big screen, small text

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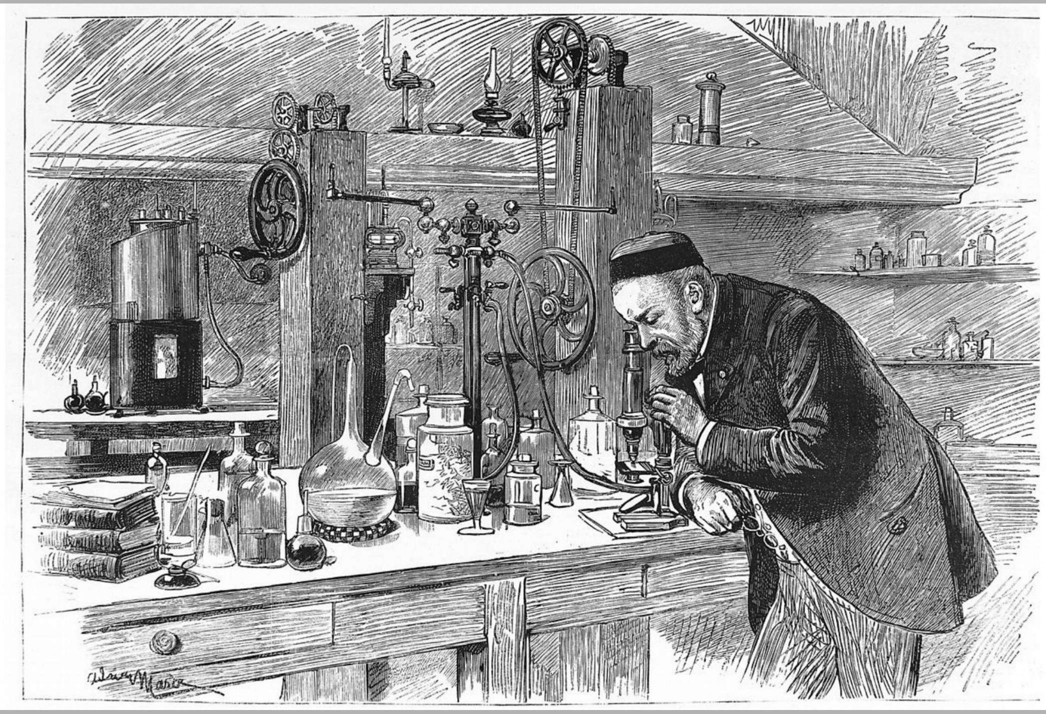
‘This is not how we imagined it’

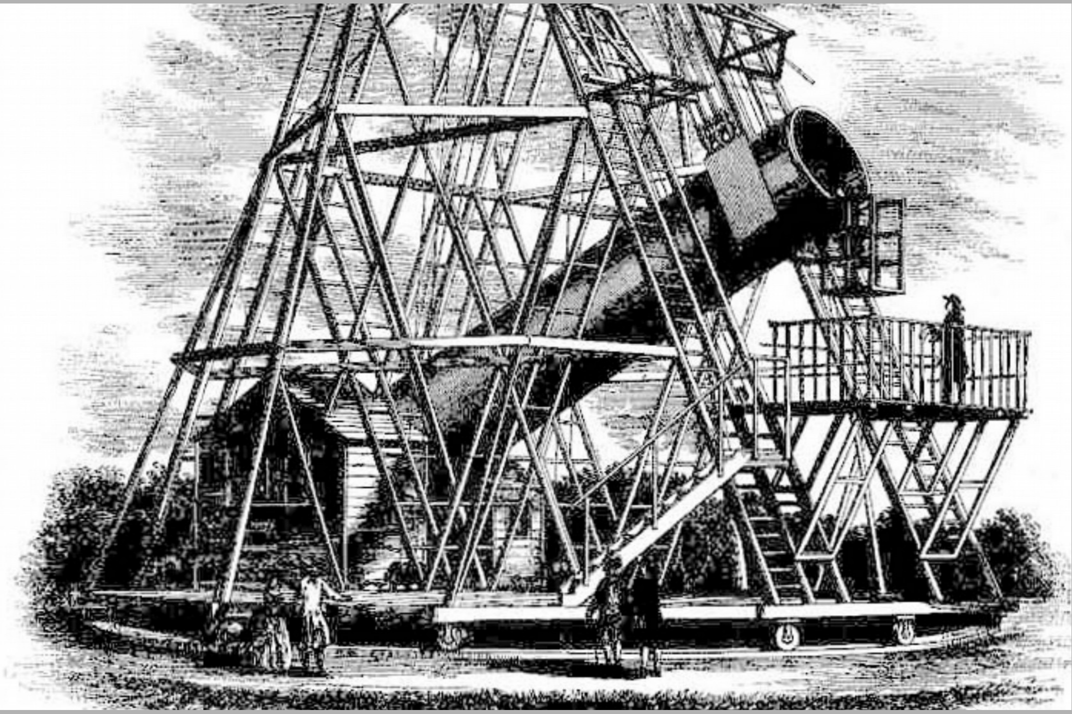
Technological Affordances,

Economic Drivers

and the

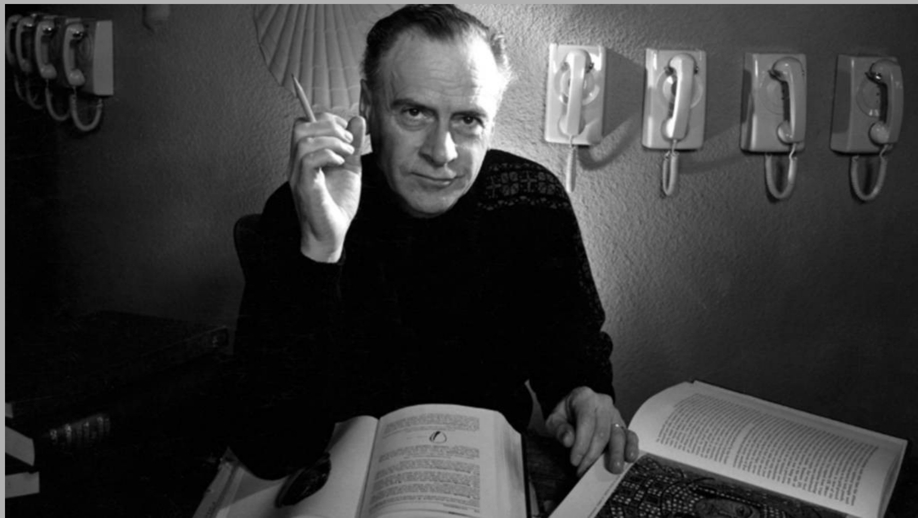
Internet Architecture Imaginary





The medium is the message

– Marshall McLuhan



Infrastructure sets the invisible rules that govern the spaces of our everyday lives

