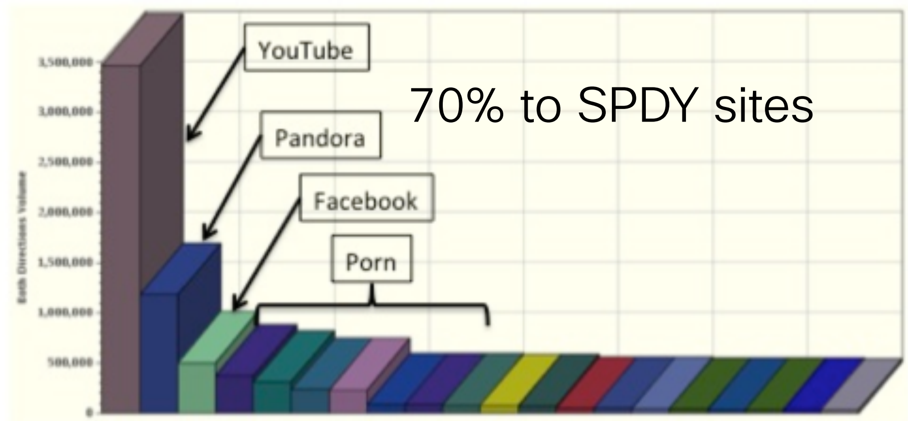



Figure 1: Mobile Streaming Destinations

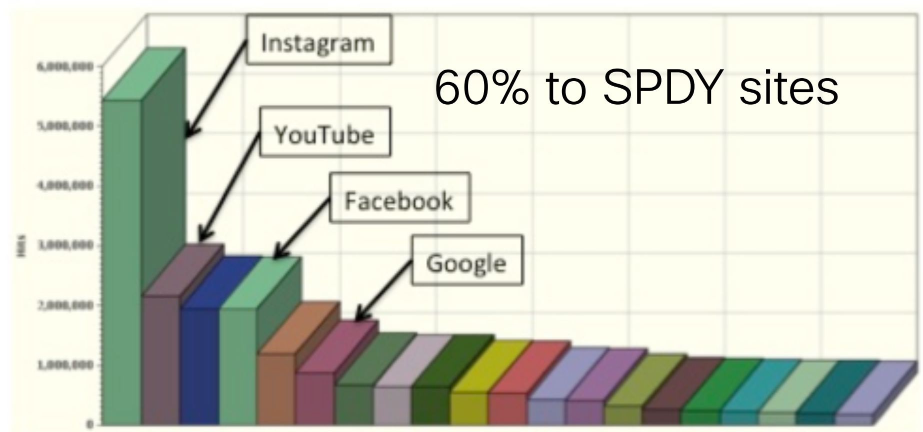



Figure 2: Mobile HTTP Destinations

Data from a nameless mobile customer

# KAIKAKU FOR IP NETWORKS
## INDUSTRY LEADERSHIP

### From

IPv6, MPLS, PPPoE, DHCP, IPv4, Tunnel, TE, FRR, MPLS TP, OTN, XXX GE, GMPLS, ATM, SDH

### To

IPv6, DHCP, Tunnel, XXX GE

**TeraStream**

- Drastic simplification of IP networks
- IP&Optical integration
- Infrastructure Cloud model

# IPv6 deployment

- Growing allocations
  - APNIC, RIPE, LACNIC, and ARIN now below one /8 of IPv4
  - About 17% of AS's worldwide have IPv6 allocations, and growing
  - http://v6asns.ripe.net/v/6?s=_ALL;s=_RIR_RIPE_NCC;s=_RIR_ARIN;s=_RIR_APNIC;s=_RIR_LACNIC;s=_RIR_AfriNIC
- Growing traffic
  - US: today about 7% of traffic. May 2015, 13-20%
  - Germany: today, about 8% of traffic. May 2015, 18-50%
  - Consistent with standard logistic curve
  - https://www.vyncke.org/ipv6status/project.php
- Facebook internally IPv6-only for most services
  - Reason: reduction of cost in various forms
- Consistent with projections showing IPv6 replacing IPv4 over time

“When will SDN have universal deployment?”

