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How 5G will be different

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Abstract

Mobile telecommunication services incorrectly branded ?4G? are now widely available. By contrast future mobile technology, dubbed 5G, has already received coverage in the mainstream press, but does not yet exist. This article summarises the ?state of play? in 5G by reviewing the requirements that are driving its development, the performance targets it is aiming for and the technologies being explored to achieve these. It also compares the main capabilities of 5G with those of the earlier generations of mobile technology. Finally, it looks at what 5G services are expected to offer from the users? perspective.

Introduction

Most users of mobile phones in Australia probably know that the latest and greatest mobile technology is ?4G?. They might even have heard of the next evolution of mobile technology ?5G? which has already made headlines in the mainstream press, even though it is some years from becoming a reality.

So where does the marketing hype around 5G end and the technical reality begin? This article will attempt to answer several questions about 5G: Why do we need it? What technologies will it embody? How will it be developed? What user benefits will it bring?

Why we need 5G

There is almost universal agreement amongst vendors and carriers that mobile technologies beyond 4G/LTE-A will be needed, and needed soon. The mobile industry has been a victim of its own success. The multimegabit mobile data bandwidths that have been available since the introduction of high speed packet access (HSPA), coupled with increasing functionality in smartphones and tablets, have fuelled growth in demand for speed and capacity in mobile networks that shows no signs of abating.

Nokia Siemens Networks (now Nokia Solutions & Networks, NSN) in 2011 produced a white paper ?2020: Beyond 4G Radio Evolution for the Gigabit Experience? (NSN 2011 [5]). There was no mention in it of 5G, but it said: ?Extrapolations of current growth trends predict that networks need to be prepared to support up to a thousand-fold increase in total mobile broadband traffic by 2020...[assuming] a ten-fold increase in broadband mobile subscribers and up to 100 times higher traffic per user (beyond 1Gbyte/sub/day)?.

It suggested that this would be achieved by increasing the number of base stations ten-fold, increasing spectral efficiency ten-fold and increasing the available spectrum ten-fold. All this, it said, would need to happen without mobile operators gaining significant revenue increases. Clearly no one is going to pay 1000 times more for their mobile service than they pay today. Therefore the cost per bit will have to come down about 1000-fold over the same period!

By 2020 also the mix of connected devices will also have shifted significantly. The population of personal communications tools like smartphones and tablets will have been overtaken by ?the Internet of Things? (IoT): a huge variety of devices from wearables to connected cars. According to research firm Gartner (2013 [6]), IoT - which excludes PCs, tablets and smartphones - will grow to 26 billion installed units in 2020, representing an almost 30-fold increase from 0.9 billion in 2009.

While many of these devices may not be heavy users of bandwidth, the sheer volume of them will impose a significant signalling load on the networks to which they are connected. It is envisaged that 5G networks will have to handle millions of ?always on? devices in a single cell and devices for which the signalling traffic will consume almost 100 percent of the citation provided bandwidth they use.

What technologies will 5G embody?

Today?s 3G and 4G networks were conceived primarily to serve one sort of device: the mobile phone, or a modem that was functionally identical to the data communications capability of the phone. 5G networks will need to serve many different types of devices with widely different requirements and therefore will not adopt a ?one technology fits all? solution.

According to an Ericsson White Paper ([7]2013), today?s wide area technologies will continue to evolve to deliver enhanced system performance and more capabilities, but they will be complemented with other technologies for particular use cases that they are ill-suited to addressing. Ericsson says that 5G will be ?a set of seamlessly integrated radio technologies? and that the evolution of LTE will be fundamental to this future, as will the evolution of HSPA and Wi-Fi.

To support the expected orders of magnitude increase in device numbers, base station densities will have to increase massively. Ericsson and other vendors foresee indoor deployments with access nodes in every room and outdoor deployments with access nodes at lamppost distance apart. These devices will have transmission bandwidths possibly of several gigahertz and will operate at frequencies as high as 100GHz.

