The *generation*

Work is underway to determine what 5G mobile communications might comprise. By **John Walko**.

Mobile device users in the UK have just been offered mouth watering deals to entice them to shift to faster data rate services as competition finally comes to the 4G market. 02, Vodafone and 3 are trying to make up ground on Everything Everywhere, which was allowed to use its 1800MHz spectrum last October.

But another long term battle is being starting as Britain, if not necessarily British companies, stakes a claim for R&D leadership in what is loosely referred to as 5G.

What will 5G technology deliver and why is it already becoming an acrimonious business? The answer to the first point is that it is too early to know, because 5G is still not defined. Much of the research, by companies and – more interestingly and importantly – by groups linking industry and academia, is targeting the World Radiocommunications Conference, scheduled for November 2015.

It is there where the research will be evaluated and fought over, as delegates decide on the technologies to be considered for a 5G specification and standard. The outcome is a clue to the second point – judging by past efforts, the consequences can be huge in terms of IP rights and the royalties that might accrue.

The British input will be hugely influenced by work underway at the University of Surrey. "We plan to have the world's first 5G test bed," Professor Rahim Tafazolli boldly told *New Electronics*. Initial trials should be running before the end of next year, with the test bed covering about 4km^2, including the university campus and parts of Guildford. "We are aiming for some 15 access points and hope to test the performance of several hundred different type terminals in both outdoor and indoor usage conditions. Crucially, all the technologies developed and proposed will have to work in real world environments."

Surrey University's Centre for Communications Systems Research is a leading developer of potential 5G technologies

Prof Tafazolli's group, which has been working on 5G technologies and concepts for the past three years, received a £35million shot in the arm last October, allowing it to create a dedicated 5G Innovation Centre. About a third of that is government R&D funding, the remainder is from industrial partners, including Samsung, Telefonica Europe (02's owner), Huawei, Rohde & Schwarz, Fujitsu and Aircom.

End of the line for OFDM?

"Beyond LTE and LTE-Advanced, which must both be regarded as 4G, we will need completely new air interfaces – and not necessarily the OFDM (orthogonal frequency division multiplexing) schemes which underpin 4G. These could use non orthogonal multiplexing to provide the very high capacities and speeds we are targeting (up to 10Gbit/s) and revolutionary advances to provide the kind of spectrum and energy efficiencies that will be needed," said Prof Tafazolli. The shared throughput per cell capacity anticipated for LTE-A, by contrast, is some 100Mbit/s.

Prof Tafazolli, who heads the University's Centre for Communications Systems Research, claims: "We have achieved numerous advances likely to be suitable for 5G; in many cases, using computer simulations and mathematical analysis and modelling. Now, with the additional resources and partners, we will be able to integrate these technologies and optimise them. We also plan to look at the kind of processors likely to be needed, the protocols and algorithms, then disseminate the results so equipment suppliers can implement them in new hardware."

Also on the agenda are antenna technologies, higher order modulation schemes, rf front ends and baseband signal processing. Above all, Prof Tafazolli stresses, the focus must be to make more efficient use of the spectrum and to deploy higher frequency bands to achieve higher bandwidths. "If there is one thing on which we are all agreed," he said, "it is that we are facing a 'spectrum crunch' that needs to be solved urgently."

The Centre will target the potential use of much higher frequency bands, between 60 to 80GHz, millimetric wave options and frequencies of less than 5GHz. While all this

Photo: Donald MacLellan

sounds impressive, Prof Tafazolli stresses nothing is likely to be available commercially until at least 2020 – and only then if the operators can make a business case for 5G.

This was never going to be a straightforward journey – a fact highlighted in May 2013, when Samsung announced with much fanfare that its researchers had achieved '5G' mobile data rates, transmitting at 1Gbit/s over 2km using the 28GHz band and millimetre wave channels.

The prototype is a matchbox sized array of 64 antenna elements connected to custom built signal processing components. By varying the signal phase dynamically at each antenna, the transceiver generates a 10° wide beam that can be switched quickly in any direction. To connect with one another, basestations and mobile radios would sweep their beams continuously to seek the strongest connection, thus getting round obstructions and taking advantage of reflections. The company suggests the system could be used at frequencies between about 3GHz to 300GHz, depending on spectrum availability. In subsequent outdoor experiments, the transmitter sent data at 1Gbit/s to two receivers moving at 8km/hr. For non line of sight connections, the range reduced to between 200m to 300m.