(Question I was asked not long ago by media)

Software Defined Networking

- Not a technology: It’s a paradigm
- Many implementations calling themselves SDN

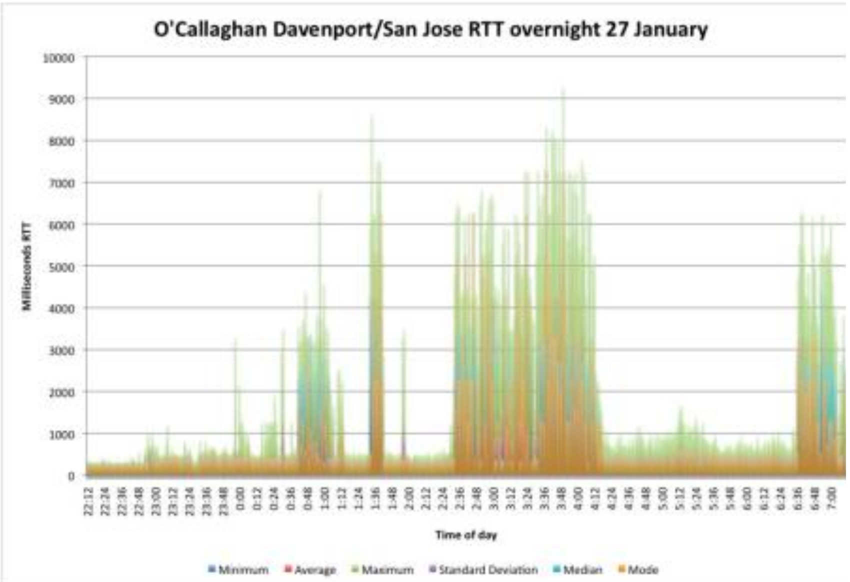
Key characteristics:

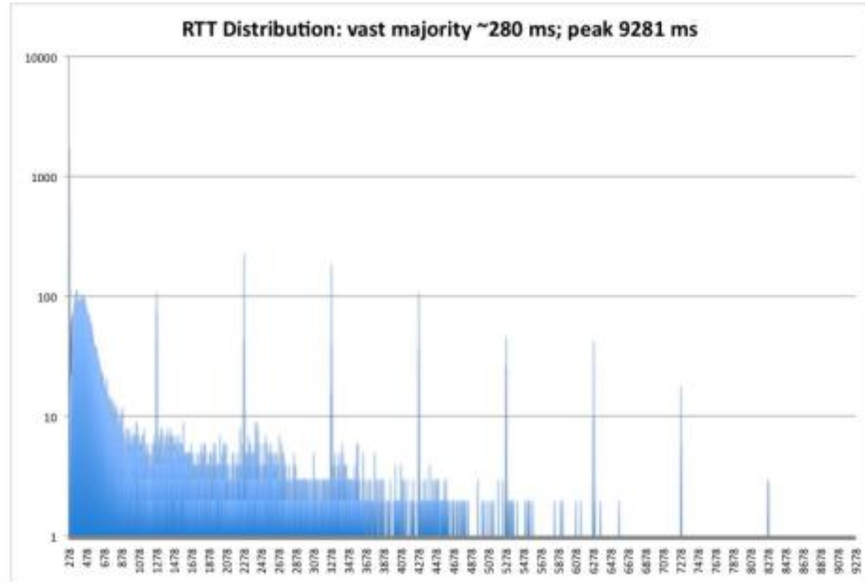
- Centralized configuration management
- Often centralized routing control
- In data centers, network and host virtualization (“cloud”)

