Professor Nigel Linge

FROM PACKET SWITCHING TO THE CLOUD

Telecommunication engineers have always drawn a picture of a cloud to represent a network. Today, however, the cloud has taken on a new meaning, where IT becomes a utility, accessed and used in exactly the same on-demand way as we connect to the National Grid for electricity. Yet, only 50 years ago, this vision of universal access to an all-encompassing and powerful network would have been seen as nothing more than fanciful science fiction.

The first electronic, digital, stored-program computer was built in 1948 and heralded the dawning of a new age.

DATA COMMUNICATIONS[1]

These early computers were large, cumbersome and expensive machines and inevitably a need arose for a communication system that would allow shared remote access to them.

An obvious candidate for such a system was the national telephone network but that had been designed and optimised for the transmission of the human voice and not the digital binary digits used by computers. Consequently, the Modulator/Demodulator or modem was designed to convert the computer's data bits into signals that could be accepted and transmitted by the telephone network. The Datel Modem No. 1A became available within the UK in 1964 and was capable of transmitting data at a rate of 200 bits per second (bit/s).

By March 1969, the GPO reported that 3,334 modems were in use on its network - a figure that represented a 230% increase on the previous year. This clear and growing demand for data services resulted in the GPO commissioning in July 1970 an experimental, manual call-set-up, data network that used modems operating at 48,000bit/s (48kbit/s).

However, computer communications is different to voice communications not only in its form but also its nature. Whereas a voice call has a clearly defined beginning and end with a reasonably continuous transfer of information in between, remote access to a computer is a much more sporadic form of communication. Therefore tying up a telephone line continuously between a user and computer is an unnecessary waste of resources because, for much of the time, no data is being sent.

An alternative approach was needed and both Donald Davies at the National Physical Laboratory (NPL) in the UK and Paul Baron at the RAND Corporation in the USA were working on precisely that. In the mid-1960s they both independently invented the concept of packet switching in which data is assembled into a short sequence of data bits (a packet) which includes an address to tell the network where the data is to be sent, error detection to allow the receiver to confirm that the contents of the packet are correct and a source address to facilitate a reply.

Since each packet is self-contained, any number of them can be transmitted over the same physical network, one after the other, with each potentially representing a totally different and separate communication. In the USA these concepts were taken forward by the Advanced Research Project Agency (ARPA), which, under the guidance of Larry Roberts, developed its ARPAnet network for linking computers in North America. The first four computers were connected to the ARPAnet in December 1969 and by 1970 the network was extended internationally with a satellite link to the Goonhilly earth station in Cornwall and from there via undersea cable to the NORSAR seismic research facility in Kjeller, Norway. Meanwhile back

in the UK, Donald Davies and his team built the NPL Data Communication Network, which became operational in July 1971 as the world's first packet switching local area network.

Connecting the UK to ARPAnet was achieved on 25 July 1973 when, under the direction of Professor Peter Kirstein of University College London, the first data packets were exchanged between University College London and the Information Sciences Institute in California. Whilst this connection used a satellite link operating at 9.6kbit/s, it was actually routed via Kjeller in Norway where a new earth station had been commissioned that removed the necessity to use Goonhilly. On the 14 November 1973 the first full public demonstration of ARPAnet in the UK was provided by Professor Kirstein when he delivered a lecture to the Institution of Electrical Engineers. Also in 1973, Robert Metcalfe was working at Xerox PARC when he invented a local area packet-switched network called Ethernet. Standardised as IEEE 802.3 in 1983 and IEEE 802.11 (WiFi) in 1999, Ethernet has become the dominant local area network technology with a multi-billion dollar global market.

