Reflections on the History and Future of the Internet

(from a technical perspective)

Kees Neggers

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The Internet: A Wonderful Accident

- Designed as a network for researchers in the 60's and 70's
- Now an essential infrastructure for the "network society"
  ....but it was never designed for that role….
- The Internet is clearly not future proof
- A better internet is urgently needed

Time Frame

- 60s development of packet switching
- 70s introduction of data communication networks
- 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

  ….introduction of a new Internet is long overdue

Major players

- Telephone network operators: PTTs and AT&T
- IBM
- Other (mini) computer companies
- Governments
- Standard bodies: CCITT/ITU-T, ISO, IEEE and IETF
- Networking research projects
- DARPA
- Users

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

Development of packet switching in the 60s

- First ideas originated at
  - MIT, J.C.R. Licklider and Leonard Kleinrock (1961-1967),
  - RAND Corporation, Paul Baran (1962-1965) and
  - NPL, Donald Davies and Roger Scantlebury (1964-1967)
- 1968 ARPANET RFQ for Interface Message Processors (IMP's)
- 1969 ARPANET's first demo of an open-access packet ***network***
  - 4 computers connected via a connection oriented subnet based on IMP's designed and built by Bolt Beranek and Newman (BBN)
- 1970 NCP Host to Host protocol, application development could start
  - no end-end host error control, host could only connect to an IMP

First data networks in the 70s

- 1972 Louis Pouzin at IRIA develops plans for CYCLADES, the first network to be designed as an ***internetwork*** based on an end-to-end architecture
  - connection less, datagrams, layered structure, Transport Service (TS) in hosts
- 1972 Start of the International Packet Networking Group, INWG, soon to be associated with IFIP as Working Group 6.1 (WG6.1)
  - Two internetworking proposals: INWG 39 by Kahn/Cerf and INWG 61 from Cyclades
- 1974 TCP article in IEEE TC by Bob Kahn and Vint Cerf “A Protocol for Packet Network Interconnection”
- 1976 INWG 96 consensus proposal was formally submitted to CCITT and ISO as the IFIP recommendation for an international internetworking standard
- 1976 CCITT published the first X.25 recommendation

Birth of the Internet in the 80s

- All participants of the INWG were supposed to implement the INWG 96 proposal, however DARPA decided to continue along the lines of the 1974 IEEE TCP publication
- 1978 TCPv3 was split into TCP and IP
- 1980 “final” TCP/IPv4 specification
- 1 January 1983 NCP was phased out, ARPANET was based on TCP/IP
- 1986 start of NSFNET, based on TCP/IP, open to all US academic research

  ….and nearly immediately ran into congestion collapse problems
- Patching began

So what went wrong?

- ARPANET was setup for a closed group of DoD researchers, to give them terminal access to remote computers and simple file transfer
- ARPANET gradually had grown bigger connecting also sites that were not on the reliable IMP subnet
- 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
- When IMPs were phased out, the reliable subnet disappeared and was replaced by the NSFNET 56 Kbps backbone lines
- TCP/IP was not able to support the interconnected LANs over this unreliable connection less network service

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

- ARPANET was a prototype network built to be used by a limited group of DoD researchers with very modest services in mind
- It perfectly realised this goal with the resources available at that time
- 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
- These networks emerged into the global Internet we have today
- Which is now used for many things it was never designed for

Why were ISO and CCITT not able to fix this?

- Fundamentals of networks and protocols were not yet well understood
- Conflicting interests among the major players
  - PTTs - IBM - Computer companies – Governments
- Overly complex solutions and slow progress
- Poor initial interworking between different implementations
- Users were left in the cold and started using TCP/IP which was freely available, first locally on their LANs and finally worldwide
- Governments and PTTs tolerated this, they still saw TCP/IP as interim
- PTT networks ran out of speed, early 90’s with X.25, end 90’s with ATM
- TCP/IP had won the war and the Internet became an essential infrastructure

Why is the IETF not able to fix this?

- 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

What role played The Netherlands

- In 1982 EUnet started with its central node at CWI in Amsterdam
- 25 April 1986 .nl assigned to CWI
- In 1986 SURF provided seed money to start RARE, now called GEANT, that offered a home to kickstart Ebone and the RIPE NCC
- 17 November 1988 CWI gets connected status to the Internet
- The Dutch Government took a pragmatic position
- Dutch PTT was open for experimentation, also for international connections
- NIKHEF and SURFnet started exchange points in Amsterdam which evolved into the AMS-IX

2STiC: *Security, Stability and Transparency in inter-network Communication*.

- A new joint research programme to increase the security, stability and transparency of internet communications, see: www.2stic.nl
- By developing and evaluating new types of internet that will complement and co-exist with the current Internet to support 21st century applications
- Experimenting with and contributing to emerging internet architectures, such as SCION, NDN and RINA
- Operating a national programmable network based on P4 switches
- Long-term objective is to establish a centre of expertise in the field of trusted and resilient internets
- Current participants: SIDN Labs, the University of Twente, the University of Amsterdam, SURFnet, NLnet Labs and TUDelft

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
- So the momentum is there, let’s do something about it