Widely experimented with, no single solution at this point to say is “deployed”


http://en.wikipedia.org/wiki/Hype_cycle

# Things I'm thinking about…
# Data Center Latency Control




Best shown using an example…

Ping RTT from a hotel to Cisco overnight
RTT varying from 278 ms to 9286 ms

Delay distribution with odd spikes about a TCP RTO apart;
Suggests that we actually had more than one copy of the same segment in queue

# What is buffer bloat? Why do I care?

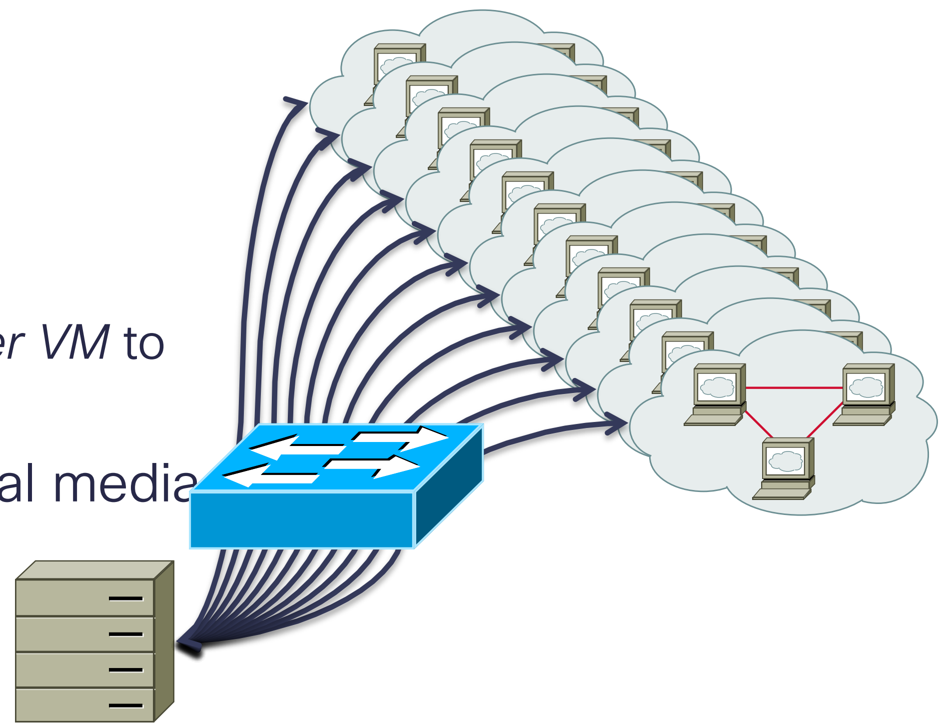
*Because few applications actually worked*

# Persistent Deep Queues

- In access paths (Cable Modem, DSL, Mobile Internet)
  - Generally results from folks building a deep queue with permissive drop thresholds
  - One DSL Modem vendor provides ten seconds of queue depth
- In multi-layer networks (WiFi, Input-queued Switches)
  - *Channel Acquisition Delay*
  - Systems not only wait for their own queue, but to access network
  - In WiFi, APs often try to accumulate traffic per neighbor to limit transition time
  - In Input-queued switches, multiple inputs feeding the same output appear as unpredictable delay sources to each other
  - In effect, **managing *delay* through queue**, not queue depth

- Names withheld for customer/vendor confidentiality reasons
- Common social networking applications might have
  - $O(10^3)$ racks in a data center
  - 42 1RU hosts per rack
  - A dozen Virtual Machines per host
  - $O(2^{19})$ virtual hosts per data center
  - $O(10^4)$ standing TCP connections *per VM* to other VMs in the data center
- When one opens a <pick your social media application> web page
  - Thread is created for the client
  - $O(10^4)$ requests go out for data
  - $O(10^4)$ 2-3 1460 byte responses come back
  - $O(45 \times 10^6)$ bytes in switch queues **instantaneously**
  - At 10 GBPS, **instant 36 ms queue depth**