– Keller Easterling

The uses made of technology are largely determined by the structure of the technology itself

– Neil Postman

We shape our tools
and thereafter they shape us.

–John Culkin

Infrastructure is both relational and ecological

– Susan Leigh Star

- Materiality
  - The relational effect of matter matters

- Affordances
  - Constraining as well as enabling features
  - ‘functional and relational aspects which frame, while not determining, the possibilities’

– Ian Hutchby

A sociotechnical imaginary:

- visions,
- symbols,
- futures

that exist in groups and society which influence

- behavior,
- individual identity,
- collective identity,
- development of narratives,
- Policy,
- institutions

Co-production: the simultaneous processes through which modern societies form their epistemic and normative understandings of the world

– Sheila Jasanoff

Network Working Group B. Carpenter, Editor
Request for Comments: 1958 IAB
Category: Informational June 1996

Architectural Principles of the Internet

Status of This Memo

This memo provides information for the Internet community. This memo does not specify an Internet standard of any kind. Distribution of this memo is unlimited.

Abstract

The Internet and its architecture have grown in evolutionary fashion from modest beginnings, rather than from a Grand Plan. While this process of evolution is one of the main reasons for the technology's success, it nevertheless seems useful to record a snapshot of the current principles of the Internet architecture. This is intended for general guidance and general interest, and is in no way intended to be a formal or invariant reference model.

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1. Constant Change

In searching for Internet architectural principles, we must remember that technical change is continuous in the information technology industry. The Internet reflects this. Over the 25 years since the ARPANET started, various measures of the size of the Internet have increased by factors between 1000 (backbone speed) and 1000000 (number of hosts). In this environment, some architectural principles inevitably change. Principles that seemed inviolable a few years ago are deprecated today. Principles that seem sacred today will be deprecated tomorrow. The principle of constant change is perhaps the

Technology is a very human activity – and so is the history of technology.

– Melvin Kranzberg

Standard setting is a wild mix of politics and economics

– Shapiro and Varian

Theoretical framework

- Science and Technology Studies
  - Technological materiality
  - Co-production
  - Socio-technical imaginaries

- International Political Economy
  - Consolidation / Market concentration
  - Self-regulation
  - Commercialization

Methods

- 25 interviews
- Quantitative analysis of all RFCs
- Qualitative analysis of 25 RFCs
- Quantitative and qualitative mailinglist analysis
- Participant observation during four years (11 meetings)

Internet Architecture Imaginary (1)

- End-to-end principle
  - Intelligence at the edges
  - Network only provides datagram transport
  - Low complexity
  - High robustness

  But...

The purpose of this document is not, therefore, to lay down dogma about how Internet protocols should be designed, or even about how they should fit together. Rather, it is to convey various guidelines that have been found useful in the past, and that may be useful to those designing new protocols or evaluating such designs.

A good analogy for the development of the Internet is that of constantly renewing the individual streets and buildings of a city, rather than razing the city and rebuilding it. The architectural principles therefore aim to provide a framework for creating cooperation and standards, as a small "spanning set" of rules that generates a large, varied and evolving space of technology.

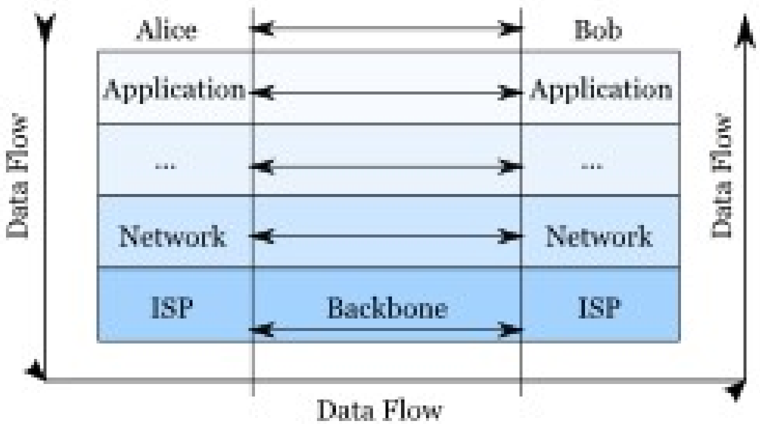
Some current technical triggers for change include the limits to the scaling of IPv4, the fact that gigabit/second networks and multimedia present fundamentally new challenges, and the need for quality of service and security guarantees in the commercial Internet.

As Lord Kelvin stated in 1895, "Heavier-than-air flying machines are impossible." We would be foolish to imagine that the principles listed below are more than a snapshot of our current understanding.

2. Is there an Internet Architecture?

2.1 Many members of the Internet community would argue that there is no architecture, but only a tradition, which was not written down for the first 25 years (or at least not by the IAB). However, in very general terms, the community believes that the goal is connectivity, the tool is the Internet Protocol, and the intelligence is end to end rather than hidden in the network.

End-to-end principle



(Another step is to choose leaders that we trust to exercise their good judgement and do the right thing. But we're already trying to do that.)

4. Issues with Scoping the IETF's Mission

4.1. The Scope of the Internet

A very difficult issue in discussing the IETF's mission has been the scope of the term "for the Internet". The Internet is used for many things, many of which the IETF community has neither interest nor competence in making standards for.

