RTT TECHNOLOGY TOPIC
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LTE Advanced and LT HSPA
Big band economics

A big band ambition – the government has spoken
At the end of December, the UK government **announced** that we would all have 50 Mbps broadband access by 2015, putting the UK at the top of the European league table rather than where we are today in the low teen rankings. Public policy will apparently be shaped to ensure this will mostly be achieved with private sector funding.

The extent of the role that wireless plays in this process both in UK and rest of the world markets is dependent on delivery costs benchmarked against other delivery options including cable, copper and fibre. Potential cost reductions are assumed to be dependent on improving spectral efficiency and peak and average data rates.

One of the proposed mechanisms to achieve an increase in speed is to implement within band and or between band channel bonding. This is proposed both for LT HSPA Evolution (40 MHz channels) and LTE Advanced (100 MHz channels) and includes bonding TDD downlink channels with existing FDD band plans, the repurposing of Channel 55 and 56 in the US being one example.

Within band channel bonding is already used in WiFi access networks. However mobile broadband has to be deployed into licensed spectrum. Channel bonding requires the allocation of wide operational bandwidths that are either contiguous, within band channel bonding, or non contiguous, between band channel bonding. This means that existing bands need to be broadened and or new allocations need to be structured to support composite wideband channel bandwidths. The problem with this is that to be technically efficient, contiguous within band allocation requires a change to present competition policy. To be commercially efficient this policy has to be agreed on a global basis. The alternative, non contiguous between band, requires a fundamental change to user equipment RF front end design. The investment appetite to realise these technical changes within a five year time scale is not presently apparent.

The ability to resolve this disconnect will largely determine the success or failure of the LT HSPA and LTE Advanced standards process. In this month's Technology Topic we explore what needs to be done to ensure that worthy political ambition is not frustrated by a failure to comprehend the changes that need to be made to align spectral and competition policy with technology and engineering reality.

Big Band ambitions- frustrated by Big Band economics?
On the basis of presently proposed standards, LTE advanced user equipment will need to be capable of accessing and processing channel bandwidths of 100 MHz within the next five years. The equivalent Long Term HSPA technology plan calls for an aggregation of up to eight five MHz channels. The transition to wider channel bandwidths over the past thirty years has provided the basis for high peak data rates and efficiency gain from multi user multiplexing and has been enabled by improvements in DSP capability. 100 MHz channel bandwidth processing for example is predicated on the availability of 22nm CMOS delivering four times the gate and memory density and twice the processing speed of present 45nm devices, a step function performance gain, the benefit of silicon scaling. Inconveniently most RF components do not scale and performance gains are incremental. As a consequence base band performance gains for one user translate into an RF performance loss for multiple users.

From a regulatory perspective there are no legacy band allocations capable of supporting 100 MHz of contiguous bandwidth. One option is to make additional bandwidth available, for example Bands 22/41 between 3400 and 3600 MHz and/or Bands 23/42 between 3600 and 3800 MHz. Clearing this part of C band will be challenging politically and only worthwhile if the end result is technically efficient. This is in turn dependent on resolving the coexistence issues implicit in bonded and adjacent FDD/TDD channels.

The market motivation for channel bonding in LTE Advanced and or LT HSPA is driven by an assumed need to deliver equivalent performance to the peak data rates claimed to be available from WiFi access networks (greater than 100 Mbps). The market headlines talk of 650 mbps for LT HSPA and up to 1 gbps for LTE Advanced. In the real world channel bonding can deliver high peak data rates to an individual user only at a disproportionate opportunity cost to other proximate users. If other users are also channel bonding, everyone loses out.

In WiFi systems there are three non over lapping 20 MHz channels available at 2.4 GHz within 80 MHz of operational bandwidth and eight 20 MHz channels at 5 GHz within 200 MHz of operational bandwidth. WiFi channel bonding either combines two of these carriers into one within band 40 MHz channel or channel bonds a 2.4 GHz channel with a 5 GHz channel with the theoretical intention of doubling throughput. In practice the increase in adjacent channel interference with in band bonding cancels out most of the theoretical gain and in many cases results in a loss of net throughput in terms of multi user performance.

