Reflections on the Evolution of the Internet

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The Internet: A Wonderful Accident

- Designed as a network for researchers in the 60's and 70's
- By 'accident' evolved in an essential infrastructure for the "networked society"

  ....but it was never designed for that role….

- The Internet is clearly not future proof, a better internet is urgently needed

Communication networks evolution

- Telephone network
  - Designed for voice, circuit switched, connection oriented, focus on path, required very reliable components, central control
- Cable TV networks
  - Designed as a one to many infrastructure, broadcasting over coax cable
- Data communication networks and the Internet
  - Designed for data communication, packet switched, connection less, focus on end points, no central management
- Hybrid networks
  - combination of (optical) circuits and packet switching

Data communication networks Evolution

- 60s development of packet switching, *Baran, Davies*
- 70s introduction of data communication networks
  - *ARPANET, Pouzin-CYCLADES, X.25*
- 80s birth of the Internet based on TCP/IPv4
- 90s Internet winner in ‘protocol war’, end off PTT monopolies, commercialisation of the Internet, dot-com boom, IPv6
- 00s wireless networking, next generation internet projects
- 10s “All IP” networking, more next generation internet projects
- 20s Internet of Things, ongoing search for a new internet

..introduction of a new internet is long overdue..

Why is this so difficult?

Many players with clashing interests

- Telephone network operators
- IBM
- Other (mini) computer companies
- Governments
- Standard bodies
- Networking research projects
- DARPA
- Users

Standards

- *formal standards*: approved by standards bodies like ITU, IEC, ISO, IEEE, IETF, W3C, ETSI etc. Use is voluntary.

- *de jure standards*: standards made mandatory within a jurisdiction by law, rules, regulations etc. In EU via European Norms.

- *de facto standards*: developed by others, resulting in specifications that achieve widespread use

…standards are like toothbrushes…

Everyone wants to use one,
they just don't want to use someone else's.

ARPANET

- 1969 Start of ARPANET, based on Interface Message Processors, IMPs
- 1970 Network Control Protocol, NCP, added for host-to-host communication
- 1972 Start of the International Packet Networking Group, INWG, to try to interconnect all evolving networks, chartered as IFIP WG6.1 in 1974
- 1976 INWG 96 proposal was submitted to ISO and CCITT for standardisation
- All participants of the INWG were supposed to implement the INWG 96 proposal, however DARPA decided to continue along the lines of their 1974 IEEE TCP publication
- For more details on this period read INWG and the conception of the Internet: An eyewitness account by A. McKenzie

Birth of the Internet

- 1978 TCPv3 was split into TCP and IP, but the TCP/IPv4 specification was only “finalised” in 1980
- 1 January 1983 NCP was phased out, ARPANET was based on TCP/IP
- 1986 start of NSFNET, based on TCP/IPv4, open to all US academic research

….and nearly immediately ran into congestion collapse problems

Why?

- TCP/IP worked fine over the connection oriented network services of the IMPs, or ***locally*** on campus LANs with little or no packet loss, so things looked great

- TCP/IP, being just an unreliable connection less network service, was unable to support the interconnected LANs over the 56 Kbps NSF backbone

Patching began

What are the major flaws of TCP/IP

- Wrong naming and addressing model
  - No naming: IP-address points to interface, not the application
  - TCP was originally designed as an internetwork protocol on top of the IMP network and emerging satellite and radio packet networks
  - After the split in TCP and IP however, the internetwork and the network layer shared the same address space, as a result the Internet is not an internetwork
- Wrong congestion control, relying on the end hosts only
- No security mechanisms as part of the design
- Best effort service, no quality of service mechanisms
- Increasingly complex patches are constantly needed to survive

Resulting in

- Problems to support mobility, multi-homing and multicast
- Problems to support real-time and low latency applications
- Lack of security
- IPv6 and NATs complicate the situation even further
- And so does the move of voice and streaming video towards IP

Why was this not fixed earlier?

- All believed the Internet would soon be replaced by networks based on the international standards to be developed in ISO and CCITT
- Governments had made support of the ISO standards mandatory for all network purchases funded with government money
- As a result no fundamental improvements were undertaken,

….the Internet just needed to be kept alive until replaced by ISO networks

However

- The international standardisation efforts produced too little too late
- TCP/IP code became freely available, started to be used in networks everywhere
- Packet switching with TCP/IP, especially internationally, was much cheaper
- The TCP/IP networks emerged into the global Internet we have today

….Which is now used for many things it was never designed for

Why is the IETF not able to fix this?

- Focus on existing Internet and insisting on backwards compatibility
  - *Nevertheless they created IPv6 which is not backwards compatible, it is a different network with still most of the fundamental flaws of IPv4*
- Backwards compatibility will never remove fundamental flaws
  - *'A hardened piece of junk propagates all through the system', Barton*
- Vested interest in current network by active participants

But the search for a better network is still on

- RINA, Recursive InterNetwork Architecture, John Day, Boston University, http://pouzinsociety.org/
- SCION, Scalability, Control, and Isolation on Next-Generation Networks, ETH Zurich, https://www.scion-architecture.net/
- NDN, Named Data Networking, Van Jacobson, Xerox PARC, https://named-data.net/project/
- FG NET-2030, ITU-T Focus Group Technologies for Network 2030, https://www.itu.int/en/ITU-T/focusgroups/net2030
- NIN, Non-IP networking, https://www.etsi.org/technologies/non-ip-networking
- NewIP, Proposal for “Shaping Future Network” by Huawei, https://www.huawei.com/en/industry-insights/innovation/new-ip
- 2STiC, Security, Stability and Transparency in inter-network Communication, Joint Research Programme initiated by SIDN Labs, https://2stic.nl/

Conclusion

- TCP/IP brought us a wonderful Internet
- Current Internet is no longer fit for purpose
- A new architecture is needed sooner rather than later
  - We know how to build better internets
  - The technology to do so exists
  - Societal awareness for a better internet is growing fast