Internet Architecture:

Past, Present, and Future

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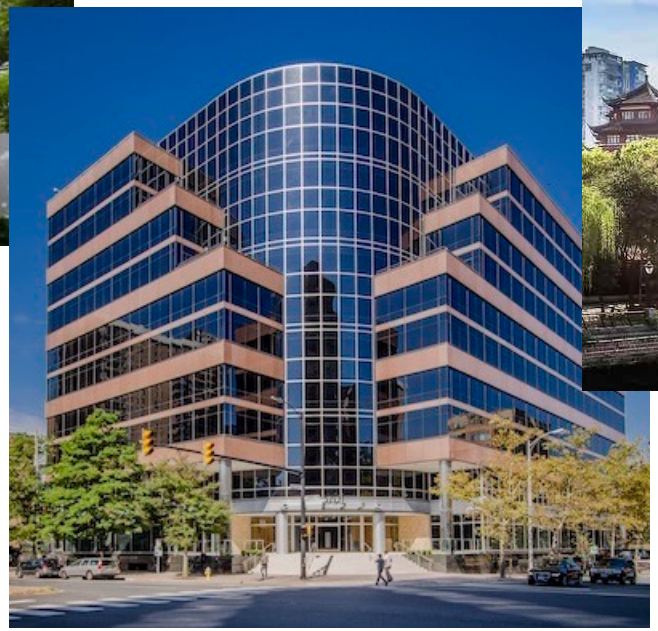
Let’s talk about Internet Architecture

- What is Architecture? Internet Architecture? Buildings…



Internet Architecture

- But buildings are … well ... buildings
- **Architecture** is about **how we build them**: the overall design

Internet Architecture

- Some phrases from former IETF and IAB Chairs (they ought to know):

  - Internet architecture is about the small and the large.
  - Not about the details of an individual piece, but about how the pieces fit together.
  - It's about identifying bigger-picture trends.

  - The same addresses, protocols, and applications work in all different kinds of networks.
  - As the Internet has grown, many new technologies have been introduced.
  - Interoperability determines whether a technology becomes a building block or simply an application.

  - The goal is connectivity; the intelligence is end to end, not hidden in the network.
  - Putting it together requires technical cooperation.
  - The key to global connectivity is the inter-networking layer.

Internet Architecture

- In other words, Internet Architecture is about how the many smaller pieces fit together to make an Internet.
- “Fit together” broadly, not in the details; the details are for the protocols.
- A properly architected Internet is...
  - Interoperable
  - Scalable
  - Stable
  - Resilient
  - Secure ?

How did we start architecting the Internet?