The Internet isn't value-neutral, and neither is the IETF. We want the Internet to be useful for communities that share our commitment to openness and fairness. We embrace technical concepts such as decentralized control, edge-user empowerment and sharing of resources, because those concepts resonate with the core values of the IETF community. These concepts have little to do with the technology that's possible, and much to do with the technology that we choose to create.

Internet Architecture Imaginary (2)

- Permissionless innovation
  - No barriers for deployment of new protocols
  - No need to negotiate with entities in the middle of the network
  - Response to Telco era (and perhaps Acceptible Use Policy of ARPANET & NSFnet)

Internet Architecture Imaginary (3)

- Openness (network)
  - Reach any endpoint on the Internet without being hampered, altered or stopped
  - Ability to add new endpoints to the network
- Open standards
  - Voluntary
  - Freely accessible
- Open governance
  - Transparent
  - Open participation
  - Open archives

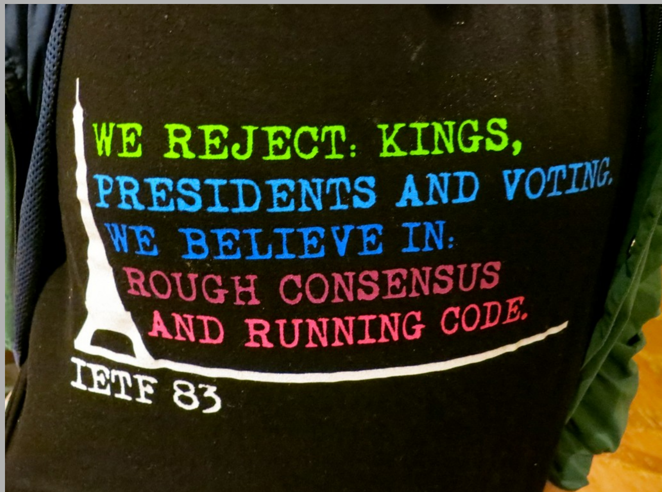
We reject: kings,

presidents and voting.

We believe in: rough consensus

and running code.

– Quote from Dave Clarke in the Tao of the IETF



Explicit discussions about rights and freedoms, as well as social impact of technology have featured in RFCs since their beginnings

–Sandra Braman

Commercialization & Privatization (end 80s, early 90s)

- US government cedes direct control:
  - ARAPNET (Dept of Defense)
  - NSFNET (Dept of Education)
  - ESNET (Dept of Energy)
- Establishment of Commercial Internet Exchanges
- Formal institutionalization of:
  - Internet Engineering Taskforce
  - Internet Society
  - Regional Internet Registries

Crack in the imaginary: Rise of the Middlebox

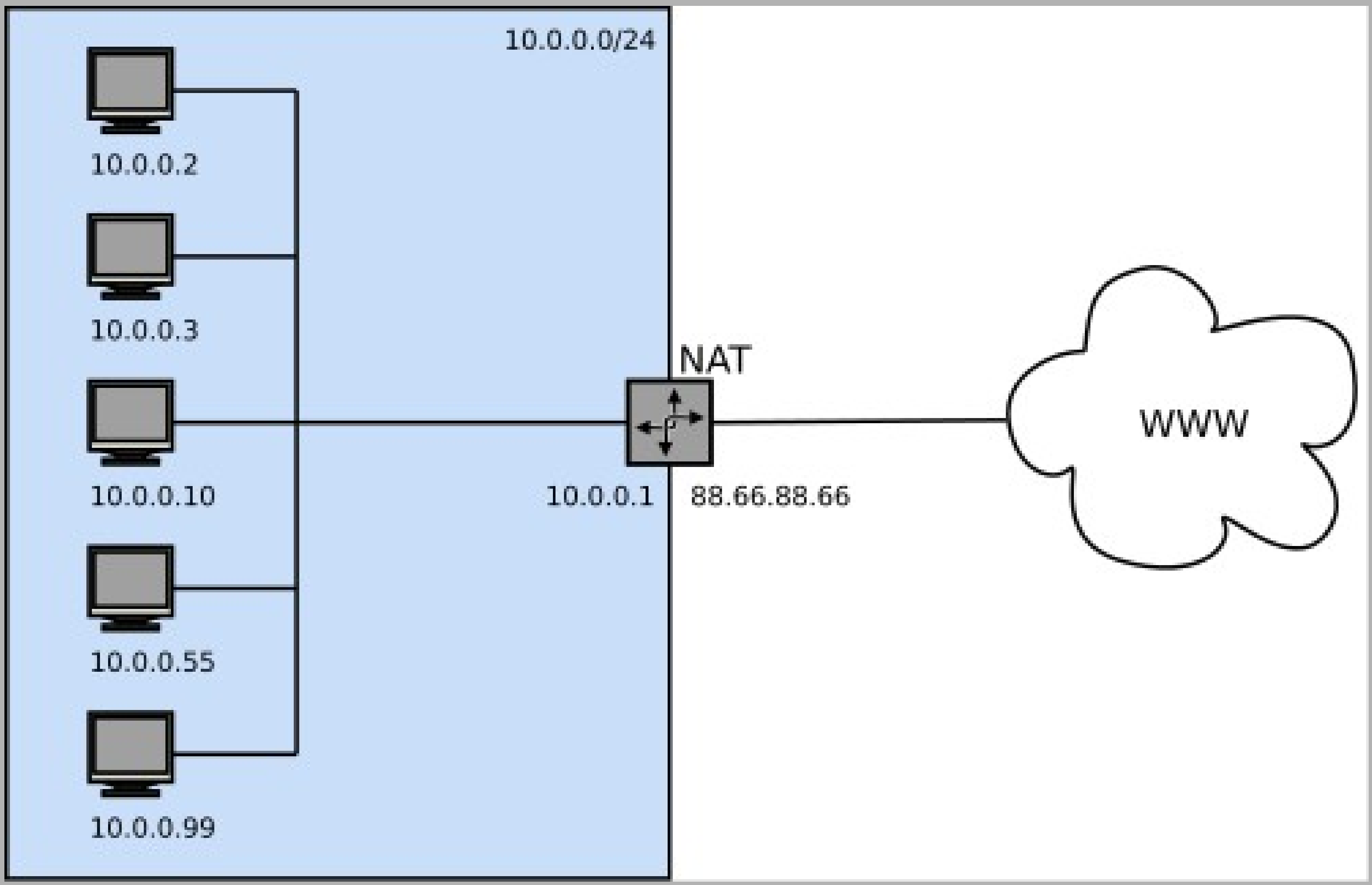
- IPv4 running out
  - ‘only’ 4.3 billion IP addresses
  - No replacement done yet

