Autonomic Computer Systems CS321: Why the Internet is Being Overhauled

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Overview 2011-10-04

- Internet development periods
- A+B) Selected problems in the Internet architecture
  – addressing, naming, routing and mobility (wrt autonomics)
  – NAT, peer-to-peer, sensor networks, security
- C) Selected debates over the Internet Architecture
- Since 2000: Future Internet research
  from FARA to Named Data,
  from delay-tolerant networking to gossip protocols
- Van Jacobson's CC slide set

Internet Development Periods

1969	first RFC
1970ies	current architecture emerges (IP/TCP split)
1980ies	deployment in universities
	congestion problem, first Internet worm, ISO vs IP war
1990ies	Web success story for the masses
	address problem, IPv6 proposal, QoS and overprovisioning
2000ies	Patches allover (and IPv6 still not coming)
	NAT dominates, net overprovisioning, content delivery networks
2010	Research on Future Internet still ongoing (EU, US, Japan)
2011	Open Network Foundation: reprogrammable switches (OpenFlow)

Note: 15 year networking innovation cycle (from idea to widespread use)

A) Selected Problems in the Internet

1. Addressing
2. Naming
3. Routing:
   routing (in-)stability, no source routing, multipath routing
4. Terminal and Network Mobility

A.1) Addressing

2^{32} look like a big number, but it's not a big enough address space.

- Addresses are allocated to subnets, not end systems:
  many unsused addresses inside a subnet, cannot be recycled
- IPv6 promises a solution (128 bits)

A hidden operational problems (see a later lecture):
poor scaling at the "default-free-zone" due to bad address aggregation

A.2) Naming

- DNS: Map human friendly logical names to IP addresses
- Works through delegation (subtrees),
  serves as indirection mechanism (rotating resolution)

Problems:
– critical infrastructure (Kaminsky bug, Internet dead if DNS dies)
– DNS names hosts, but applications need content and services
– not fast enough for supporting mobility (see below)

A.3) Routing

- The “Border Gateway Protocol” is the work horse for the Internet’s hidden routing hierarchy (autonomous systems)
- Known to be unstable (long convergence time)
- Abused to map contractual relationships to global routing

Insecure routing redirects YouTube to Pakistan Feb 24, 2008

On Sunday, YouTube became unreachable from most, if not all, of the Internet. No "sorry we're down" or cutesy kitten-with-screwdriver page, nothing. What happened was that packets sent to YouTube were flowing to Pakistan. Which was curious, because the Pakistan government had just instituted a ban on the popular video sharing site. What apparently happened is that Pakistan Telecom routed the address block that YouTube's servers are into a "black hole" as a simple measure to filter access to the service. However, this routing information escaped from Pakistan Telecom to its ISP PCCW in Hong Kong, which propagated the route to the rest of the world. So any packets for YouTube would end up in Pakistan Telecom's black hole instead.

A.3) Routing (contd)

- End user’s can’t influence routing (in case of problems)
- In theory, there is source-routing in IP,
  but it’s disabled for security reasons
- Research shows that routing could be made more optimal (e.g. RON - resilient overlay networks)
- Multipath routing not welcome (would be nice for bandwidth), because re-ordered TCP packets are bad

A.4) Terminal and Network Mobility

- Terminal should be able to easily re-attach to the Internet, without having to restablish all sessions
- A cluster of terminals (e.g. body network) should be able to easily re-attach, too

Today, the IP address serves as Identifier and Locator:
– identifier: which end system
– locator: routable destination end point

We should be able to change locator without changing Id

B) More Problematic Internet Behaviors

1. NAT
2. peer-to-peer
3. sensor networks
4. always-on (no rendez-vous)

B.1) Network Address Translation

- NAT was proposed as a way out of IPv4 address shortage:
  only part of intranet's hosts are mapped to the global addr space
- Violates the tenet of a flat network of peers, end systems are at the mercy of "middle boxes":
  – cannot easily publish content
  – problem of symmetric setup (video conferencing)

NATs have been source of heated debates, but are here to stay (because of quasi-security feature and address space decoupeling)

Some researchers proposed address translation as a key building block for a future Internet.

B.2) Peer-to-peer Networking

- An application use case:
  instead of a star-like server-client pattern go for a mesh of participants
- Attractive for bandwidth usage (collateral/parallel delivery paths, mitigates server bottleneck)

P2P caught the Internet community as a surprise, showed deficit of network fabric to efficently deploy data to many end systems in parallel.

