# RTT TECHNOLOGY TOPIC
## December 2009

## Information Networks in an Information Age

Immediately after the Second World War, a decision was taken to capitalise on the work that Alan Turing had done at Bletchley Park on the Colossus code breaking machine and build a general purpose electronic computer.

The work was done at the National Physical Laboratory and was based on Alan Turing's conceptual discovery of the Universal Turing Machine, a computer that is not structured to carry out particular tasks

**The result was a computer, the Automatic Computing Engine that at the time was probably the fastest in the world.**

Thirty years later Seymour Cray delivered a **Cray 1A supercomputer** to the Aldermaston Atomic Weapons Authority where it still remained in 1990, the last operating Cray 1A in the world.

The machine cost £8 million pounds and had a Freon cooling system and an early form of vector processing that allowed the computer to achieve then unrivalled operating speeds.

Both of these computers are on display in **The Making the Modern World Gallery of the Science Museum.** The gallery traces the impact of technology and engineering from 1750 to 2000 on every day life from 1750 to 2000 and includes the **1832 Babbage Difference Engine** – the ancient ancestor of today's modern computing industry.

The Making the Modern World Gallery and the Flight Gallery were made available to us for **Cellular 25**, an event designed to change the way we think about the future global role of cellular communication.

A sister gallery is now proposed that will showcase computing and communication innovation over the past twenty to thirty years. The gallery will be called 'The Making of Modern Communication' and will have a practical educational focus, showing how communication and computing products work.

It is intended that **Cellular 25** will help provide some funding for the proposed new gallery.

The presentations made at the event are available **here**

Photographs taken at the event are available **here**

In this month's technology topic we use The Difference Engine, The Automatic

Computing Engine and the Cray Supercomputer as reference points to explore how the convergence of computing and communications has created a new generation of Information Networks that dominate the developed world today. These networks have the potential to transform the rest of the world both in terms of social and economic progress, education and health.

However there are fundamental differences between computing and communication in terms of cost and investment return which need to be factored in to these global ambitions.

We suggest that present telecommunications investment in developed economies will not result in networks that are more cost efficient or energy efficient than the networks being replaced.

This is not to say that these networks will be socially and economically unprofitable.

Telecommunication networks will be **the connection engines of the information age** delivering benefits that with political will can be evenly distributed across developed, emerging and survival economies, a net gain for all.

**From Difference Engine to Connection Engine**

Babbage's design in the 1830's embodied almost all the conceptual concepts of the modern electronic computer. The Babbage engine never quite worked in practice due to tolerancing problems and Babbage's tumultuous temper but it was intended to be a general purpose machine which could be programmed with punched cards to perform almost any function.

Similarly the Automatic Computing Engine and Cray Super Computer were described as general purpose machines but were applied to a very specific purpose, both were used to model and analyse the behaviour of atomic explosions.

Modern cellular networks are similar in that they have had a general purpose, providing person to person connectivity but are now evolving into being broader multi purpose delivery platforms. However **at heart a cellular network is still a connection engine.**

Moore's law has powered the cellular industry to the point where **a cellular switch which would fill up a large room in the 1980's** can now be fitted in a **box** that can shipped by lorry or air lifted to deliver instant emergency communication in to disaster zones.

Although voice communication has to date been the predominant application, these networks are now beginning to do far more both in terms of imaging and video and data.

We have come to assume that each generation of computer is faster and more cost and energy efficient than its predecessor.

Similarly it might be assumed that each new generation of cellular network provides faster connection speeds at lower cost with ever better energy efficiency and that this provides the basis for an improved financial return.

Both of these assumptions are false.

The first practical automatic telephone exchange based on electro mechanical switching was introduced by **Almon Strowger** in 1888 and was first introduced to the UK in 1912. **Strowger exchanges** remained in use until the mid 1990's proving the point that telecoms equipment when fit for purpose can have a remarkably long life cycle particularly when compared to modern day computing life cycles.

The development of electronic switching in the 1950's proved to be a surprisingly painful and expensive experience with practical deployment only being realized through the **1960's in the US** and **rather later in Europe** and the rest of the world.

These exchanges however remain today at the heart of every telecommunications network including every cellular network in the world and are completely fit for purpose for the job which they were intended to do, setting up, maintaining and clearing down telephone calls.

We also sometimes forget that exchanges have also been very efficient at generating and distributing power and for many people the idea that an old fashioned fixed phone still works in a local power outage provides a curious comfort.

However there is now a general assumption that telecommunication networks including cellular networks are moving away from centralized switching and transitioning to distributed architectures with IP based addressing and prioritization.

There is however no compelling evidence that this transition will either be cost efficient, energy efficient or directly environmentally efficient.

IP networks were and are considered to be more resilient than traditional networks based on centralized switch architectures.

They bear a close resemblance to the postal service where packets can and often do travel by many and various routes from origin to destination.

As with postal systems, packets can be stored (buffered) during the delivery process and as with postal systems packets can be lost or have to be deliberately discarded if the storage or buffer space overflows.

This results in a variable customer experience. Post offices traditionally manage this by introducing differential pricing, first and second class stamps and guaranteed or signed for delivery. IP networks manage this by introducing multiple service levels based on multi level packet prioritization.