They are likely to use radio access technologies quite different from those in the macro networks, but will nevertheless be tightly integrated with those macro networks.

Today?s cellular networks ?trombone? all traffic to a central switch, even between devices in close proximity. This mode of communication will be neither appropriate nor practicable for communications functions that are primarily only invoked when devices are co-located. However unlike today?s short-range communications technologies ? bluetooth and Wi-Fi ? in 5G this device-to-device communication will use licensed spectrum and will take place under network control to ensure that performance and reliability requirements can be met. LTE standards are already evolving to cater for device-to-device communications.

Additional spectrum alone is not expected to satisfy the ever-increasing demand for bandwidth. Communications capacity will be further increased by increasing the number of antennas on transmitters and receivers to create more signal paths, by exotic advanced modulation techniques and by full duplex communications technologies in which the same spectrum is used simultaneously for transmit and receive functions. (Today?s cellular technologies either use different frequencies for transmit and receive or transmit and receive on the same frequencies at different times).

According to a recent ZTE White Paper (2014 [8]) research is focussed on new coding and modulation schemas and multiple access techniques. In the area of multiple access, major research efforts include NOMA (non-orthogonal multiple access) and FTN (Faster-Than-Nyquist). Research on receivers has focused on the development of new waveforms that support MIMO (multiple-input and multiple-output), and full duplex techniques with shortened TTI (transmission time interval) radio links. Other new techniques such as software-defined air interface are expected to enable future networks to use multiple radio access technologies and multiple frequencies simultaneously.

These disparate radio technologies, the need to support many different types of devices - including devices that communicate directly with each other but under network control - and the need for a network that is ?user aware? will place massive demands on the core switching and processing resources of future networks. The new technologies of software defined networking and network functions virtualisation will be called on to meet these demands and networks will transition to an intelligent cloud architecture.

This network cloud will coordinate the disparate types of network resources, manage inter-radio access technology, inter-frequency and inter-site radio access and interference cancellation to deliver improved network performance, especially at the cell edge.

Intelligent cloud technologies will also be needed to provide spectral agility for 5G networks. Work is already underway on global harmonisation of future mobile spectrum, but the regional diversity of LTE spectrum ? there are more than a dozen different bands ? shows just how hard this will be (Wikipedia 2014 [9]).

According to Huawei (2013 [10]), to maximise spectrum efficiency, spectrum access and programmable air interface technologies will be needed that are capable of mapping service requirements to the best suitable combinations of frequency and radio resources. The continuing deep integration of SDN and cloud architecture technologies will help realise this, Huawei suggests that these technologies will: facilitate the on-demand customisation of mobile networks to ensure QoS, reduce energy consumption and enable operators to maximise the value of their network investments

Much of the focus of 5G research is on reducing latency and while latency will clearly always be limited by the speed of light, this only becomes significant when accessing distant resources (light travels about 300km in one millisecond); many of the applications envisaged for 5G will operate over much shorter distances, so the limiting factors will be network switching and processing times.

Huawei talks of ?faster than thought? speeds (ie minimal latency), so fast that ?the apparent distance between connected people and connected machines will shrink to a virtual ?zero distance? gap.? It suggests that ?instant immediacy? in mobile services will support the proliferation of whole new set of mobile apps that push the capabilities of communications beyond what is currently possible.

How is 5G being developed?

Despite the countless adverts for ?4G? mobile phones and services there are very few 4G mobile networks in commercial operation. Long Term Evolution (LTE), the technology now almost universally referred to as ?4G?, is no such thing according to the official rankings of mobile technologies. That term is reserved for LTE Advanced (LTE-A).

The marketeers managed to blur the boundaries between 3G and 4G and sow confusion. They are likely to do so to a greater extent with 5G because, unlike the definition of LTE-A as 4G, there is yet no clear and unambiguous definition of a standard for 5G, only a general consensus on its required performance, some of the technological advances that will be needed to achieve that performance and the functionality it will be required to deliver. The general view seems to be that commercial 5G networks will start to appear around 2020.