- Security considerations
  - Internet was no longer comprised of trusted actors

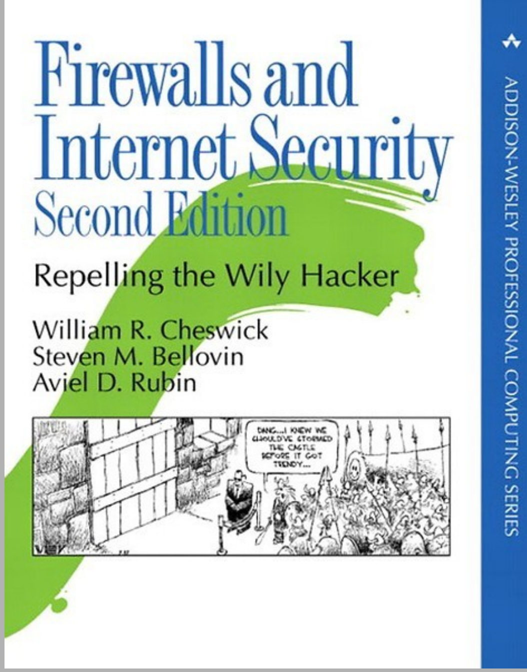
- Perceived need from network operators differentiate business models

(RFC3725)

Network Address Translation



Firewalls



- Security
- Administrative control

‘a lot of networks do a lot of bad things to peer-to-peer traffic’

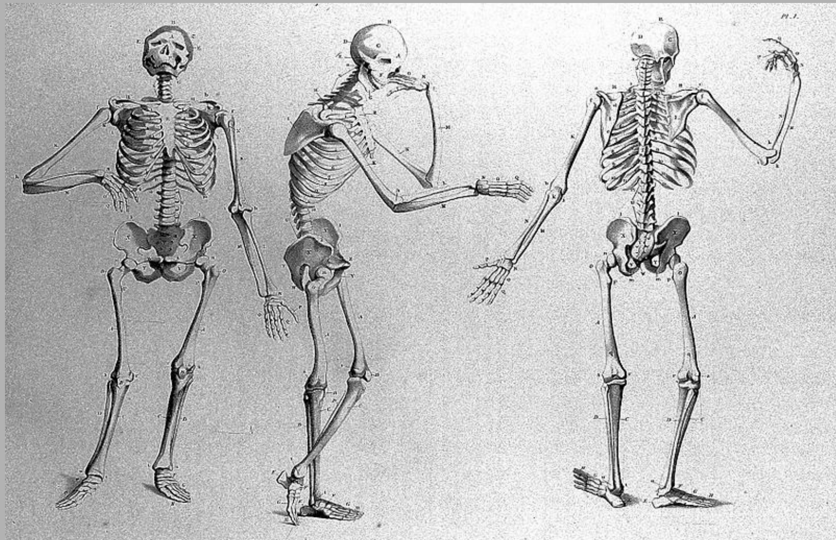
‘firewalls didn't serve only a security purpose, they also served an administrative control purpose, that's a third party in the midst of the peers who are talking to each other. So it's been difficult for Internet peer to peer things to take off. ‘

Network management

- Quality of service
- Caching
- Prioritization of services

Rise of the Middlebox (4)

- Added functionality to the network
- Not at the edges, but in the network
- This led to ‘ossification’
- Introduced directionality, created users and producers
- Created a new **affordance structure** in the Internet architecture



Example 1 : TLS1.3

```
If a server established a TLS connection with a previous version of
TLS and receives a TLS 1.3 ClientHello in a renegotiation, it MUST
retain the previous protocol version.  In particular, it MUST NOT
negotiate TLS 1.3.

Structure of this message:

   uint16 ProtocolVersion;
   opaque Random[32];

   uint8 CipherSuite[2];    /* Cryptographic suite selector */

   struct {
       ProtocolVersion legacy_version = 0x0303;    /* TLS v1.2 */
       Random random;
       opaque legacy_session_id<0..32>;
       CipherSuite cipher_suites<2..2^16-2>;
       opaque legacy_compression_methods<1..2^8-1>;
       Extension extensions<8..2^16-1>;
   } ClientHello;
```

Example 2: Stream Control Transmission Protocol

- Transport layer replacement for TCP
- Multiple streams
- Multiple transmission paths
- No head of line blocking
- Described in 39 (!) RFCs
- Worked perfectly in the lab
- Blocked by many NATs
- Never reliably worked on the Internet
- Because of reordered affordances

First RFC:

April 2002

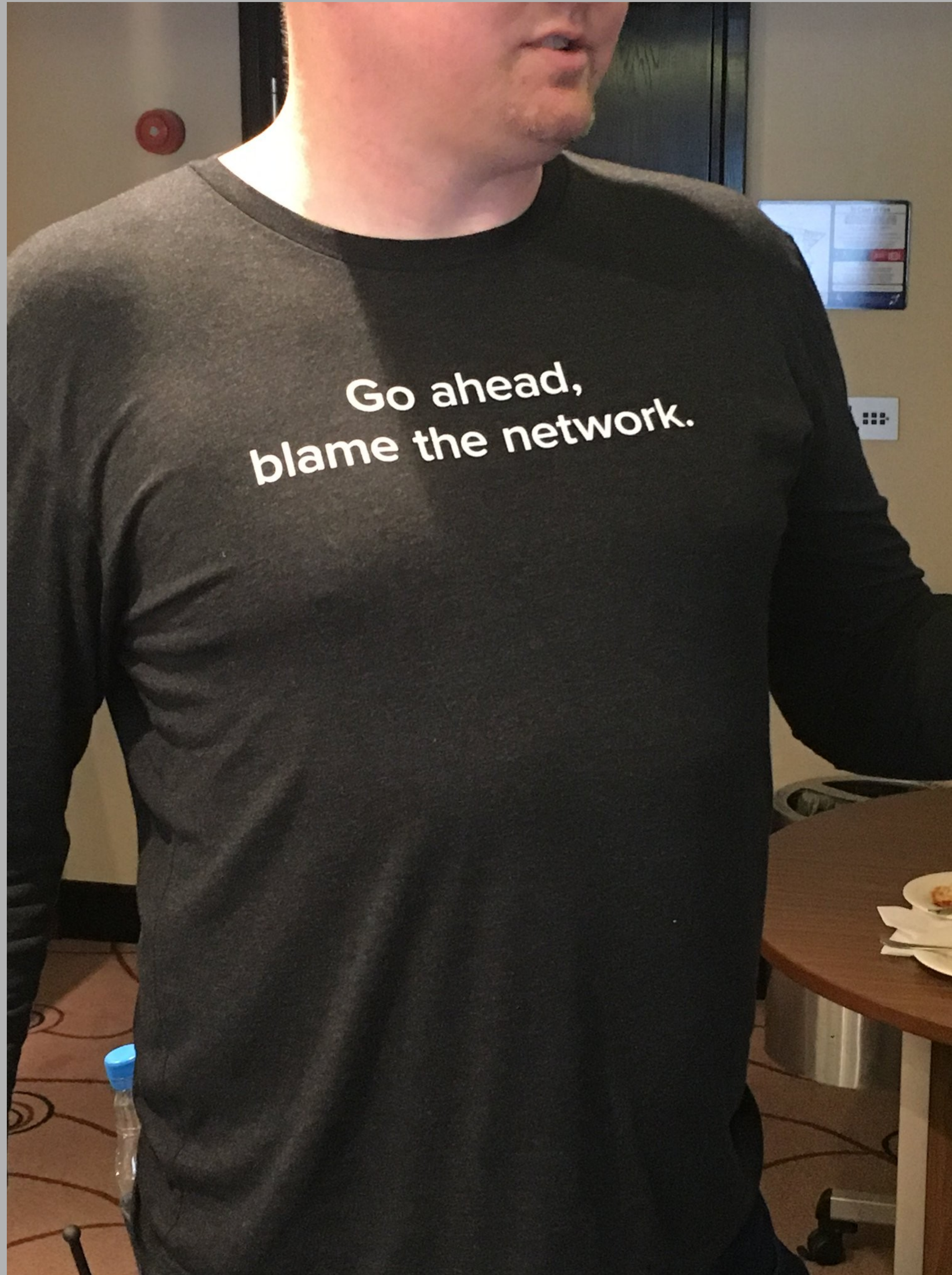
Last RFC:

November 2017

Protocol

Failure

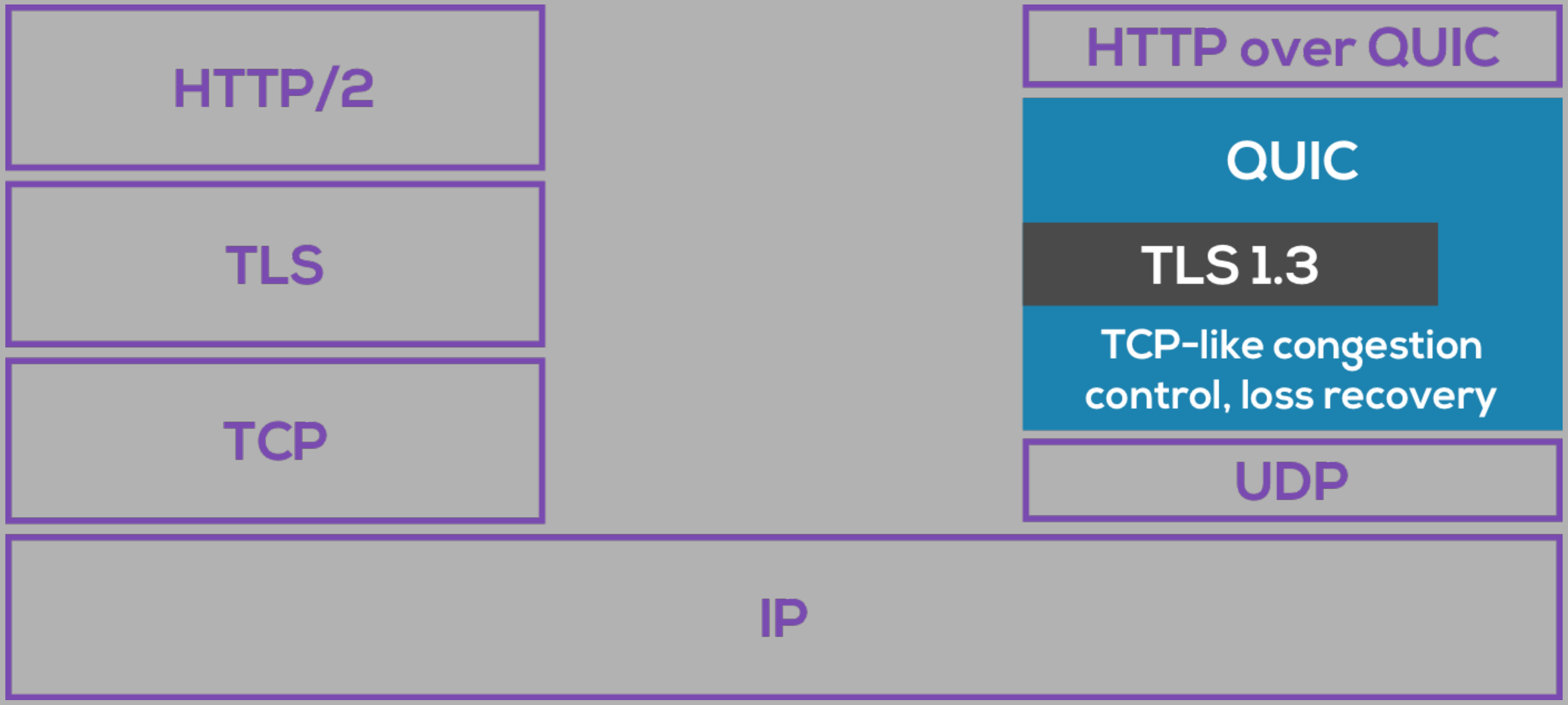
- RFC8261: Datagram Transport Layer Security (DTLS) Encapsulation of SCTP Packets
- RFC8087: The Benefits of Using Explicit Congestion Notification (ECN) informational
- RFC7829: SCTP-PF: A Quick Failover Algorithm for the Stream Control Transmission Protocol
- RFC7765: TCP and Stream Control Transmission Protocol (SCTP) RTO Restart experimental
- RFC7605: Recommendations on Using Assigned Transport Port Numbers bcp
- RFC6951: UDP Encapsulation of Stream Control Transmission Protocol (SCTP) Packets for End-Host to End-Host Communication
- RFC6633: Deprecation of ICMP Source Quench Messages
- RFC6526: IP Flow Information Export (IPFIX) Per Stream Control Transmission Protocol (SCTP) Stream
- RFC6525: Stream Control Transmission Protocol (SCTP) Stream Reconfiguration
- RFC6458: Sockets API Extensions for the Stream Control Transmission Protocol (SCTP) informational
- RFC6096: Stream Control Transmission Protocol (SCTP) Chunk Flags Registration
- RFC6084: General Internet Signaling Transport (GIST) over Stream Control Transmission Protocol (SCTP) and Datagram Transport Layer Security (DTLS) experimental
- RFC6083: Datagram Transport Layer Security (DTLS) for Stream Control Transmission Protocol (SCTP)
- RFC6053: Implementation Report for Forwarding and Control Element Separation (ForCES) informational
- RFC5923: Connection Reuse in the Session Initiation Protocol (SIP)
- RFC5827: Early Retransmit for TCP and Stream Control Transmission Protocol (SCTP) experimental
- RFC5811: SCTP-Based Transport Mapping Layer (TML) for the Forwarding and Control Element Separation (ForCES) Protocol
- RFC5062: Security Attacks Found Against the Stream Control Transmission Protocol (SCTP) and Current Countermeasures informational
- RFC5061: Stream Control Transmission Protocol (SCTP) Dynamic Address Reconfiguration
- RFC5043: Stream Control Transmission Protocol (SCTP) Direct Data Placement (DDP) Adaptation
- RFC4960: Stream Control Transmission Protocol
- RFC4895: Authenticated Chunks for the Stream Control Transmission Protocol (SCTP)
- RFC4820: Padding Chunk and Parameter for the Stream Control Transmission Protocol (SCTP)
- RFC4666: Signaling System 7 (SS7) Message Transfer Part 3 (MTP3) - User Adaptation Layer (M3UA)
- RFC4460: Stream Control Transmission Protocol (SCTP) Specification Errata and Issues informational
- RFC4233: Integrated Services Digital Network (ISDN) Q.921-User Adaptation Layer
- RFC4168: The Stream Control Transmission Protocol (SCTP) as a Transport for the Session Initiation Protocol (SIP)
- RFC4166: Telephony Signalling Transport over Stream Control Transmission Protocol (SCTP) Applicability Statement informational
- RFC4138: Forward RTO-Recovery (F-RTO): An Algorithm for Detecting Spurious Retransmission Timeouts with TCP and the Stream Control Transmission Protocol (SCTP) experimental
- RFC3873: Stream Control Transmission Protocol (SCTP) Management Information Base (MIB)
- RFC3868: Signalling Connection Control Part User Adaptation Layer (SUA)
- RFC3807: V5.2-User Adaptation Layer (V5UA)
- RFC3758: Stream Control Transmission Protocol (SCTP) Partial Reliability Extension
- RFC3708: Using TCP Duplicate Selective Acknowledgement (DSACKs) and Stream Control Transmission Protocol (SCTP) Duplicate Transmission Sequence Numbers (TSNs) to Detect Spurious Retransmissions experimental
- RFC3554: On the Use of Stream Control Transmission Protocol (SCTP) with IPsec
- RFC3436: Transport Layer Security over Stream Control Transmission Protocol
- RFC3331: Signaling System 7 (SS7) Message Transfer Part 2 (MTP2) - User Adaptation Layer
- RFC3286: An Introduction to the Stream Control Transmission Protocol (SCTP) informational
- RFC3257: Stream Control Transmission Protocol Applicability Statement informational


Go ahead,
blame the network.

The return of the strong endpoints: The Rise of QUIC

- Quick UDP Internet Protocol (QUIC)
- Stream-based protocol
- Similar to SCTP, but..
  - Developed by Google
    - Communicate between Google servers (CDNs) and browsers (mainly Chrome)
    - Experimental A/B testing
- Fallback to TCP

Includes encryption by default...