## Data Center Applications



# Taxonomy of data flows

- We are pretty comfortable with the concepts of mice and elephants
  - "mice": small sessions, a few RTTs total
  - "elephants": long sessions with many RTTs
- In Data Centers with Map/Reduce applications, we also have ***lemmings***
  - $O(10^4)$ mice migrating together
- Solution premises
  - Mice: we don't try to manage these
  - Elephants: if we can manage them, network works
  - Lemmings: Elephant-oriented congestion management results in HOL blocking

# Question:

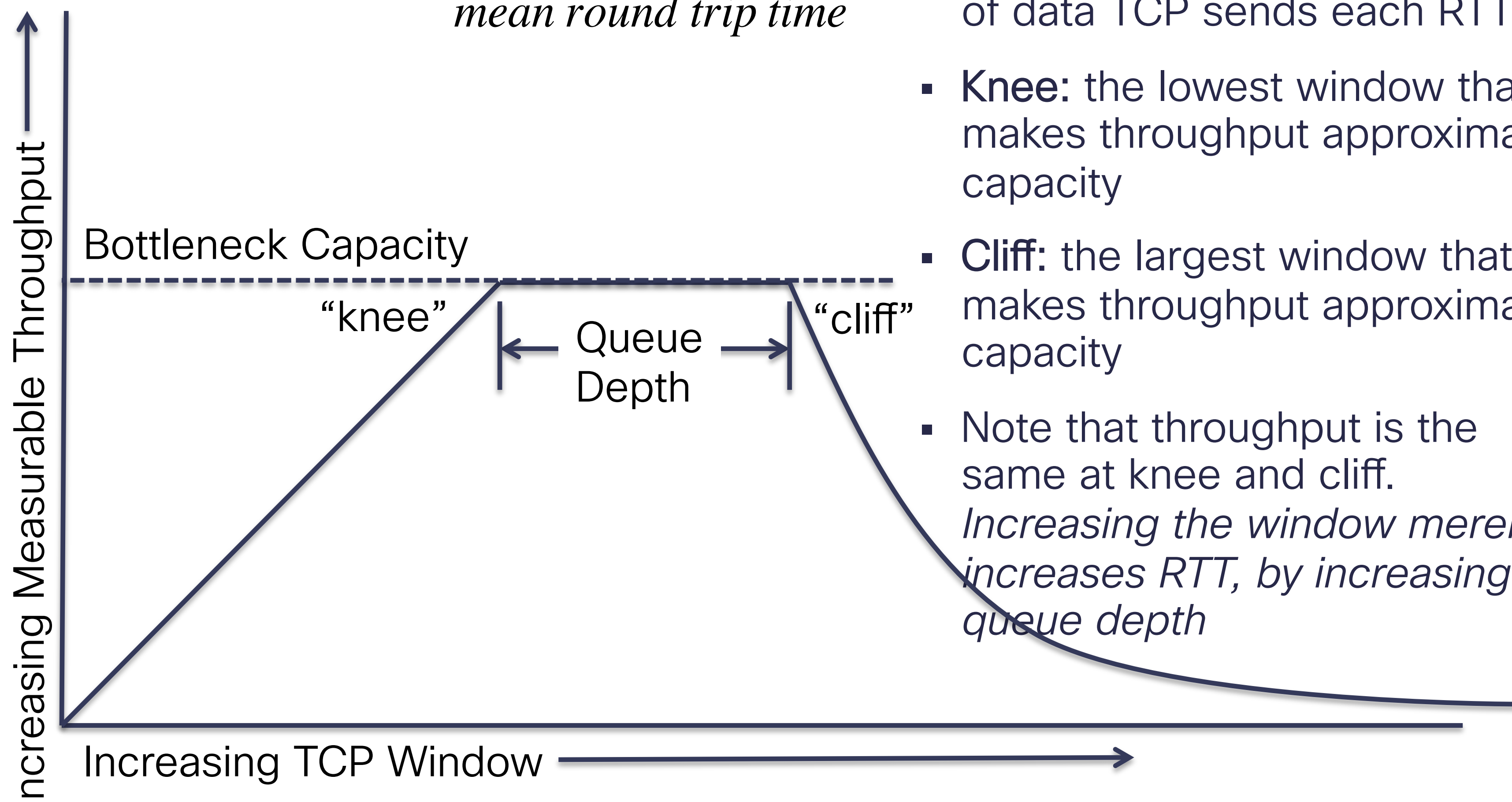
- ECN/Loss-based TCP Congestion Control (CUBIC and NewReno)
  - Works reasonably well on 10 ms and 100 ms timescales
  - Works marginally well on geosynchronous satellite RTTs (slow start issues)
  - Do we all agree that it works on 1000 microsecond and shorter timescales?