Nevertheless the marketeers are already on the 5G bandwagon, seeking the kudos of 5G leadership. One of the first was Samsung. On 13 May 2013 the company issued a press release claiming that it had successfully developed technology that ?sits at the core of 5G mobile communications system and will provide data transmission up to several hundred times faster than current 4G networks.?

As a PR exercise it was hugely successful. A Google search on ?5G? and ?mobile? made shortly after the announcement produced a near monopoly of references to Samsung in the top 100 hits.

ITU: from 3G to 5G

The ultimate arbiter of 3G and 4G mobile technology standards to date has been the International Telecommunication Union (ITU). It has developed sets of requirements for mobile telecommunications systems since the 1970s, and then approved technologies and standards developed by other organisations that met these requirements, along with the frequencies in which these operate.

Thus in 1998 the organisation announced that it was ?working on one of its most ambitious projects ever: a federation of systems for third generation mobile telecommunications that will provide wireless access to the global telecommunication infrastructure . . . coined IMT 2000 [that] will make it possible to communicate anywhere-anytime offering a seamless operation of mobile terminals worldwide?.

Over the next decade technologies were developed, submitted to and accepted by the ITU as meeting the requirements of IMT-2000 (International Mobile Telecommunications 2000) and those technologies are what we know as 3G today.

In 2003 the ITU initiated the next phase in the evolution of mobile technology, in Recommendation ITU-R M1.1645, ?Framework and overall objectives of the future development of IMT-2000 and systems beyond IMT-2000.?

That set of requirements became known as IMT-Advanced and the ITU announced in October 2010 that ?LTE-Advanced and WirelessMAN-Advanced [have been] accorded the official designation of IMT-Advanced, qualifying them as true 4G technologies? (ITU 2010 [11]). In can be argued that WirelessMAN-Advanced was an evolution of the earlier IEEE802.16 WiMax technology and has gained very little market traction compared to LTE-A.

The ITU is adopting a similar approach for 5G but, given the number of other initiatives already underway and the ITU?s relatively late start, it seems unlikely that it will play such a central role.

ITU Working Party 5D is developing a new Recommendation ITU-R M [IMT.VISION] ?Framework and overall objectives of the future development of IMT for 2020 and beyond? that the ITU says ?will help encourage and guide industry and administrations in further development of IMT for 2020 and beyond.?

In a liaison statement to external organisations, issued in February 2013, the ITU said: ?The scope of this Recommendation will focus on what the roles of IMT will be and how IMT can better serve society in the future, and the framework and overall objectives of further development of IMT for 2020 and beyond. It will be based on global market, technology and spectrum trends, including user demand for mobile broadband communication services, new service applications and the needs of developing countries?

The ITU plans to stabilise the document in early 2015 and to capture the current perspectives of the industry on the future vision it called on external organisations to submit material no later than the 18th meeting of WP 5D, but preferably earlier. That meeting was held in Vietnam in mid February 2014.

Asian players on the rise

The ITU?s role aside, the evolution of 5G will be significantly different from that of 3G and 4G thanks to the rising power of Asia, particularly China, both as a market and as a source of technology.

Research firm IHS (2014) has forecast that 4G (LTE) smartphone sales in China in 2014 will be around 72 million units, 16 times greater than in 2013, and will reach 300 million by 2018. And IDC (2014a) on 29 January forecast there would be a total installed base of 1.4 billion ?smart connected devices? in China by the end of 2017.

Chinese telco equipment maker Huawei ? which announced on 6 November 2013 (Huawei 2013a [12]) that it would invest a minimum of $US600 million in research and innovation for 5G technologies by 2018 - in mid-2012 overtook Ericsson, the world?s then-largest telecom vendor in terms of revenue (Le Maistre 2012 [13]).

Huawei, Ericsson and all the other major vendors will be devoting considerable R&D resources to 5G wireless but standardisation will only be achieved by their participation in organisations like the ITU that foster the co-operation needed to bring their different ideas together. There are several significant initiatives underway.

