RTT TECHNOLOGY TOPIC
February 2006

Competitive Networks

Our January Hot Topic, 'The Bit Rate Race' provided a basis for comparing wide area air interfaces in terms of functionality and power and bandwidth efficiency.

In this month's Hot Topic, we look at some of the technologies and techniques being used to deliver a more competitive radio network proposition.

We suggest that future networks will need to develop new mechanisms for capturing user bandwidth and user value and that the most successful networks will be those that most successfully compete for billable revenue - aggressively competitive networks.

Competitive networks are intelligent networks with ambition. They may also be described as **'Smart' Networks'** using 'smart' in the contemporary sense of a network having **a developed ability to make money.**

Competitive networks may have other obligations, which may include social and political gain. **Smart competitive networks** are efficient at **translating social and political gain into economic advantage.**

Economic gain is the product of a composite of cost and functional efficiency and added value.

Added value is delivered through service provision and billing but is dependent on a broad mix of enabling technologies and enabling techniques that evolve over time.

This process of technology evolution is managed within a standards making process that in itself determines the rate at which new technologies are deployed.

The standards making process also introduces a cyclical pattern of technology maturation which is not naturally present in the evolutionary process, which is largely linear (a statement that we defend later in this Hot Topic).

This produces market distortions that reduce rather than enhance added value.

An understanding of the evolutionary process is therefore a useful precondition for identifying technologies that deliver long term competitive advantage and provides an insight into how standards making could become and probably will become more productive over time.

Charles Darwin's contribution to the theory of network evolution.

To study the evolutionary process, where better to start than Charles Darwin.

Inspired by amongst others the famous botanist, geologist, geographer and 'scientific traveller' the Baron von Humboldt (the current man), Darwin spent five years (1831-1836) on the HMS Beagle observing the flora and fauna of South America.

From these observations Darwin developed his theories of natural selection.

In parallel, similar studies on similar expeditions to the Amazon were leading Alfred Russell Wallace to develop and promote similar theories which in turn prompted Darwin (in 1859) to publish 'On the Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life'.

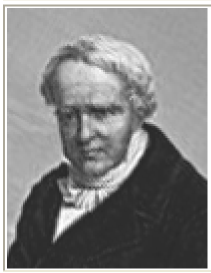
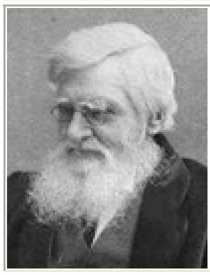
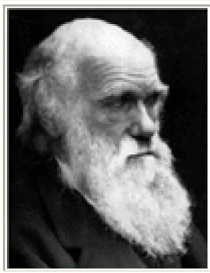
A summation of Darwin's theory
Evolution exists.
Evolution is gradual.
The primary mechanism for evolution is **natural selection.**
Evolution and natural selection occur through a process of on going **specialisation.**

So what relevance does Darwin and his fellow botanist and naturalist colleagues have to cellular network design and cellular network evolution?

Well, to paraphrase,

'The survival (or success) of each organism (cellular network) is determined by that organisms (cellular network's) ability to **adapt** to its environment'.

'The fittest (most power and bandwidth efficient networks) win out at the expense of their rivals(other network providers) because they succeed in **adapting** themselves best to their environment'

Famous bearded botanists and their role in cellular network design		
Alexander von Humboldt **1769-1859**	**Alfred Russell Wallace** **1823-1913**	**Charles Darwin** **1809-1882**
		

The dynamics of adaptation
Darwin suggested that the process of evolution and adaptation occurs over millions of years.

One way or another humans seem to have used those millions of years to achieve a competitive advantage over (most) other species. This competitive advantage is based on energy efficiency (output available for a given calorific intake), observational abilities (sight, sound, smell) and the ability to use observed information intelligently to avoid danger or to exploit locally available opportunities.

To us, the process of long-term adaptation is unnoticeable due to the time scales involved. The process appears to us to be static.

However part of the process of successful adaptation over time is to become more adaptive, particularly in the way in which we conserve energy, the way in which we manage to have energy available to support short concentrated bursts of activity, and the way in which we couple these processes to observed information.