The reasons for this are subtle but significant. In a 20 MHz OFDM WiFI channel with a peak processing rate of 54 Mbps, the data stream is block and forward error encoded and multiplexed on to 48 sub channels each of which are modulated using 64 QAM. The modulated sub channels are multiplexed with four pilot tones to provide a reference for demodulation and bracketed with 12 zero filled guard band sub channels. The sub channels are then block processed using a 64 point FFT and sent as samples to the RF modulator after passing through the based band digital to analogue converter. The products of the FFT modulation occupy about 17 MHz of the 20 MHz channel. A bonded channel doubles the size of the FFT (128 points) and doubles the sampling and clock rates. The problem revolves around how to filter the 40 MHz and 20 MHz channels. Ideally in a superhet there would be two switched filters in the IF stage and an unswitched anti aliasing filter at baseband. As this is costly, the normal solution is just to filter at the 40 MHz channel spacing. Additionally for cost reasons most transceivers are direct conversion rather than superhet. A 40 MHz direct conversion receiver will experience something of the order of a 60 dB loss of ACI protection to the adjacent 20 MHz carrier compared with a superhet centred on a 20 MHz channel. It might be assumed that the FFT provides enough filtering to off set this but in practice the composite SinX/X response of the sum of the receiver FFT bins results in bin leakage which pulls down the channel rejection floor for the receiver to 25 to 30 dB. The result will be a significant reduction in range for the 40 MHz transceiver, of the order of 60%. This is due to a loss of sensitivity and selectivity on the receive path. On the transmit path the channel bonded waveform will lose a minimum of three dB of power per OFDM bin. (The TX power output is spread over twice the channel bandwidth of a 20 MHz channel). PA back off will probably make this worse.

The other problem is that channel bonding reduces the opportunities for frequency reuse particularly in the 2.4 GHz band with at most two frequencies rather than the three previously available. With a three channel re use, a throughput of between 22 and 36 Mbps could be supported. With two channel re use this drops to 11 Mbps. A more detailed analysis of this is available in a **TI White Paper.**

There are potentially two schools of thought as to how this experience applies to LTE TDD and or LT HSPA. One school of thought is that conventional frequency re use is no longer needed as other mechanisms fulfil the same function. For instance different users can be separated by being allocated different OFDM sub carrier groups and resource blocks within an extended wide band channel. The other school of thought is that traditional frequency re use really works rather well and usefully exploits spatial separation between users and WiFI access nodes or between users and LTE e node B stations.

Overall efficiency will also be determined by how the spectrum is allocated commercially. The traditional approach to maximising auction income would be to encourage five operators to bid for 20 MHz each. However this would imply all operators using TDD spectrum, for example in Bands 41 or 42, would need to have inter clocked networks and coordinated management of user asymmetry within and between each 20 MHz channel.

Alternatively the assumption is made that user to user interference just averages out. This might be plausible if the five ‘sub bands’ within a 100 MHz channel could be coordinated both in terms of absolute timing and traffic asymmetry. This however implies one network under the control of one operator with bandwidth leased to multiple service providers.

Another alternative is to enable user equipment to be capable of processing multiple 20 MHz channels across multiple bands. This implies having multiple transmit and receive paths simultaneously active in the RF front end over and above the multiple path channel processing already implicit in MIMO implementation. No one is quite sure how to do this yet and any solution would be significantly more complex than an equivalent dual band WiFi transceiver.

Dual carrier channel bonding is being proposed for the US 1900 band and the LTE Advanced and LT HSPA proposals can be regarded as an extension of the bonded channel principle but the consequent RF front end complexity is presently daunting.

2015 seems like a long time away but the RF component industry is already struggling to meet present extended band plan requirements. The combination of MIMO and within band and between band channel bonding would seem to be stretching present R and D resource and RF engineering investment a step too far.

The integrated policy challenge

Part of the problem is that the standards process remains focused on an assumed user appetite for ever high peak data rates. The mechanisms needed to achieve this can be summarised as more bands, wider bands, multiple technologies within a band, channel bonding and MIMO. Each of these has an associated performance cost, coupling a decrease in multiple user spectral efficiency with an increase in component cost and investment risk.