China, Japan and Korea

Confusingly what looks like it should be the name of the ITU?s 5G project, IMT-2020, is actually a Chinese initiative. According to China?s Future Mobile Communications Forum, (FMCF 2013 [14]) in February 2013, China's Ministry of Industry, Development and Reform Commission and its Ministry of Science jointly set up the IMT-2020 (5G) advance group to build a 5G technology research and standard promotion platform. An IMT-2020 5G Vision Summit was held in May.

At the same time a similar initiative was underway in South Korea. According to the Korea IT Times, its members are the Electronics and Telecommunications Research Institute (ETRI), major telcos, SK Telecom, KT, LG Uplus and major electronics companies, including Samsung Electronics, LG electronics, KMW and Dio Interactive (Korea IT Times 2014 [15]).

MSIP expects the 5G Forum will perform as the initiator of global cooperation, and will propose the formation of Asian Council to lead the international standardisation of 5G technology,? the report said. China and South Korea lost no time in trying to take global leadership in 5G standardisation. The two formed in July 2013 a partnership to set global standards for 5G. According to iTersNews (2013 [16]) during Korean President Park Geun-hye?s state visit to China, Korea?s 5G Forum and China?s IMT-2020 Promotion Group signed a MoU, to co-operate on 5G technology standardisation, research projects and 5G spectrum resources.

Yoon Jong-lok, South Korea?s vice-minister with the Ministry of Science, ICT and Future Planning (MSIP), told a press briefing: ?We hope that Korea and China would become an epicentre of 5G technology to open up fresh huge market opportunities around [the] Yellow Sea, the most densely populated region.? However he said other organisations were welcome to join their effort.

Meanwhile Japan kicked of its national 5G research initiative, ARIB 2020, in September 2013 and in December South Korea, China and Japan joined forces on 5G standardisation, according to a report in Korea?s etnews.com (etNews 2013 [17]).

UK creates 5GIC

In the UK, 5G research is centred on 5GIC, an initiative of the Centre for Communication Systems Research (CCSR) and the University of Surrey that started in October 2012 with an announcement (University of Surrey 2012 [18]) that CCSR and the University had secured ?11.6m of UK Government funding for the centre and expected to receive a further ?24m from industry participants.

The organisation was formally created in November 2013 when the list of participating organisations that had contributed more than ?30m was given as: Aeroflex, AIRCOM International, BBC, BT, EE, Fujitsu Laboratories of Europe, Huawei, Ofcom, Rohde & Schwarz, Samsung, Telef?nica and Vodafone (University of Surrey 2013 [19]).

A new purpose built facility to house the 5GIC is being built on the University of Surrey?s main campus. It is expected to be completed in January 2015 and will be home to 150 researchers and around 100 PhD students.

EU?s 5G PPP and METIS 5G initiatives

On 17 December 2013 the European Commission announced (EC 2013 [20]) 5G PPP: Advanced 5G networks for the Future Internet (5G), one of eight new public private research partnerships. It aims ?to stimulate the development of network internet infrastructure to ensure advanced ICT services for all sectors and users.?

The EU will invest around ?700 million in the 5G PPP by 2020 and expects this to be matched by the private sector partners in the venture.

This is not the first EU backed initiative on the 5G front. On 27 November 2012 the EU launched METIS (Mobile and wireless communications Enablers for the Twenty-twenty Information Society), a consortium of 29 partners spanning telecommunications manufacturers, network operators, the automotive industry and academia. Its aim is ?to respond to societal challenges for the year 2020 and beyond by laying the foundation for the next generation of the mobile and wireless communications system.?

METIS is co-funded by the European Commission as an Integrated Project under the Seventh Framework Programme for research and development (FP7). It will receive ?16 million ($A24m) of its ?27 million ($A41m) budget from the EU.

METIS brings together the biggest mobile infrastructure vendors - Alcatel-Lucent, Ericsson, Huawei, Nokia and Nokia Solutions & Networks (Nokia Siemens Networks at the time) - along with major carriers Deutsche Telekom, Docomo, Telecom Italia and Telef?nica, motor manufacturer BMW and numerous academic institutions.