The work on packet switching at the NPL and ARPA naturally drew the attention of the Post Office which, in 1977 establish its trial Experimental Packet Switching Service network. This network comprised three packet switching exchanges, designed using the Ferranti Argus 700E processor, located in London, Manchester (actually Dial House in Salford) and Glasgow with interconnecting links running at 48kbit/s. Needless to say that at this time several other countries were developing their own public data networks which created an incentive to harmonise their respective designs towards a common network interface. Consequently, the International Telegraph and Telephone Consultative Committee, now the International Telecommunications Union, established Study Group VII for the development of standards relating to data communications services. In March 1976 it published its Orange books which included the specification of a standard for packet-switched wide area networks called X.25 and a standard for interconnecting such networks called X.75.

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The X.75-based International Packet Switch Stream (IPSS) Service opened in 1978 with an international exchange located in London and links to data networks in the USA, Canada, Japan and into Europe via Euronet. On 20 August 1981 the UK, X.25-based, Packet Switch Stream (PSS) service was opened with switching exchanges designed using the Telenet TP4000 processors and built by Plessey Controls (Poole). By 1983 customers were offered a fully digital interface with the launch by British Telecommunications (formerly Post Office Telecommunications) of the KiloStream (64kbit/s) and MegaStream (2Mbit/s) services. In 1984 KiloStream was expanded to provide International KiloStream facilitated by links provided through satellite earth stations at Goonhilly in Cornwall or Madley in Herefordshire.

The development of X.25 was driven by the telecommunications companies (telcos) that were seeking to establish national public data networks. However, telcos had a philosophy that the network service must be inherently reliable which led to the criticism that X.25 was inefficient and too complex. A different school of thought in network design was emerging from the USA, not driven by telcos but by computer scientists. Their view was that the data network did not need to be inherently reliable providing that the computers using the service could detect and correct any packet errors that occurred in transmission. This work culminated in 1974 when Vinton Cerf and Bob Kahn published their Transmission Control Protocol and Internet Protocol (TCP/IP) suite. On 1 January 1983, ARPAnet adopted TCP/IP as its standard protocols and in 1991 the ARPAnet morphed into the Internet.

HOME AND OFFICE COMPUTING

These early data networks were used by companies for business processing applications and by the research community for remote access to mainframe computing services. The concept of using a network for information retrieval purposes as we do today began to emerge with the launch of Viewdata services. Post Office Telecommunications launched the world's first public Viewdata service called Prestel in March 1979. Customers were able to use their television sets, linked via a telephone, to access a central Information Retrieval Centre where data was organised into a series of information pages. Prestel proved very successful with 80,000 user terminals connected by 1988 generating a total of 9.1 million accesses per week for pages offered by 1,300 information providers. One of the most popular services was Prestel Travel and gateways offered access to a broader range of services that included personal banking, train timetables, stocks and shares trading, education and even a basic form of email called Prestel Mailbox, which was launched on 15 October 1984.

Using the television as an access terminal for Prestel was logical because in the late 1970s domestic customers simply did not have a computer in

By 1970 the network was extended internationally with a satellite link to the Goonhilly earth station in Cornwall.

their homes. This was of course set to change because of the invention of the microprocessor, which now fuelled a revolution in home computing.

On 29 January 1980, Sir Clive Sinclair launched the UK's first sub-£100 home computer, the ZX80, which was followed on 5 March 1981 with the ZX81 and then on 23 April 1982 with what became Britain's best selling computer, the ZX Spectrum.

Priced at between £125 and £175 the Spectrum became the computer of choice for teenagers keen on playing games or becoming budding computer programmers. The BBC Micro, designed and built by Acorn Computers was launched in December 1981 and was rapidly adopted within UK schools and supported by learning materials produced by the BBC. Connecting a home computer to the outside world in the 1980s was of limited but growing interest because of the success of services such as Prestel's Micronet 800 which allowed people to play online games, to download software, to post messages, to send and receive email and to publish pages in a gallery area. Inevitably, this early and highly influential period in the development of the home computer was characterised by a range of incompatible machines, the predominant use of which was playing games. That changed when IBM launched its Personal Computer on 12 August 1981. Originally intended for the professional market, this standardised hardware design with its MS-DOS operating system provided by Microsoft spawned a series of compatible derivatives that started to become affordable for the home user.