Small parts, large jigsaw

Impressive work, yet Samsung was widely criticised for overhyping the 'breakthrough' and underplaying the potential problems, such as unfavourable propagation. Many commentators also took the company to task for claiming that adaptive antenna technology 'sits at the core of 5G mobile communications'. Researchers at Surrey's 5G Innovation Centre said Samsung's work touched on just one – admittedly important – area of research. The verdict? 'It's just a small part of the larger jigsaw'.

It was also pointed out that NTT DoCoMo had, just weeks earlier, demonstrated uplink packet transmission at 10Gbit/s using the 11GHz spectrum, again in an outdoor experiment.

The Japanese carrier is one of a few companies identified by market researcher Strategy Analytics (SA) as an 'early leader' in 5G; the others being Ericsson and Huawei. Interestingly, on the components side, Guang Yang, SA's senior analyst for wireless network platforms, picked out Qualcomm and Intel as 'ones to watch'. Qualcomm is an obvious choice, Intel less so. "Intel is keen to gain more influence in mobile technologies, particularly in areas such as integration between cellular and wlan, and small cell/heterogeneous networks. I predict it will want to improve its position in cellular through 5G," Yang told *New Electronics*.

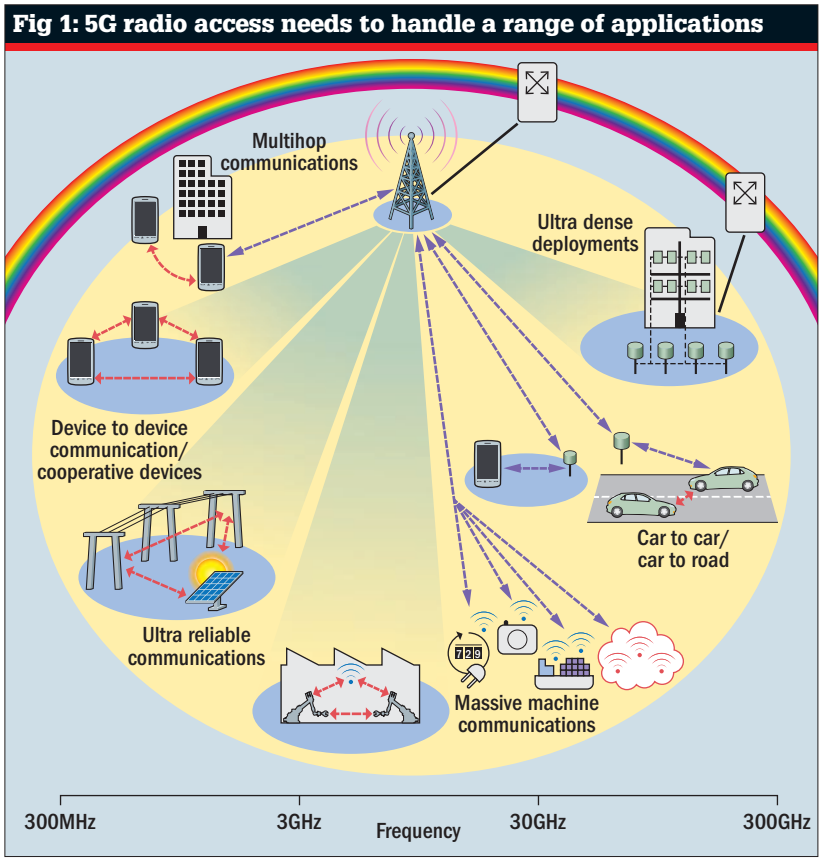
A few months ago, Intel created the Strategic Research Alliance, aiming to link carriers and university labs. To date, only Verizon has signed up, but it has attracted some of the most prominent academic research establishments in the US and several in Asia. Intel has, so far, committed $3m, but more can be expected – and time is on its side, if the results prove promising. To its credit, Intel has positioned 5G as an aspirational and still undefined set of technologies, rather than a network as such. It suggests 5G should focus on positioning mobile broadband provision beyond raw speed and into concepts such as pervasive connectivity and on getting a resilient link to the Internet whether a subscriber is in a tunnel, on top of a skyscraper or in a congress area vying with thousands for a fast connection.