- Would latency control work better if we had the endpoints measuring RTT and actively maximizing throughput while minimizing latency?

# Simple model of TCP throughput dynamics

$$\text{mean throughput} = \frac{\text{effective window in bytes}}{\text{mean round trip time}}$$

- **Effective Window:** the amount of data TCP sends each RTT
- **Knee:** the lowest window that makes throughput approximate capacity
- **Cliff:** the largest window that makes throughput approximate capacity
- Note that throughput is the same at knee and cliff. *Increasing the window merely increases RTT, by increasing queue depth*




Yes, there is a more complex equation that takes into account loss. It estimates throughput above the cliff.

# Delay-based Congestion Control

- Arguably the most stable approach
- Several algorithms:
  - Vegas
  - CalTech FAST
  - Swinburne CDG
- Applicable to TCP, DCCP, or SCTP

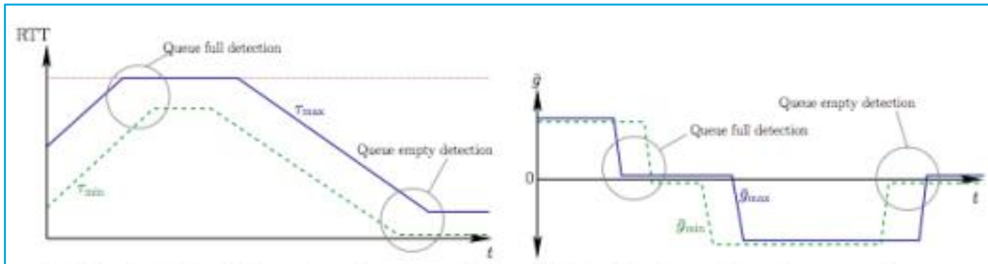
- CalTech FAST
  - Simple,
  - IPR issues
  - Yields systemically to loss-based models,
  - Tunes to knee plus alpha

$$\boxed{cwnd' := cwnd \times \frac{base\ RTT}{mean\ RTT} + \alpha}$$

- Swinburne CAIA Delay Gradient
  - Implemented in FreeBSD 9.2 and later
  - Tunes to minimize *variation in delay* when it can, *loss* if it determines it is competing with a loss-based competitor

# Swinburne CAIA Delay Gradient

- *Neither loss-based nor delay-based*
  - Responds to observed jitter
  - Switches to a NewReno mode when necessary
  - Recent papers suggest should enhance Data Center communications




(a) Idealised RTT dynamics for queue full and empty events

(b) Idealised gradient dynamics for queue full and empty events. ($\bar{g}_{\min}$ and $\bar{g}_{\max}$ are vertically offset for clarity.)