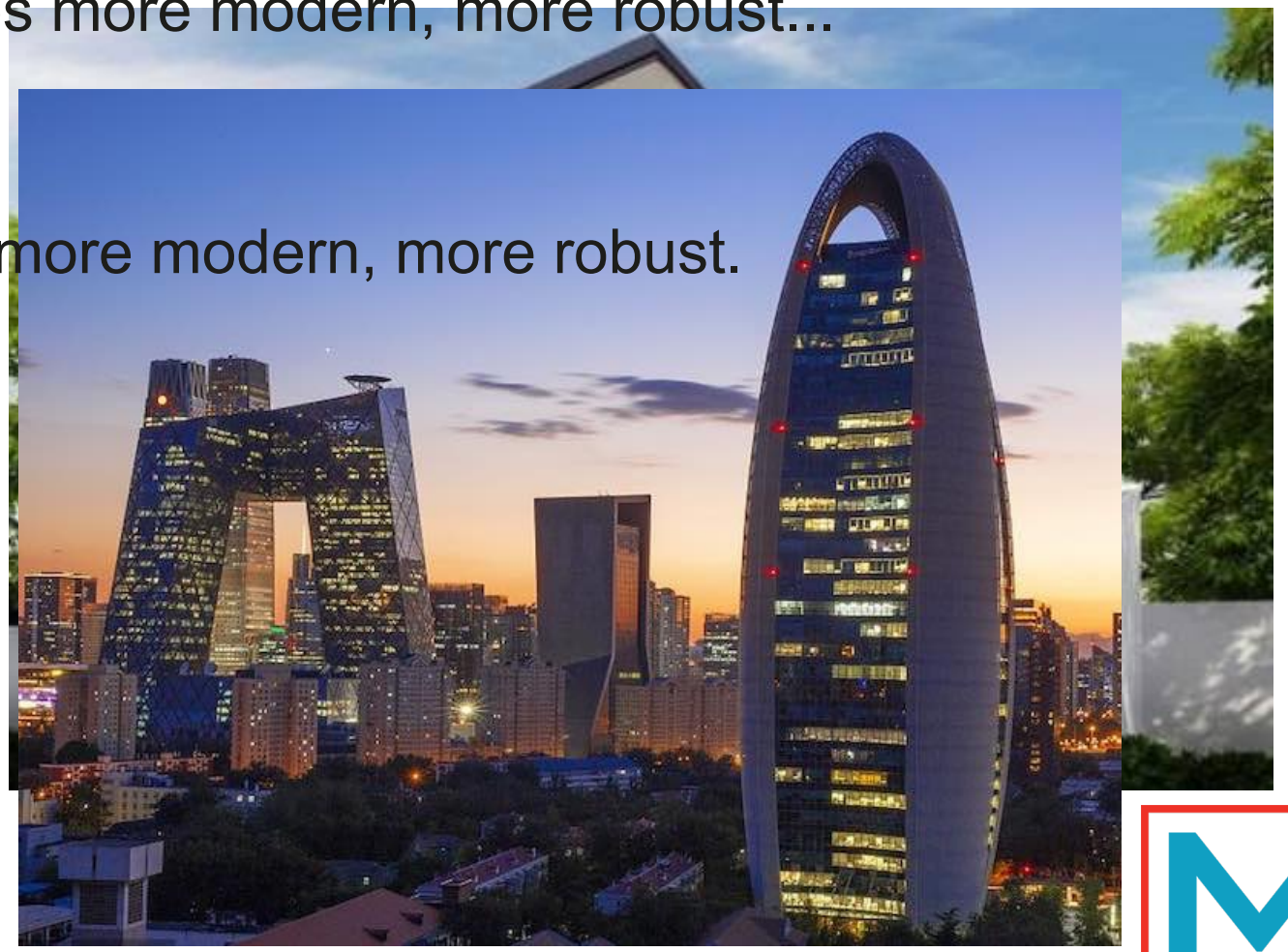
- Early on, a lot of things were ad hoc.
- Protocols were developed as needed.
- Routing tables and /etc/hosts files were distributed by hand.
- What passed for email was transferred via FTP.
- Putting a new host onto the Internet was a manual process, much hacking.
- Architecture? What?

But, gradually, an architecture evolved.

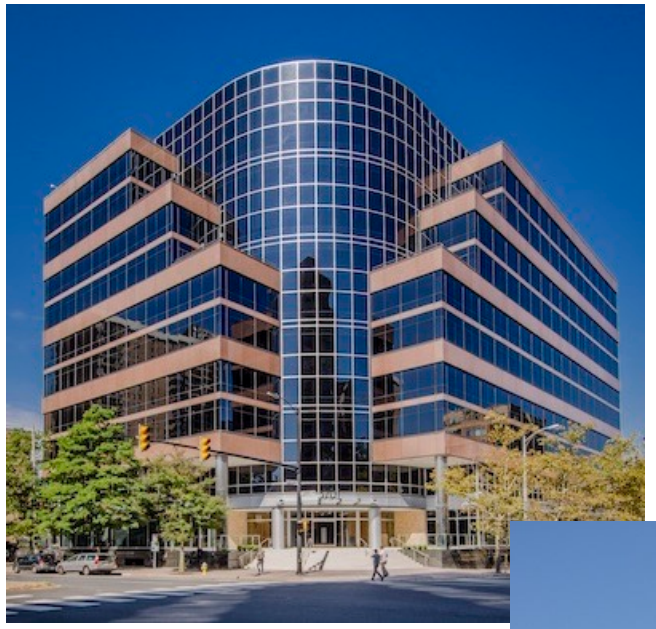
- Email protocols were developed, replacing FTP.
- DNS was developed, replacing /etc/hosts.
- Routing protocols, such as BGP, were developed.
- Protocols were developed… and written down.
- And we found that we had an architecture
  - We had pieces that fit together in consistent, predictable ways.
  - When we fit them together right, things became interoperable, scalable, stable, resilient.
  - And we knew how it worked, how they needed to be fit together.
  - We just didn't really write it down.

Just as buildings change over time…

- and their architecture becomes more modern, more robust...
- the Internet changes...
- and its architecture becomes more modern, more robust.



And as building architecture differs by purpose...



And as building architecture differs by purpose...