The main objective of METIS is to lay the foundation for, and to generate a European consensus on, future global mobile and wireless communications system. In a press release the EU said: ?The METIS overall technical goal is to provide a system concept that supports: 1000 times higher mobile data volume per area: 10 times to 100 times higher number of connected devices; 10 times to 100 times higher typical user data rate; 10 times longer battery life for low power machine-to-machine-communications; five times reduced end-to-end latency.?

Metis? specific goals are much more modest. It aims to ?provide valuable and timely contributions to pre-standardisation and regulation processes, and ensure European leadership in mobile and wireless communications.? It hopes to achieve these goals by April 2015 when it is scheduled to be wound up, leaving further work to established standardisation and regulatory bodies.

Intel leading US 5G co-operation

In contrast to the activity in Europe and Asia, 5G research co-operation in the US appears to be minimal and lead not by any government body but by one company, Intel.

Intel?s initiative is modest ($US3m only) and appears to be the only one of its kind (Gigacom 2013). Moreover, Intel seems to be keeping its initiative fairly low-key. The only information it has put out is two blog posts, one short post (Intel 2013 [21]a) in July 2013 announcing the initiative, and a second with rather more detail (Intel 2013b [22]) that lists the goals of the project.

Intel said it would invest at least $US3 million to support wireless research at more than 10 universities around the world including Stanford University, ITT Delhi and Pompeu Fabra University in Barcelona. Research topics will include how to improve quality of service via context awareness, wireless device power efficiency and enabling new radio spectrum.

The initiative, named as an Intel Strategic Research Alliance, includes industry partner Verizon, but Intel has given no details of Verizon?s involvement.

The NGMN Alliance

The major mobile operators in February 2014 launched their own 5G standardisation initiative (ngmn 2014 [23]), through the Next Generation Mobile Networks (NGMN) Alliance, a body formed by a group of international network operators in 2006 that has to date been focussed on LTE standardisation.

The NGMN said that its board ? CTOs from 19 leading international operators ? has made a decision to focus the future NGMN work programme on defining the end-to-end requirements for 5G, in recognition of the fact that the scope of 5G extends significantly beyond the radio access layer.

It said the initiative would deliver key operator requirements to guide the development of future technology platforms and related standards, create new business opportunities and satisfy future end-user needs. It intends to work in close collaboration with all industry partners and other relevant initiatives and within the well-established NGMN processes.

The first major outcome will be an industry white paper to be delivered before the end of 2014 to support the standardisation and subsequent availability of 5G from 2020.

The Wireless World Research Forum

Another inhabitant of the 5G ecosystem is the Wireless World Research Forum (http://www.wwrf.ch/ [24]) whose stated goal is ?to encourage research that will achieve unbounded communications to address key societal challenges for the future.? It has been in existence since 2001 and claims to be ?the unique forum where the wireless community can tackle the key research challenges.?

It lists its steering board as being: Alcatel-Lucent France; China Mobile; DoCoMo Eurolabs; Huawei Technologies; Nokia and Nokia Siemens Networks (now Nokia Systems and Networks). Otherwise, its membership is not made public. According to its LinkedIN profile (http://www.linkedin.com/company/wireless-world-research-forum [25]) it has over 140 members from five continents, representing all sectors of the mobile communications industry and the research community.

It does not appear to have any formal role in the evolution of 5G standards but says: ?By searching out the issues, flagging them up to opinion leaders, and then working with our liaison partners, and you, to deal with them, we drive the development of the Wireless World.?

It has produced a series of white papers (see http://www.wwrf.ch/outlook.html [26]) on various aspects of future wireless technologies under the umbrella title of ?Visions and research directions for the Wireless World.?

What will 5G mean for users?

This is perhaps the most intriguing question of all. Apart from the introduction of video calling and multimedia messaging in 3G, from the user?s perspective the evolution from 2G to 4G has been all about speed ? increased downstream, and upstream, bandwidths that have enabled mobile networks and devices to offer a whole gamut of appealing content and services ? accompanied by significant reductions in costs per Gigabyte that have made these services affordable.