THE INTERNET AND ACCESS TO THE INTERNET

The next important advance came in March 1989 when Sir Tim Berners-Lee published his now iconic paper entitled, "Information Management: A Proposal" [1], in which he proposed an integration of hypertext with the Internet to create what he termed the WorldWideWeb. Information coded as hypertext could be transmitted over the Internet using the hypertext transfer protocol (http) and displayed on a computer using dedicated browser software. Tim Berners-Lee created his first web browser in November 1990 and the World Wide Web software was released onto the Internet in August 1991 thus transforming it from an obscure network into a valuable source of information to which millions wanted access. By December 1992 there were 26 known web servers on the Internet but within a year that number had increased to 200. Today the total number of web servers is probably unknown but in June 2008 Google reported that it had detected over one trillion unique active web page addresses.

For the domestic customer, connecting their computer to the outside world took on a new urgency. Unfortunately, because domestic telephones were permanently wired, early slow-speed modems had to use an acoustic coupler into which was plugged the handset of a conventional telephone.

An important step that overcame this limitation occurred on 19 November 1981 when BT introduced its plug and socket interface for the home which meant that modems could now have a direct electrical connection to the telephone line. In 1988, ITU Recommendations V.21 and V.23 extended modem speed to 1200bit/s. This was followed in 1991 with the V.32bis Recommendations which increased speeds to 14.4kbit/s and then, on 25 September 1998, modems reached their pinnacle of development with the release of the V.90 Recommendation which offered a maximum download speed of 56kbit/s and a maximum upload speed of 33.6kbit/s.

Connecting a home computer to a modem and a telephone line was nevertheless still only solving half the task because connection to the Internet required a leased line and this was way beyond the means of a domestic customer. This led Cliff Stanford to propose a new form of business that would act as the intermediary between the domestic user and the Internet. He bought leased line access to the Internet and then charged customers a monthly subscription for which they could have dial-up access via his company to the Internet. Demon Internet therefore became the UK's first Internet Service Provider when it was launched on 1 June 1992.

From the mid-1990s onwards there was a rapid growth in the number of Internet users worldwide driven by the expansion of available web content, improving modem technology, the declining price of owning a personal computer and easier-to-use graphical browser interfaces.

A growing user community naturally drove the evolution of the web itself with websites becoming more sophisticated and multimedia rich. The move from Web 1.0 to Web 2.0 saw the emergence of interaction and collaboration epitomised by the social networking revolution and now Web 3.0 is creating the intelligent web and the Internet of Things concepts. However, such developments could not have been realised had new access technology not been created to replace the V.90 modem.

On 22 March 1988 researchers working at Bell Communications Research, Inc (Bellcore) in the USA filed a patent for Asymmetric Digital Subscriber Line (ADSL). This technology exploited the higher frequency carrying capacity of the local loop copper cables to transmit computer data above the voice band thus allowing for a theoretical maximum download speed of 24Mbit/s with ADSL2+. BT launched its ADSL service in June 2000 and an ADSL 2+ service in 2006. A competitor local access technology is the cable network infrastructure that was installed within the UK following the Cable and Broadcasting Act, 1984. Companies that were awarded cable TV licences built new networks based on a combination of optical fibre and coaxial copper cables, which gave them an early technological advantage over BT for the provision of high speed Internet access. For example Nynex CableComms began a trial of cable modem technology on

its Manchester network in 1996 that offered customers a download speed of 10Mbit/s and an upload speed of 768kbit/s. Through numerous mergers, these companies were consolidated as Virgin Media in February 2007.

Our thirst for speed is relentless, driving the need to replace the local loop copper by fibre. Providing fibre to every home in the country is currently prohibitively expensive but installing fibre from the exchange building to the street cabinet is practical and this is the basis for the current roll-out of super-fast broadband services.