- Internet architecture differs by purpose.
- In addition to an overall Internet architecture...
- ...we have specific (sub-)architectures for specific pieces.
  - Routing architecture
  - Data center architecture
  - IoT / constrained environment architecture
  - Applications architecture
  - Transport-layer architecture
  - Security architecture !

Routing Architecture

- BGP, OSPF, IS-IS, MPLS
- Control Plane vs Data Plane (or Forwarding Plane)
- Automated neighbour discovery
- Path computation
- Routing in mobile networks
- Routing in constrained networks
- Locator/ID separation

Data Center Architecture

- The Cloud: massive decentralization
- Software Defined Networking: centralized, programmable management
- Virtualization: at the server level, at the network level
- Network Slicing: multiplexing virtual networks
- Autonomic data center management: heal thyself
  - heal, configure, administer, optimize, defend...

IoT / Constrained Environment Architecture

- Hits every layer and technical area
- Low-power, sporadic connectivity
- Routing in low-power and lossy networks
- IPv6 is a critical element, expanding the address space
- Efficient transport and congestion control when everything is on the Internet
- How to communicate and represent information efficiently and compactly
- How to make it all secure and to preserve privacy

One Thought for the Future on IoT

- IoT is a largely untapped technology.
- Current IoT scenarios are weak, limited, narrow.
- I want to see wide-ranging IoT that really takes advantage of Internet resources to change the way we work and the way we live.
- Here's a modest scenario that illustrates what I'm talking about...

An IoT Scenario

- You invite me to a meeting at your office; I accept it on my calendar.
- My alarm clock wakes me up early on the meeting day.
- My coffee maker has coffee ready early.
- My car already has a route set to take me to your office...
- ...and to pass by the inexpensive fuel station – the car is low on fuel.
- My wife is in a meeting that's running late, so I'm asked to pick up the kids from school.
- And my refrigerator tells me that I need to stop for milk.

Applications Architecture, Including Real-Time Apps

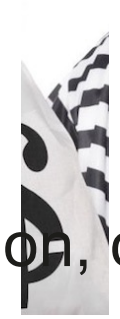
- The World Wide Web: a fundamental transformation
- Social networking: new ways of interpersonal communication
- Gaming: driving technology through entertainment
- Media streaming: the majority of Internet traffic today
- Teleconferencing: getting our business done
- HTML5: moving plug-ins to standard mechanisms