Other significant improvements in the transition from 3G to LTE have been greatly reduced latency, high definition voice and the introduction of end-to-end IP in the transition from 3G to LTE.

Much higher bandwidths and further reductions in latency are being bandied about by the promoters of 5G. South Korea has mentioned a goal of 1Gbps for its first 5G trials in 2017. Huawei says: ?a 10Gbps individual user experience . . . will emerge between 2020 and 2030? (Huawei 2013 [14]). By contrast, LTE-Advanced, which is already in commercial operation, has a theoretical maximum downstream bandwidth of 3Gbps.

NTT Docomo claims to have already demonstrated 10Gbps uplink bandwidth in December 2012 using 400MHz of bandwidth at 11GHz from a moving vehicle (the transmission distance was not specified). It also suggests that latency will be reduced to 1mS from the 5mS of LTE.

Some 5G researchers have ambitions well beyond 10Gps: infinite capacity, or at least the perception of it. This is the stated goal of the UK?s 5GIC research centre at the University of Surrey. According to Rahim Tafazolli, head of the University?s Centre for Communication Systems Research, a rate that is always sufficient to meet the user?s needs would create the perception of infinite capacity.

There has to date been relatively little discussion about the economic benefits that might accrue from widespread deployment of 5GA 2012 study undertaken by Deloitte and the GSMA [27] (Deloitte 2012 [28]) concluded that a doubling of mobile data use would lead to an increase of 0.5 percentage points in the GDP per capita growth rate across the 14 countries studied and that countries with a higher level of data usage per 3G connection had seen an increase in their GDP per capita growth of up to 1.4 percentage points.

The most intriguing suggestions about what 5G will mean are not directly related to speed and latency, nor to economic benefits but rather centre on an as yet only vaguely defined idea of network intelligence. Tod Sizer, wireless research leader at Alcatel-Lucent?s Bell Labs, in a blog post points out that, by the time 5G arrives, it is likely that fixed line telephony will be just about dead and that 5G will be ?THE communication of the future and not just the wireless radio solution? (Sizer 2014 [29]). Therefore, he says: ?There are two major improvements that we need to bring to communications: flexibility to tailor the network to the application, the person, where they are, and what their needs might be; and to optimise the full end-to-end performance between a user and the person or application with which they are communicating.?

A child of today, in her twenties in the next decade, will, he says, expect ?a network that adapts to her, rather than forcing her to adapt to the network, and with a performance that is seamless and always meets her expectations, wherever she happens to be.?

His colleague Michael Peeters, CTO of Alcatel-Lucent?s Wireless division, put this another way (in conversation with the author in November 2013). ?Today the end user adapts to the service that is available. For me 5G is exactly the other way round. The communication service will adapt to what the user needs. Having the network figure out what you are doing and adapting is the grand vision for 5G.?

ZTE (2014 [8]) expresses a similar view but in a more technology-oriented way: ?Research on 5G will be focused on user experience, rather than simply increasing network capacity. ... In order to deliver improved user experience, 5G researchers need to develop new user-centric service provisioning models that are informed by usage and service patterns. Acquiring deeper insights about users will enable researchers to formulate key performance indicators (KPIs) for 5G networks that will drive order-of-magnitude improvements in network capacity, bandwidth maintenance, peak data rate, latency reduction and high-accuracy indoor location monitoring. ... Users will expect consistent on-demand access to services including office applications, social networking tools, e-commerce and online financial services platforms.?

The marketeers are clearly going to have a field day with this. In fact they already haveThis quote is from a video [30]produced by US telco Sprint:

?Where is the smart network? The network that is constantly acting and reacting, customising and tailoring itself to each person engaging with it. A network that is self-aware, that is sentient adjusting millisecond by millisecond to the microdemands of all the people tapping in to it... [A network] that automatically [knows] how to maximise the experience for everyone and every thing using it.? (Sprint 2013 [31])

Trouble is, this is not a vision of the future but a promotion for Sprint?s LTE network, Spark, being rolled out today!