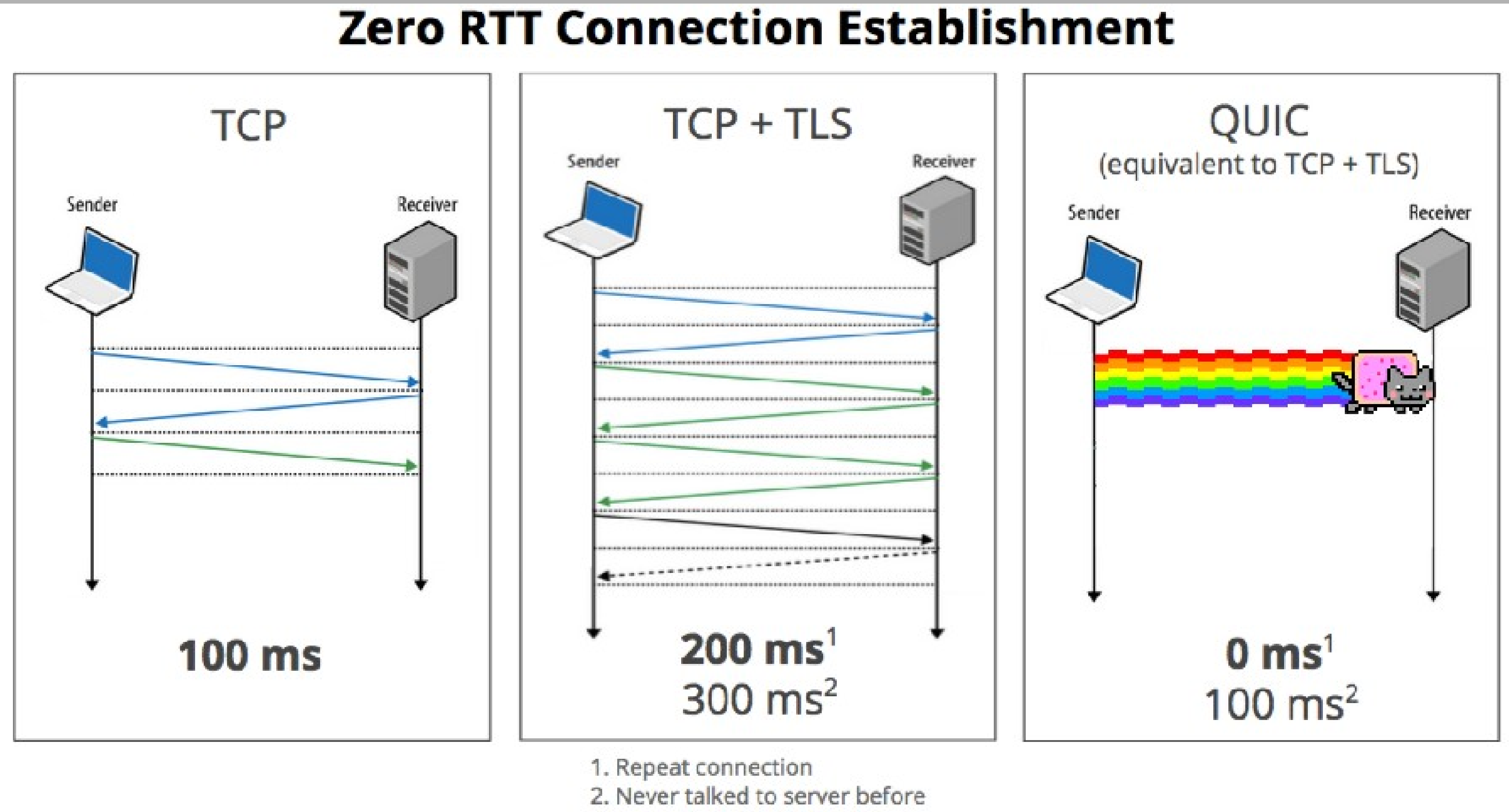


...as much as possible

“Let’s not share anything [with the network] unless we really need to because I don't care whether it’s ossified or whether it’s not. We’ve tried this in the past and we’ve failed because people ossify whatever is visible. I don't care what they can and cannot use it for. I just don't want to share it unless there is…

The burden of proof, in my opinion, is on the operators to say we really, really, really can’t run our networks unless we see this one bit. And if they can prove that, then maybe it’s fine at that point.”