In theory this increases the multiplexing efficiency of the network, trading variable delay against network utilization efficiency and trading delivery bandwidth efficiency against memory bandwidth occupancy.

However this requires routers to read and interpret IP addresses together with the priority labels embedded with the address. This information then provides the basis for a complex buffering and routing decision.

But this introduces variable delay into the delivery budget. The overall delay and the variability of the delay can be reduced by using hardware accelerators and high speed memory.

These are costly energy absorbent devices.

Even more frustratingly, just as in the traditional postal system, many of the packets delivered over the network are unwanted and have negative value – they annoy the receiver. These unwanted packets get in the way of latency sensitive end to end services including voice communication.

In a cellular network these costs are multiplied in several ways.

IP address overhead has to be accommodated within the RF link budget and the unwanted and unneeded negative value packets cost money to deliver.

Wireless marketing teams have decided that users want and need to be offered high peak data rates even if this compromises average data throughput.

High peak data rates can only be achieved by using higher level modulation schemes that are inherently noise sensitive and perform poorly most of the time resulting in user frustration and packet send retries that absorb network bandwidth and battery and network power.

The higher order modulation schemes require more linear and therefore less power efficient radio frequency transmitters.

The adaptation schemes needed to manage and mitigate these effects in turn introduce variable delay and add to the overall energy budget.

At this point you might question why the fixed and mobile telecommunications industry remains so set on IP network implementation.

The idea that LTE networks will be more cost efficient and power efficient than the networks they are replacing is naïve. The notion that they can be profitable is not.

**Telecoms - the tobacco industry of the 21$^{st}$ century?**

Telecommunications networks including cellular networks now provide access to instant information on a scale that would have been hard to imagine thirty years ago.

Information is addictive and develops dependency, two core ingredients of a successful business model.

Even better, the capital and energy costs of storing and managing the information in thousands of server farms around the world are paid for by other third parties.

For 150 years (from 1850 to the year 2000), the telecommunications industry has made money out of people's desire and need to inter relate to one another – the telegraphy and telephony age. Telegraphy and telephony provided a basis for social and economic progress based on social, economic and business efficiency, profitability with a social purpose.

Information networks extend that model by helping us to interrelate with the physical and **intellectual** world around us.

Information can of course be **misused** but in general it has to be assumed that informed decisions and actions are better than uninformed decisions and actions.

Broader and more efficient access to information should at least theoretically enable **wiser more broadly collective decision making,** the world should become more **intellectually efficient.**

However the tobacco analogy would suggest there may be longer terms costs attached which are not presently visible and might only become evident in the distant future. It has taken Europeans **500 years** to wake up to the health risks of tobacco but if the world was to worry about unknowable long term risk then the world would never move on.

In the meantime the telecommunications industry appears to have reinvented itself more by accident than intent.

The economic implications are however neither simple nor straightforward.

Electro mechanical switches were expensive to develop and slow to be deployed. In the UK depressed wage rates after the First World War meant that it was more economic to use human operators to set up a call.

The financial returns from the investment were substantial but were based on an extended deployment cycle. The development cost of the Strowger exchanges still in use in the 1990's had been amortized over more than 100 years and the capital costs would have typically been amortized over forty years or more

It would be surprising if the electronic switches installed over the past thirty years did not have a similar long tail in terms of investment return. Old technology takes a surprisingly long time to die.

The counter argument is that the computing revolution has changed the economic rule book and that R and D and capital amortization now has to be achieved in months not years and certainly not over fifty years or more. The fact that a Cray computer was still being used fifteen years after it was delivered is considered absurd.

But **communications is not computing.**

There are similarities, both are dependent on hardware and software but this is where the similarity ends.

The mechanics of connection are more complex than the mechanics of calculation. Telecommunication networks are dependent on signaling systems and protocols that take decades to develop and which absorb thousands of man years of international standardization effort. **SS7 signalling** is one example.

Cellular networks also have to develop and standardize the **radio access** part of the network. Adding IP protocol to fixed or wireless networks introduces additional cost and complexity.

It is no surprise therefore that the companies that have enjoyed the most success in the telecommunications industry and that are presently the most resilient are those that have managed to support long term investments that realize long term returns bearing in mind that the definition of long term in this context is thirty years or more.

In Europe that includes companies that have ownership and shareholder structures that give them a measure of protection against institutional shareholders focused on shorter term returns.

Telecommunications companies in command and control economies similarly can find it easier to justify thirty to fifty year investment returns.

Whether US companies can still do this must be open to question.

**Roads and railways and the power and water economy – the justification of long term returns**

If we are defining telecommunications as just another transport system along side roads and railways and power and water utilities (see last month's technology topic) then it is reasonable to assume that the model of the last one hundred and fifty years will carry on for the next 150 years. Change occurs over decades rather than days and the return on investment is on a similar time scale.

The fact that telecommunications networks have reinvented themselves as information networks does not alter this fundamental truth but should reassure us that the telecommunications industry continues to have a socially and economically profitable purpose.

Curiously the industry may also be able to deliver indirect rather than direct environmental gain. We return to this topic next month.

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