Other aspirations include support for billions of devices – not just smartphones and tablets, but also sensors for machine to machine and car to car communications, cloud computing, personalised networks and all the elements in the Internet of Things concept.

Such a wish list is mirrored by leading infrastructure suppliers and operators; all keen to extend their reach and reduce the cost of transmitting and receiving data.

Huawei is also collaborating with universities. Tong Wen, who heads its 5G technology development, said the area is

Fig 1: 5G radio access needs to handle a range of applications



Source: Ericsson

'one of the top priorities', with some 200 engineers specialising on 5G in dedicated groups in Ottawa, Munich and Shanghai. This is no surprise to Yang. "Chinese companies see 5G as a major opportunity to lead the global mobile communications sector. The industry has formed a working group to coordinate and promote R&D and standardisation activities. They have also just signed a MoU with the Korean 5G Forum for collaborative research."

European and US equipment suppliers and carriers are no less eager to influence how this technology is developed, standardised and deployed. One effort at the Polytechnic Institute of New York University – backed by the US National Science Foundation – focuses on advances in lighter antennae, with direction beam forming capable of bouncing signals off buildings using the millimetre wave spectrum. The work, led by influential mobile communications technologist Professor Ted Rappaport, will also target full duplex antenna techniques that enable simultaneous transmission and reception in the same rf carrier frequency, potentially doubling capacity. National Instruments (NI) is providing much of the gear for the test bed.

NI is also backing 5G efforts at the Technical University of Dresden, where the focus is on novel OFDM techniques and extending the use of multiple antenna MIMO technology beyond today's 8x8 systems. "To address speeds of 10Gbit/s using OFDM means the a/d conversion with 10bit resolution alone would represent a power consumption challenge that cannot be resolved with existing technology. Hence, a new physical layer needs to be found," suggests Dr Gerhard Fettweis, the Vodafone chair in mobile communications systems at TU-Dresden.

On a wider scale, and using this year's Mobile World Congress as a platform, European Commission vice president Neelie Kroes set out her stall that Europe needs to regain the lead in developing mobile communications technologies. "I want 5G to be pioneered by European industry, based on European research and creating European jobs – and we will put our money where our mouth is," said Kroes as she pledged €50m across eight projects as part of the Seventh Framework Programme.

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Guang Yang, Strategy Analytics

Europe primes the 5G pump

About a third of the €50m has been earmarked as additional pump priming for the Ericsson led METIS project: the catchy moniker for Mobile and wireless communications Enablers for the 20:20 Information Society.

The 30 month project, underway since last December, is investigating options ranging from super dense small cell networks (a step forward from the current idea of placing small cells in every office, room, car or appliance), heterogeneous networking and smart antenna technologies to virtualised cloud radio access networks. "We naturally have in house 5G focused initiatives, looking at a variety of user cases and air interface possibilities, but we view METIS as a powerful consortium that will come forward with exciting concepts," Magnus Frodigh, Ericsson's director of Wireless Access Networks, told *New Electronics*.

Many of the 29 participants are research institutions and universities, linked with industrial partners that include four of the top five global vendors of infrastructure gear (Alcatel-Lucent, Huawei and Nokia Siemens Networks); carriers such as Deutsche Telekom, France Telecom/Orange, Telefonica and NTT DoCoMo; and industrial partners such as BMW and Elektrobit. The line up speaks to the wide brief encompassing M2M and car to car connectivity, modulation and data coding advances, improved interference management and receiver design.

A smaller, but more aptly named, EU project is 5GNOW (Fifth Generation Non-Orthogonal Waveforms for Asynchronous Signalling). "We started with the premise that it may be time to abandon synchronism and orthogonality in a network and admitting some cross talk or interference, and to control these by new transceiver structures and transmission techniques," said Dr Gerhard Wunder, project coordinator at the Fraunhofer Heinrich Hertz Institute. He added network robustness improvement is also a crucial component, as is ensuring that future networks are more oriented towards 'differentiated service architectures'.

The group – which also includes Alcatel Lucent, TU-Dresden, CEA-Leti, Polish start up IS-Wireless and NI's Hungarian operations – is developing PHY and MAC layer concepts more suitable for heterogeneous networks and expects to have a demonstrator by the end of next year.

Obstacles and opportunities loom in 5G development, with much hanging on the outcome. But the concept also involves the challenges on which engineers thrive.