Latency wins

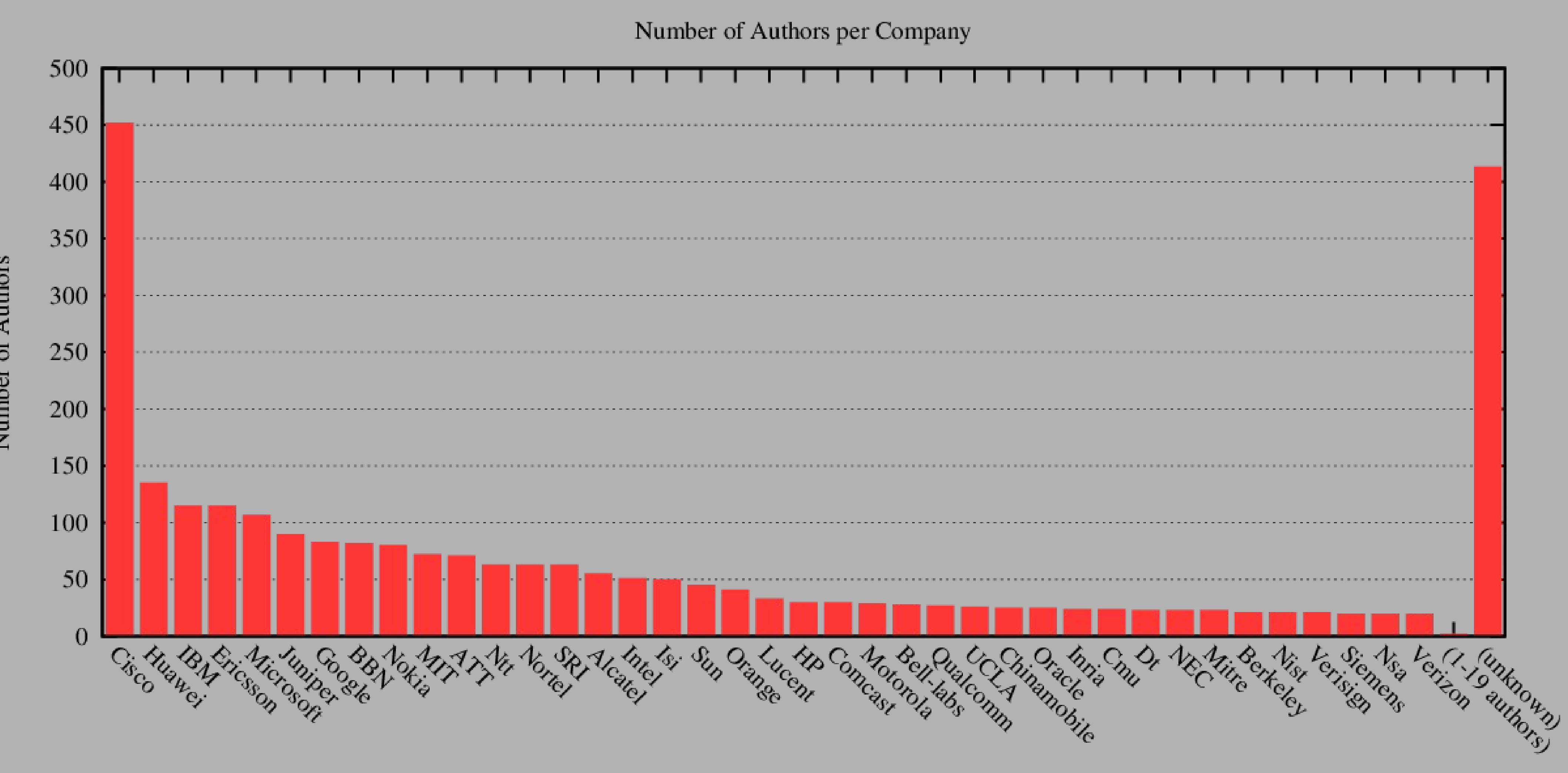


All’s well that end(-to-end)s well?

- Only large effort by a transnational corporation with significant control of the network could make this evolution, and change affordance structure
- QUIC tooling not readily available (yet)
- QUIC deployment will arguably strengthen consolidation
- NAT directionality is still in place
- With ubiquitous encryption it is harder to analyze on the network (for researchers as well)
- Network operators are not pleased

Imaginaries They Are A-Changin’

‘you need to play in some of the operators or vendors earning models in order to get something deployed’


Number of Authors per Company
Number of Authors
500
450
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Cisco
Huawei
IBM
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Juniper
Google
BBN
Nokia
MIT
ATT
Ntt
Nortel
SRI
Alcatel
Intel
Isi
Sun
Orange
Lucent
HP
Comcast
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Qualcomm
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Verizon
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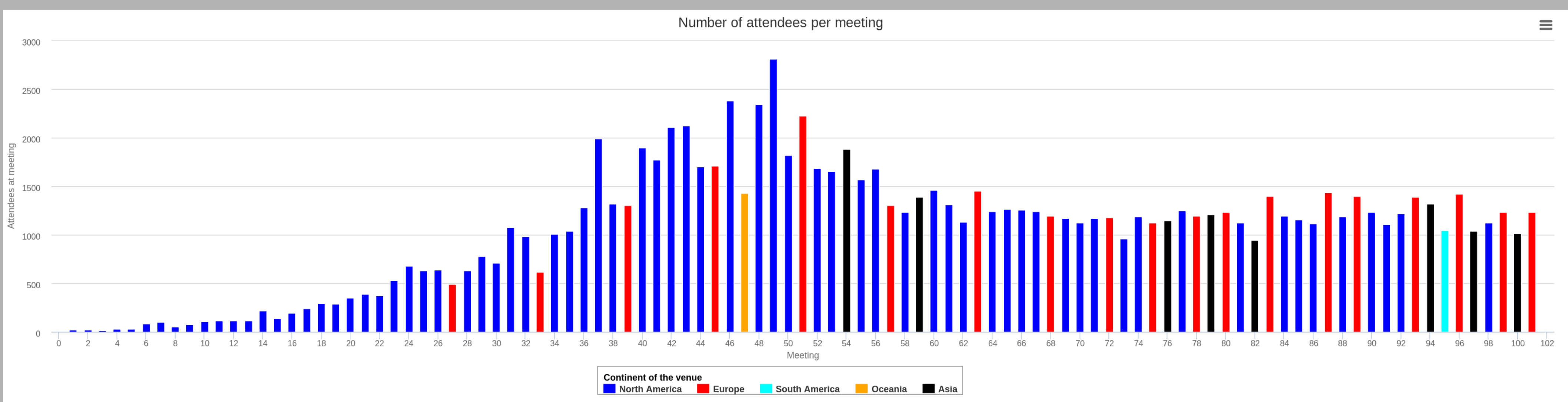
Number of attendees per meeting
Attendees at meeting
3000
2500
2000
1500
1000
500
0
Meeting
Continent of the venue
North America
Europe
South America
Oceania
Asia

‘[m]yths are important for what they reveal (including a genuine desire for community and democracy) and for what they conceal (including the growing concentration of communication power in a handful of transnational media businesses)’

– Vincent Mosco

Conclusions (1)

The sociotechnical Internet architecture imaginary and its self-regulatory governance model have not been able to safeguard the ability of researchers, small companies or individuals to innovate on the Internet protocol level.

Permissionless innovation has undermined itself and the end-to-end principle.

Conclusions (2)

Increasingly the bottom lines of companies became a first-order consideration for protocols to be adopted and implemented

Political conceptions of the architectural imaginary are fading into the background.

Conclusions (3)

The importance and size of the Internet architecture has only grown, and with it its societal implications.

Societal implications are not structurally considered.

BAM!

Conclusions
(academic style)

By combining STS and IPE lenses I foregrounded how economic drivers spurred iterative changes in the affordances and materiality of the Internet architecture

¯_(ツ)_/¯

Credits

- Image sources:
  - Slide 7: Jim Fenton on Twitter
  - Slide 21: Clemens Schrimpe on Twitter
  - Slide 24: Thiag Rondon on Medium
  - Slide 35: EveryRFC by Mark Nottingham
  - Slide 36: Clemens Schrimpe on Twitter
  - Slide 40: Original Google image edited by Qrator Labs
  - Slide 43: Jari Arkko and IETF
  - Author profile pictures are retrieved from their respective websites

```
if write code(protocols):
   consider human rights implications
elif run internet infrastructure:
   respect human rights
elif engage in internet governance:
   build in human rights protections
else
   carry on and use FLOSS
```