A new larger street cabinet needs to be installed alongside the existing one to house the digital subscriber line access multiplexer which is linked back to the equipment in the exchange building via a dedicated fibre. Hence, this fibre-to-the-cabinet solution reduces the length of copper in the data path and has the potential to increase local loop download speeds to 80Mbit/s. By the summer of 2012, Openreach was reporting that it has achieved 10 million homes with its fibre-to-the-cabinet roll-out.

MOBILE COMPUTING

In parallel with the technical advances that brought the web into our homes with its the mobile phone began its transformation into a pocket computer. An early example was the Nokia 9000 Communicator released in 1996 that offered a handset that could be opened to reveal a full computer keyboard, large screen and a set of standard office applications.

In 1997, Nokia released the 7110 which was the first mobile to allow access to the web via a Wireless Application Protocol browser. It was Ericsson's R380 released in 2000 that is now regarded as the first true smartphone which combined the functionality of a mobile phone, personal organiser, Wireless Application Protocol browser, email and SMS messaging.

Then in 2007 Steve Jobs announced that Apple was entering the mobile phone market. Apple's iPhone has been a truly disruptive technology that redefined the design and functionality of the smart-phone. A move from 2G to 2.5G (General Packet Radio Service) networks provided users with increased data carrying capacity by routing Internet access over a separate packet switched service. This was further enhanced with the move to 3G, and now 4G service eliminates circuit-switched voice to provide a high speed mobile network that is completely packet-switched. Similarly the national telco-operated networks are being refined and remodelled as packet-switched-only Next Generation Networks in which a single infrastructure delivers all of our telecommunication services.

FINALLY, THE CLOUD

Perhaps surprisingly, as early as 1962, Joseph Carl Robnett Licklider put forward a vision of an intergalactic computer network. In many ways the original ARPAnet and now the web are physical realisations of this vision but it was not until 1999 that salesforce.com pioneered the concept of delivering enterprise applications through a website. This was then followed in 2002 by Amazon Web Services that offered a suite of web-based services for storage and computation. These have subsequently been added to by Amazon's Elastic Compute Cloud and Google Apps that allow organisations to host their applications within the web.

Today, the cloud is seen as some universal entity that can be accessed as easily from home as it can on the move. A UK Internet user will typically spend 90 minutes per week accessing social networking sites and email (Ofcom) and over 50% of those users will go online via their smartphones (Office for National Statistics). Underpinning all of this is the pioneering work and engineering achievement that first brought us packet switching and which now has developed that technology to turn the cloud from a mere symbol into a global business that is expected to be worth $241 billion by 2020.

FOOTNOTES

[1] A series of articles by Phil Kelly, "Computer Communications – the early days 1966 – 1986", were published in The Journal of the Institute of Telecommunications Professionals, Vol 4 pt 4, Dec 2010, Vol 5 Pt 1, Mar 2011 and Vol 5 Pt 2, Jun 2011

ABBREVIATIONS

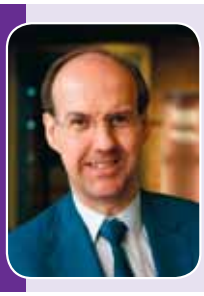
ADSL	Asymmetric Digital Subscriber Line
ARPA	Advanced Research Project Agency
NPL	National Physical Laboratory

References

1. Berners-Lee, T. Information Management: A Proposal. CERN, Mar 1989, May 1990.

ABOUT THE AUTHOR

NIGEL LINGE



Nigel Linge is Professor of Telecommunications at the University of Salford where he is responsible for teaching computer networking technologies at both undergraduate and postgraduate level and undertaking research into communication protocols, location-based services and the application of networks to energy monitoring. In addition, he has an active interest in the preservation and promotion of telecommunications heritage. He is a member of the ITP, Fellow of the IET and BCS, a CEng and CITP.