Conclusions

The essential differences between the capabilities of 5G, compared to those of the previous generations of mobile network technology, are contrasted in Table 1.

Table 1 ? Comparison of 5G with previous generations of mobile network technology. (Source: Ericsson)

Generation	Theoretical maximum downstream data speeds	Latency*	Technology	Years of introduction (approx.)	Key features
1G	-	-	AMPS, NMT, TACS	1980-1990	Voice or slow data using voice channel modems.
2G	14.4kbps	-	GSM, D-AMPS, CDMA	1990-2000	Narrowband data using the voice circuit + SMS text messaging
2.5G	114kbps	~700mS	GPRS	2001-2004	Addition of packet data enables phones to be used for web browsing, but latency is very high
3G	31.Mbps peak	200 - 400mS (edge) ~120mS (WCDMA)	CDMA2000 (1XRTT, EVDO) UMTS (WCDMA) Edge	2004-2006	Videocall and multimedia message support
3.5G	168Mbps (dual carrier HSPA+)	60-80mS	HSPA, HSPA+	2006-2010	Data is IP end to end
3.9G	300Mbps	~10mS	LTE, WiMAX	2009 --	LTE boost speeds, spectral efficiency, reduces latency.
4G	3Gbps	<5mS	LTE-A, WiMax 802.16m	2013 --	LTE-A uses spectrum aggregation and other techniques to increase bandwidth.
5G	10Gbps (maybe)	~1mS	Evolution of LTE-A, others to be determined	2020 (Maybe)	5G will use multiple radio access technologies for different use cases.

* Latencies are approximate times for network switching and routing and do not include distance-based propagation delays.

Frequency usage is a different matter. 5G is much less confined to particular bands of radio spectrum than its predecessors. Figure 1 (courtesy of Ericsson) shows which different bands of frequencies are likely to be utilised by 5G, from 300 MHz to 300 GHz, in different service applications.

[32]

Figure 1 ? 5G will use a variety of different radio access technologies across a broad range of frequencies to cater for many more device types and many different use cases. Source: Ericsson

It's clear that the evolution of mobile technologies is accelerating. Korean telco SK Telecom is credited with being the first to launch a true commercial 4G (ie LTE-A) mobile service, in June 2013 (Telecompaper 2013 [33]). That was 10 years after the ITU kicked off its 4G standards initiative and just under three years after the standards were finalised.

The industry is talking of having commercial 5G networks in operation in six years, and there are no standards yet in sight. Also, arguably, the technology advances needed to achieve the goals of 5G will be greater than those that underpinned the evolution from 3G to 4G.

In other words, while 5G might seem to be too far in the future for anyone outside of its narrow specialism to be giving it much attention, that situation will change within a couple of years.

If all goes to plan the mobile industry will deliver the super-smart 5G network with near-zero latency and 'infinite' capacity that adapts to the users? needs, but it will most likely be entrepreneurial and creative individuals who come up with ways to exploit these features, grow new industries and disrupt others. So it's probably not too early for some of the thinking behind 5G to be reaching a wider audience.

It?s possible that the industry will fail to achieve the technical goals it has set for 5G but also a failure to achieve consensus on standards would be a significant setback.

Already two camps are emerging: one Asia-based and one Europe based with the global vendors in both camps. Ideally these will come together to create truly global standards, minimising costs through larger volumes and maximising the rate of innovation.

However markets in Asia will be large enough to 'go-it-alone?, and they have done so in the past. Japan had its own 2G standard, PDC, which at its peak had 80 million users (Wikipedia 2014b [34]). China developed its own 3G technology, TD-SCDMA, with some success. It was adopted by the dominant 2G era operator, China Mobile, which by early 2013 had 100 million users. However this technology choice has been blamed for the loss of its market lead over other telcos that had adopted the global 3G standards (techinasia 2013 [35]).

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