Another workaround: content distibution networks (Akamai)

B.3) Sensor Networks

- Some people think that the “Internet of things” will dominate all use cases.
  – sensors are part of the picture
  – billions of sensors feeding data into the Internet
- Some problems:
  – lack of automated address assignment
  – IP stack potentially too heavyweight for small sensor (dust)
  – duty-cycling (long sleep periods), is not good for routing, TCP

Sensor networking still quite active research, part of push towards turning the Internet into a global observatory.

B.4) Always-on (no rendez-vous)

- Why should a host accept any incoming connection, although not having an interest in it?
- Alway-on assumption is one source of Denial of Service attacks
- End systems should be able to actively choose if they want to accept communication, when and from whom
  (NAT hides nodes, but does not permit deliberate and partial exposure)

C) Selected Debates over the Internet Architecture

1. QoS vs overprovisioning
2. Tussles
3. Knowledge Plane
4. Net neutrality
5. Active Networking
6. De-Verticalization, Virtualization

C.1) QoS vs Overprovisioning

- Internet is a “best-effort” network.
  Lack of service guarantees still a source of concern (VoIP, VoD)
- Attempts to introduce “Quality of Service”:
  – resource reservation (RSVP) did not scale
  – Diff-Serv did not win the market
- Approach of many ISPs: overprovision the net, mitigating traffic bursts
  – works well!
  – Skype can use TCP
  – peak factor from 2 to 10

- Unclear how long this strategy can be continued, green Internet

C.2) “Tussles in Cyberspace”

- Classical paper of Clark et al, 2002
- Internet (management) regions have diverging interests, Internet becomes a battle ground
- Internet not well prepared for this (more a collaborative thing)

Future Internets to help negotiate tussles. Has not lead yet to real changes.

C.3) Knowledge Plane

- Another Clark et al paper (2003)
- Separation of Data plane (forwarding)
  and control plane (e.g. routing, management in general)
- Argument: knowledge plane needed for planful operation of the Internet

Background problem is: Internet is bad as self-management,
we need automated “management logic/inference capability”

Fact today is that considerable “baby sitting” is needed to setup and keep the Internet running.

C.4) Net Neutrality

Are ISPs allowed to treat some data in a preferential way?

- Succes of Internet often attributed to application-agnostic IP-layer
- Economic interest: to ISPs, differentiation of services is key for “premium prices” → “bad” peer-to-peer traffic, video-on-demand bundles

- Research: Is net neutrality stiffling innovation (at IP layer and below)?
  – Quality of Service (QoS)
  – novel architectures
- Recent Google/Verizon proposal (Aug 2010): a parallel Internet (the first being “neutral”)

C.5) Active Networking

- Network evolution and network customization:
  inventing and deploying new protocols takes very long
- Mobile code can provide late binding:
  define net functionality at run time, instead of compile-time

AN (since early 90ies) was source of heated debates, active research due to DARPA funding, but still an unrealized dream.

Finally, practical progress can be seen with OpenFlow and the Open Network Foundation initiative (2011)

C.6) De-Verticalization, Virtualization

New Internet Architectures

Since 2000, it has become accepted that the Internet Architecture (IA) needs an overhaul.

- Alternate proposals already during IPv6 debate
- Active Networking in the mid 1990ies
- NewArch DARPA study (2000-2003): “Internet ossification”
- EU projects “Situated and Autonomic Comm” since 2005
  US: “Global Environment for Network Innovations” (GENI, FIND)
  AsiaFI (“Asia Future Internet Forum”) since 2007

Currently no clear path into the future, Telcos focus on the cloud

Beyond IPv4: What is Research doing? (Selected)

- Location/Identity split:
  well recognized now, see for example FARA (“Forwarding directive, association, and rendez-vous architecture)
- Delay Tolerant Networking (DTN):
  TCP is the work horse, but has a limited reach. $\rightarrow$ “Planetary Internet”, infrastructure-less regions
- Gossip protocols:
  massive scale is a problem for (centralized) management,
  we need management mechanisms based on *local* interactions

We will come back to these topics later in this course.

Focus on Content Centric Networking (CNN)

- Van Jacobson research (since approx 2006),
  he's now at Xerox PARC
- Networking is about access to content, not client and servers
- Build a network for forwarding *and* storage,
  and secure the content, not the containers (e.g. session)
- (switch to CCN slides for IETF77, March 2010)
  https://wiki.tools.isoc.org/@api/deki/files/2634//=1.vj.isoc.mar10.pdf