The risks have to be absorbed by the vendor and operator community. The costs have to be absorbed by the operator or user community. Either way they don't make compelling commercial sense.

The regulatory process remains focussed on an assumed need for more spectrum. However to meet the peak data rate objectives implicit in the standard, new or existing spectrum either needs to be allocated or repurposed to be contiguous or requires multi band channel bonding to be implemented in user equipment.

The allocation of existing and new spectrum into contiguous bandwidth is incompatible with present auction policy which remains focused on maximising income to national treasuries. The spectrum can only be accessed efficiently with a single operator. Quite how this can be squared with present competition policy remains unclear. Multi band channel bonding is seen as the answer but is not a realistic alternative within a five year time scale.

More fundamentally these proposals highlight that standards policy should not be determined by subjective market assumption particularly when those assumptions fail to take into account basic technology and engineering reality. Similarly spectral and regulatory and competition policy should not be determined by economists without a detailed understanding of the technology and engineering costs and risks that are explicit outcomes of the decisions being made.

Additionally there is an obvious need to achieve a closer coupling between standards making, spectral policy, regulatory policy and competition policy. We could of course follow the US model of resolving these disconnects by litigation. Indeed it could be argued that the volume of litigation provides a direct measure of the inefficacy of the US standards, regulatory and policy making process. In this context the US 700 MHz band provides a more or less perfect example of the destructive power of poorly conceived poorly executed regulatory policy coupled with an auction process focussed on a short term treasury objective. The stated aim is to provide cost effective urban and rural mobile broadband access. The outcome is income for the legal profession.

The US market is of course increasingly insignificant in global market terms. Nominally it remains the world's third largest market but the two largest markets – China and India – are more than twice as large. Partly by intent and partly by accident the LTE standards process is becoming genuinely global and as such has to deliver technically and commercially efficient connectivity to sovereign nations some of which still have predominantly command and control economies. Twenty years ago GSM had an explicit political purpose, to help unite a disunited Europe. Arguably its economic impact was more profound and global. LTE has an explicit economic purpose but potentially its political impact could be more profound and global.

It will however only be politically efficient if it can be made to be commercially efficient. It can only be commercially efficient if it is technically efficient. This in turn implies that the international standards and regulatory process needs to be focused not on short term political expediency but on long term user experience value across all addressed markets.

Telecommunications and politics have always been intimately connected and this remains unchanged. What has changed is the global scale of the economic, social and political change that is now potentially achievable – the big band ambition. This ambition will only be realised through a much closer coupling of technology, spectral and competition policy, harmonised on a global rather than regional or national basis. Big band ambitions will only be realised when big band economics make sense – at present they don't.

New 2011 Mobile Broadband Economics- RF cost and performance workshop
RTT has a new workshop for 2011 which analyses how LTE Advanced and LT HSPA multi band and extended multi band user equipment determines network density, network cost and user quality of experience metrics. If you would like a detailed agenda for this workshop please e mail **geoff@rttonline.com**

RTT has produced a major 70 page study on LTE user equipment and LTE network economics. The study is written by RTT with statistics and economic modelling from **The Mobile World** and is sponsored by **Peregrine Semiconductor** and **Ethertronics.** The study, 'LTE User Equipment, network efficiency and value' is available free of charge from the linked web site. **www.makingtelecomswork.com**

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An additional level of detail on this topic and related topics can be accessed via the **Resources section** of our linked web site **www.makingtelecomswork.com**

www.makingtelecomswork.com provides a cost and time efficient way in which telecommunication engineers, product managers and policy makers can access **technical information and advice not readily available elsewhere in the public domain.**

The web site also provides information on RTT workshops, **Making Telecoms Work Europe**, **Making Telecoms Work Asia** and **Making Telecoms Work in the US.**

The workshops demonstrate how engineering issues can be practically resolved and how performance gains and cost savings can be achieved.

European work shops are held at the Science Museum in Kensington West London**. Information on the next workshop is available here.** A number of sponsorship opportunities are available linked to the web site and related Science Museum telecom industry educational initiatives.

If you would like more information on these opportunities please e-mail **geoff@rttonline.com** or phone **00 44 208 744 3163**

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