Short-term adaptation functions are noticeable. We can experience them and measure their extent and effect. We can recognise and observe the dynamic nature of the process.

In cellular network and cellular handset design, adaptation is an already important mechanism for achieving power and bandwidth efficiency and is becoming more important over time.

As such it is useful to study how adaptation works in an engineering context but using several million years of biological and botanical experience and several hundred years of biological and botanical study and analysis as a reference point.

Adaptation, scaling and context

We can take describe almost any process in an end to end mobile communications channel in terms of three interrelated functions - adaptation, scaling and context.

Adaptation is the ability of a system or part of a system, to respond to a changed requirement or changed condition.

Scale (scaling) is the expression of the order of magnitude over which the adaptation takes place (the range) and may also comprehend the rate and resolution of the response.

Context is the amount of observable information available in order for the system itself or some external function to take a decision on the adaptation process. The accuracy of the observation process and the ability of the system to interpret and act on the observed information will have a direct impact on overall system efficiency.

The function of the human heart provides a biological example. Our heart rate and blood pressure increases when we run. Our heart rate and blood pressure also increases when we use our observation system (sight, sound, smell, touch and sense of vibration) to perceive potential danger and/or local opportunity. As such, the process of adaptation is both reactive and proactive.

The scale in this example ranges from the lowest to highest heart rate. The context is either actual (we have started to run) or predictive (we know we might have to run).

Human observation systems in themselves are adaptive. For example our eyes can adapt to light intensities ranging from small fractions of a lux to over 100,000 lux. This is the scale of the adaptation process. The context, in this example, is the ambient light level.

Examples of adaptation in existing semiconductor solutions
Many present semiconductor solutions used in cellular phones and consumer and professional electronics products use adaptation to decrease power drain. In this context, adaptation is based on the ability to change the clock speed (heart rate) and or voltage (blood pressure) of the system when presented with specific processing tasks (the context).

The scale is the highest to lowest clock rate and highest to lowest voltage. The rate of response (milliseconds or microseconds) and accuracy of response will directly impact overall system efficiency. They may also be additional 'policy' issues to consider, for example the charge state of the battery and external or internal operating temperatures.

Peripheral devices such as displays (one of the largest power consuming items in most present appliances), also use adaptation by responding to changes in ambient light level or by decreasing frame rates, resolution and colour depth in response to a changed operational requirement.

Examples of adaptation in existing cellular systems
Adaptation has always been an inherent part of cellular network design. First generation analogue cellular networks used receive signal strength measurements to determine power and edge of cell handover thresholds (an intelligent use of observed information).

Second generation networks make the handset work harder in that the handset compiles a measurement report which is a composite of received signal level and received signal quality (bit error rate and bit error probability). This is sent to the radio network controller which in turn makes power control and handover decisions. The handset has traditionally been instructed to look at up to 6 base stations, it's own present serving base station and five 'neighbour' handover candidates though there is support for more extended measurement reporting (up to ten base stations) in more recent releases. Power control is implemented within a relatively relaxed duty cycle of 480 milliseconds though optional enhanced (120 millisecond) and fast (20 millisecond) power control is now supported.

So in these examples, the adaptation process is the combined function of power control and handover. The scale of power control is typically about 25 dB (first generation) or 30 to 35 dB in second generation systems, the rate is either 480 milliseconds, 120 milliseconds or 20 milliseconds and the resolution is typically half a dB. The context is provided by the measurement report. Note that overall system efficiency is determined directly by the accuracy of the measurement report and the ability of the power control and handover algorithms to interpret and act on the observed information - this is **algorithmic value.**

Release 99 WCDMA introduced more aggressive power control (an outer loop power control every 10 milliseconds and an inner power control loop running at 1500Hz), a substantially greater dynamic range of power control (80dB) and the ability to change data rate and channel coding at ten millisecond intervals.

HSDPA simplifies (effectively eliminates) power control but allows data rates and coding and modulation to be changed initially at 2 millisecond intervals and in the longer term at half millisecond intervals.

The context in which the data rate and channel coding decision is taken is based on a set of channel quality indicators (CQI's). This is a composite value (one of 30 possible values) which indicates the maximum amount of data the handset thinks it should be able to receive and send, taking into consideration current channel conditions and it's designed capabilities (how many uplink and downlink multi codes and modulation schemes it supports).