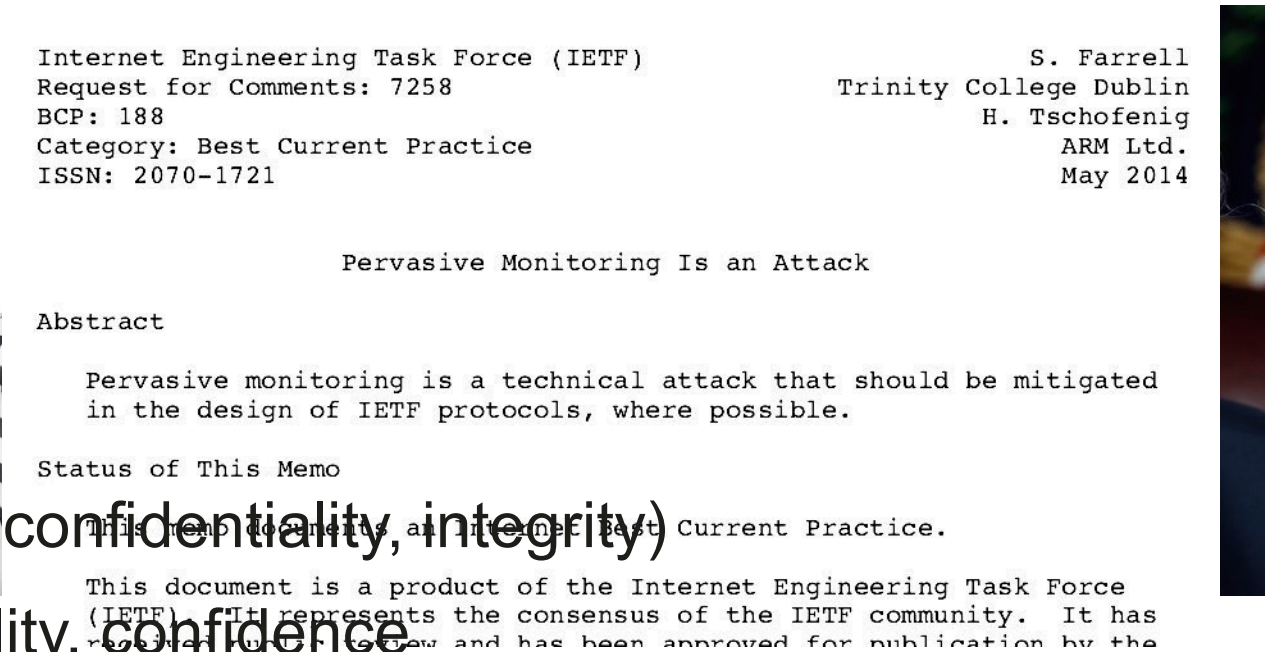
Transport Architecture

- Ubiquitous, basic transports: TCP, UDP
- “Other” transports: STCP, DCCP
- “New” transports QUIC, HTTP/3
- Transport services:
  - Looking at services needed, rather than specific protocols.
  - Reliable delivery
  - Ordered delivery
  - Congestion control
  - Transport streams

Security Architecture

- Resistance to monitoring
  - ...by criminals.
  - ...by “other” governments.
  - ...by one’s own government.
  - There’s no way to tell the difference.
- End to end security (authentication, confidentiality, integrity)
- Preserving user privacy, confidentiality, confidence
- Resilience of encryption mechanisms in the face of quantum computing





Internet Engineering Task Force (IETF) — S. Farrell
Request for Comments: 7258 — Trinity College Dublin
BCP: 188 — H. Tschofenig
Category: Best Current Practice — ARM Ltd.
ISSN: 2070-1721 — May 2014

Pervasive Monitoring Is an Attack

Abstract

Pervasive monitoring is a technical attack that should be mitigated in the design of IETF protocols, where possible.

Status of This Memo

This memo documents an Internet Best Current Practice.

This document is a product of the Internet Engineering Task Force (IETF). It represents the consensus of the IETF community. It has

Modern Internet Architecture

- Vastly updated from where we started.
- Driven by innovation.
- Media streaming drove the addition of streaming protocols.
- Need for robust teleconferencing & streaming drove HTML5 and WebRTC.
- IoT is driving constrained-environment protocols.
- Innovation continues to push it forward.

Where Is Internet Architecture Going?

- Increasing use of mobile networks; 5G.
- IoT will move forward and bring the architecture with it.
- Locator/ID separation and other routing innovations.
- Increasing virtualization and cloud services.
- Protocol (and architecture) adaptability will become more critical.
- Security: object protection, new protocols, new algorithms.
-

The Next Big Thing

- The Next Big Thing will drive the future evolution of the Internet.
- The Internet was built on iterative innovation
- No one thought we would get where the WWW took us until it did.
- No one thought we'd have this level of e-commerce until we did.
- No one thought smartphones would connect us to the world until they did.
- No one thought most Internet traffic would be media streaming until it was.
- What will someone think of next?
- And where will that take the Internet and its architecture?

What Does This Mean to M3AAWG?

- Where does our organization fit in with respect to Internet architecture?
- What can we connect to? How can we help drive things forward?

- Directly:
  - M3AAWG recommends best practices.
  - Innovations are often made without thinking about security, privacy, abuse, and best practices.
- Plug for NDSS: the Network and Distributed Systems Security Symposium

What Does This Mean to M3AAWG?

- Two talks from the 2020 NDSS Symposium bring up some points:
  - Measurements, Attacks, and Defenses for the Web (MADWeb) workshop, "Exploring the Perils of Single Sign-On"
  - Decentralized IoT Systems and Security (DISS) workshop, "OAuth 2.0 Authorization using Blockchain-based Tokens"

- M3AAWG can better connect to the academic community
  - Tie into current research on security, privacy, and abuse
  - Set up feedback loops with respect to best practices

What Does This Mean to M3AAWG?

- What we can do indirectly:
- Those who are professors...
  - ...are teaching the next innovators.
- Those who are industry leaders...
  - ...are hiring the next innovators.
- And if you're a student, a new-hire, someone in the early part of your career...
  - ...you **are** one of the next innovators!

Innovation

- The mission of the next generation of innovators is to **own** that role
  - Look at what we **can** do (but aren't), what we **could** do (if only…)
  - Look at what **no one has imagined** doing, until now.

- The mission of the rest of us is to find those innovators and create an environment where they can thrive… and innovate.
- Providing that community and that environment is absolutely a major goal of M3AAWG, and an important focal point for the future.

You see things; and you say “Why?”

But I dream things that never were; and I say “Why not?”

George Bernard Shaw, “Back to Methuselah”

Thank you.

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