Fig. 1: Queue full and queue empty scenarios, highlighting the detection areas

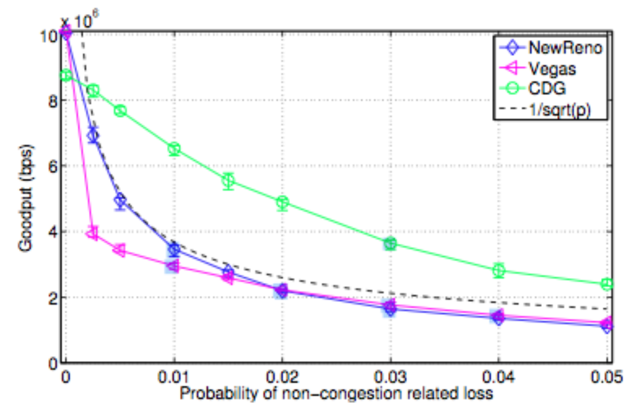



Fig. 4: Goodput of NewReno, Vegas and CDG with non-congestion losses




http://caia.swin.edu.au/cv/dahayes/content/networking2011-cdg-preprint.pdf

# Software Defined Infrastructure:

## simplification of the network

## simplification of the networked application

# Relationship between the application and the network

- End to end principle:
  - “functions placed at low levels of a system may be redundant or of little value when compared with the cost of providing them at that low level”
    - A plea for simplicity…
  - Network configuration that disrupts the intent of the application ultimately hurts both
    - Classic examples around network address translation, transcoding, etc

- *The network is the application’s “brother”, not its “friend”*

## Simplicity Principle

- "Complexity is the primary mechanism which impedes efficient scaling, and as a result is the primary driver of increases in both capital expenditures (CAPEX) and operational expenditures (OPEX)."

## Amplification Principle

- *"There are non-linearities at large scale which do not occur at small to medium scale."*
- Make local changes have only local effect
  - Small local changes with global effect destabilize a system, and
  - Attempts at global changes have significant local effect

## Coupling Principle

- "As things get larger, they often exhibit increased interdependence between components."
- Issues with translation and session management often come down to coupling between assumptions about addressing

RFC 3439: "Some Internet Architectural Guidelines and Philosophy"

# Simplification of configuration: Netconf/Yang

- An issue in network configuration has been – and continues to be – the differences in data models between software and hardware from different minds
  - Different vendors
  - Different open source projects
  - Different viewpoints
- Not a new observation:
  - *A … goal is that the architecture be, as much as possible, independent of the architecture and mechanisms of particular hosts or particular gateways.*
  - *RFC 1067, A Simple Network Management Protocol, 1988*
- Configuration paradigms moving to a model in which
  - A configuration expresses the "intent" of the administration
  - The underlying software interprets it in the local context
  - Actual configuration now limited to values that actually have to be assigned for things to work, such as prefixes (and maybe not those)

# Embedded operational intelligence: Simplification of monitoring and diagnosis

Embedded operational intelligence:

- When something is broken in the network, how do you find it?
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- Software raises alerts when it detects changes, rather than waiting for the operator or management system to come looking for them
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- SLAs and traditional **Reliability**, **Availability**, and **Serviceability** (RAS) continuously measured
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- Can improved algorithms help?
  - Example: large data center customer manages incast by manually shaping traffic
    - Would a delay-based or jitter-based latency control procedure in TCP/SCTP work better?

# Embedded operational intelligence: Simplification of deployment

- Autonomous networks:
  - A newly-installed system identifies itself to a server
  - Server tells it what the administration's intent for it is
  - It then configures itself accordingly
- draft-ietf-ospf-ospfv3-autoconfig
  - OSPF IPv6 prefix distribution within an area
  - What if we could number, and renumber, a network without operator interaction?
  - (The things that make renumbering hard are usually poor software methodologies)

# A word…

# In your research…

- Think about the fundamental principles of networking:
  - End to end: services that do what is expected of them
  - Simplicity vs Complexity
  - Amplification: managing non-linearity
  - Coupling: managing interconnectedness of components
- Test out your ideas
  - Prove that they work scaleably in real world, not just simulation