There are however many additional contextual conditions that determine admission policy. These include fairly obviously the level of service to which the user has subscribed but also the local loading on the network. Admission policy may also be determined by whether sufficient storage, buffer or server bandwidth is available to support the application.

So we have a 20 year example of evolution in cellular network design in which step function changes have been made that deliver more adaptability over a wide dynamic range (scale) based on increasingly complex contextual information.

It is this process of increasingly aggressive adaptation that has realised a progressive increase in power and bandwidth efficiency which in turn has translated into lower costs which in turn have supported lower tariffs which in turn have driven traffic volume and value.

Examples of adaptation in future semiconductor solutions

There is still substantial optimisation potential in voltage and frequency scaling. Present frequency scaling has a latency of a few microseconds and voltage scaling a latency of a few tens of microseconds but the extraction of efficiency benefits from scaling algorithms is very dependent on policy management.

Scaling policy has to take into account instantaneous processor load and preferably be capable of predicting future load (analogous to our heart rate increasing in anticipation of a potential need for more energy). Proactive rather than reactive algorithms can and will deliver significant gains particularly when used with multi processor cores that can perform load balancing. These are sometimes known as 'balanced bandwidth' processor platforms.

Examples of adaptation in future cellular networks

Developments for near future deployment include adaptive source coding, 'blended bandwidth' radio schemes that use multiple simultaneous radio bearers to multiplex multi media traffic, and 'balanced bandwidth' IP RAN and IP core network architectures that adaptively manage buffer bandwidth, storage bandwidth and server bandwidth to support bandwidth efficient multi service network platforms.

'Adaptive Source Coding' was covered in our May 2005 Hot Topic on 'Adaptive Systems'.The Hot Topic summarised the present and known future status of adaptive multi rate vocoders, AAC/AAC PLus and MP3Pro based audio encoders, JPEG image encoders and MPEG video encoders.

Over the past six months there has been significant attention given to wavelet based JPEG encoders and MPEG2000 Part 10 scalable video coders both of which provide examples of an increase in adaptability and scalability (dynamic range). Note that realisation of the power and bandwidth efficiency potential of these encoding techniques is very dependent on an aggressively accurate analysis of complex contextual information.

'Blended bandwidth' was covered in the same Hot Topic. The suggestion was that potential efficiency gains could be realised by actively sharing bandwidth between wide area, local area and personal area radio systems. Admission control algorithms could be based on channel availability, channel quality and channel 'cost' which in an ideal world could be reflected in a 'blended tariff' structure to maximise revenues and margin in combination with a more consistent (and hence higher value) user proposition.

When combined with other downlink delivery options such as DAB, DVB, these 'blended bandwidth' offerings are sometimes described in the technical literature as 'co-operative networks' or Universal (licensed PLUS unlicensed) Mobile Access. (UMA)

The technical and potential cost benefits of such schemes are compelling but adoption is dependent on the resolution of conflicting commercial objectives. The fiscal aims of co operation and competition rarely coincide unless a certain amount of coercion is used.

'Balanced Bandwidth' is a topic we will return to in future Hot Topics but essentially involves achieving a network balance between radio access bandwidth, buffer bandwidth in the end to end channel, (including IP RAN and IP core memory bandwidth distribution), persistent storage bandwidth and server bandwidth and being able to manage this bandwidth mix proactively to match rapidly changing traffic loading and user application requirements.

How SuperPhones contribute to Competitive Network Value
We have already stated that existing phones play a key role in collecting the contextual information needed to support power control and handover and admission control algorithms

Power control, handover and admission control algorithms are needed to deliver power efficiency (which translates into more offered traffic per battery charge) and spectral efficiency (which translates into a higher return on investment per MHz of allocated or auctioned spectrum).

Phones are the eyes and ears of the network.
In our November and December 2005 Hot Topics we suggested that there are three categories of phone, standard phones, smart phones and super phones.

Standard phones are voice and text dominant and change the way we relate to one another.

Smart phones aspire to change the way we organise our work and social lives.

Superphones change the way we relate to the physical world around us.

We studied the extended image and audio capture capabilities of superphones and the ways in which these capabilities could be combined with ever more accurate **macro and micro positioning information.**

Macro positioning information is available from existing satellite systems, for example GPS with it's recently upgraded higher powerL2C signal and ,at some stage, Galileo with its optimised European coverage footprint. Macro positioning is also available from terrestrial systems (observed time difference) and from hybrid satellite and terrestrial systems.

Micro positioning is available from a new generation of multi axis low G accelerometers and digital compass devices that together can be used to identify how a phone is being held and the direction in which it is pointed.

This moves competitive networks on to new territory. The eyes and ears of the network see more and hear more than ever before. The network has a precise knowledge of where users are, what they are doing and where they are going (direction and speed).

In simple terms, this knowledge can be used to optimise handover and admission control algorithms.

More fundamentally, **the additional contextual information becoming available potentially transforms both the adaptability and scalability of the network and service proposition.**

This has to be the basis of **future mobility value** in which handsets help us to **relate to** the physical world around us and networks help us to **move through** the physical world around us.

And finally back to botany and biology
Biological evolution may from time to time appear as non-linear. The Cambrian Explosion 543 to 490 million years ago (when most of the major groups of animals first appear in the fossil record) is often cited as an example of non-linear evolution.

Technology evolution may also appear from time to time to be non-linear. The invention of the steam engine or transistor for example might be considered as inflection points that changed the rate of progress in specific areas of applied technology (the industrial revolution, the birth of modern electronics). This apparent non-linearity is however a product of scaling and disappears if a longer time frame is used as a benchmark of continuing progress.

The essence of competition however remains relatively constant over time.

Have humans become more adaptive over time, have they adapted by becoming more adaptive? Possibly.

Certainly we have become more **adept** at exploiting context partly due to our ability to accumulate and record and analyse the knowledge and experience of prior and present generations.

And this is the basis upon which competitive networks will capture and deliver value to future users.

Network value is increasingly based on knowledge value but **knowledge value can only be realised if access efficiency can be improved over time**.

Access efficiency in cellular networks is a composite of power and bandwidth efficiency (the blended bandwidth proposition) and access efficiency.

Access efficiency is dependent on the efficiency of access, admission and storage and server algorithms that anticipate rather than respond to our needs.

The asset value of cellular networks has traditionally been denominated in terms of number of cell sites or MHz of allocated or auctioned bandwidth and number of subscribers.

This still remains valid but these are not inherently competitive networks.

Competitive networks are networks that exploit accumulated knowledge and experience from present and past subscribers to build new value propositions that deliver future competitive advantage. This in turn increases network asset value.

Efficient competitive networks are networks that combine access efficiency with power and bandwidth efficiency. An intelligent network with ambition and ability, a network that adapts over time by becoming more adaptive.

Specialisation
But in addition, networks need to find some way of differentiating themselves from one another, creating 'distance' in the service proposition. This is where Darwin's (and Wallace's) theories of specialisation begin to have relevance. The services required from a network in the Amazon and Malay archipelago and Galapagos Islands are different from the services required in Manhattan, Maidenhead and Mancuria. Radio and TV stations are increasingly specialised in terms of regionalised and localised content provision. Cellular networks will need to develop similar techniques in terms of their approach to specialist regionalised and localised network service platforms. As we said earlier, smart competitive networks are networks that are efficient at translating social and political gain into economic advantage. This

implies an ability to respond to extremely parochial geographic and demographic interests. A bee in Mongolia might be outwardly similar to a bee in Biggleswade but will have different local interests and requirements. A 'one size fits all' network proposition becomes increasingly less attractive over time.

The role of standards making - a postscript.
We have argued the case that technology evolution is to all intents and processes a linear process.

It may appear from time to time to be non linear but this is either due to an issue of scaling (not studying the evolutionary process over a sufficiently long time scale) or due to distortions introduced by the standards making process.

The answer is of course to make the standards process more adaptive and to avoid artificially managed step function generational changes.

Of course the counter argument here is that artificially managed change can be exploited to deliver selective competitive advantage.

This is however a manipulative process and manipulative processes tend to yield relatively short term gains.

Long term shareholder and stakeholder value is probably best served by ensuring that vendor and network operator propositions are positioned to exploit fundamental

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