RTT TECHNOLOGY TOPIC
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Mobile Broadband Radio Access Economics

The last few RTT technology topics have addressed various aspects of LTE user equipment design including ATSC and DVBT integration **(April),** Multi Band Switching **(May),** Multi Band Power amplifiers **(June),** the RF performance of LTE user devices **(July).** The **August** technology topic introduced RTT's new study 'LTE User equipment, network efficiency and value - the impact of user equipment RF and base band performance on mobile broadband radio access economics'. The study (75 page PDF) is now available as a free download from RTT's linked web site **www.makingtelecomswork.com**

Sponsored by **Peregrine Semi Conductor** and **Ethertronics** with **IWPC** and the **National Microelectronics Institute** **(**NMI) as research study partners, the study analyses the impact of LTE user equipment performance on user value and operator and industry supply chain EBITDA (**E**arnings **B**efore **I**nterest **T**ax and **D**epreciation of **A**ssets). The market, business and economic modelling in the study has been undertaken by **The Mobile World** with technical and commercial inputs from over thirty vendors including RF component suppliers, baseband vendors, infrastructure vendors and the operator and user community. As far as we know it is the first time these relationships have been modelled in this level of detail at least in the public domain.

Study outputs can be summarised as follows:

On the basis of present demand growth, there will be a 30 fold increase in data volume over the next five years from 3 to 90 exabytes. An exabyte is equivalent to one million terabytes. Over the same time scale based on present tariff trends, income will have increased by at most a factor of three.

LTE delivers spectral efficiency benefits over and above HSPA Release 6 by roughly an order of three which is impressive but short of the increase needed to balance this traffic/income disparity.

An alternative would be to reduce network cost. Some network hardware costs scale with Moore's law but some do not, RF hardware in the radio access network being one example. Although hardware cost reduction yields a reduction in capital cost investment, there are associated increases in through life software cost, an operational expense.

Operators and carriers can scale up their present spectral assets to accommodate the additional data volume. However this amount of spectrum is unlikely to be made available, any spectrum made available will be expensive and, probably most important, present and planned user equipment lacks the band flexibility to access the spectrum effectively or efficiently. Unless an operator is bidding for spectrum for speculative gain, which is rightly discouraged by regulators, there is no point in buying bandwidth if it cannot be economically used.

An alternative approach is to increase network density. This has the effect of improving the link budget which increases capacity, improves data rates and reduces user power budgets up to the point at which the radio network becomes interference limited. The problem with this from an operator EBITDA perspective is that capital and operational costs increase, a composite of site acquisition, site rental, site energy cost, hardware and software investment and backhaul costs. Backhaul costs are a particular issue in mobile broadband networks as the offered traffic will generally be more asynchronous and asymmetric than voice which means that in general bandwidth needs to be over provisioned to protect quality of service for latency sensitive traffic.

Using subscriber ADSL lines as backhaul via femtocells partly provides a solution to the back haul cost issue and can increase local area network density in a cost-effective way at the subscriber's expense. However femtocells address local area access economics not wide area or high mobility user access economics. There is some off loading from macro and micro cells to femtocells but the noise shedding benefits of this are open to debate and probably more efficiently achieved with WiFi. Femtocells do not deliver wide area or high mobility user value.

Similarly MIMO (**m**ultiple **i**nput **m**ultiple **o**utput) antennas achieves high peak data rates in small cells but if poorly implemented in user equipment compromises SISO (**s**ingle **i**nput **s**ingle **o**utput) and SIMO (**s**ingle **i**nput **m**ultiple **o**utput) performance in larger diameter micro and macro cells where average data throughput is more important, having a more direct impact on the user experience.

User experience value is not realised just from connectivity but the relevance of the connectivity. Search algorithms have become worth more than handover algorithms. This is why operator data value is increasing at a slower rate than data volume. However mobile connectivity, including wide area and high mobility connectivity, has the potential to realise additional value if specific user experience metrics can be addressed

This study demonstrates that a relatively small investment in user equipment performance optimisation yields a positive non linear gain in radio network efficiency and value. We argue that this is a prerequisite for industry profitability and a determining factor in mobile broadband radio access economics.

The present opportunities and challenges for the industry can be summarised as

A demand side opportunity
A 30 fold increase in data volume demand over the next five years.

A supply side opportunity
An additional 500 MHz of spectrum on offer in some markets over and above the 1 GHz of spectrum already allocated and auctioned on a global basis.

The problem with LTE user equipment
Accessing these two opportunities cost effectively is however critically dependent on user equipment cost and performance. Over the past ten years, spectral auctions have taken over $200 billion dollars out of the industry which might have been alternatively spent on user equipment R and D and engineering investment. This study highlights three areas where LTE user equipment performance constraints compromise LTE network efficiency and increase network cost, potentially compounding the cost/income problem.

A lack of band flexibility in LTE user equipment means that existing and new spectrum cannot be accessed effectively or efficiently.

A best and worse case performance difference of at least 7dB – a radio network cannot be accurately or efficiently dimensioned to meet defined user experience expectations with this degree of performance uncertainty.

Compromised conformance standards – the need to support new radio bands is forcing conformance standards to be compromised – each new radio band results in a further loss of

RF performance – this reduces peak and average throughput and shortens the user's data duty cycle, decreasing user experience value.

A year on year loss of RF performance in user equipment increases the demand for spectrum and radio network density with associated cost but no associated income, increasing network cost, decreasing network value. These constraints together make it hard/impossible for operators and carriers to achieve a return on present and future spectral and radio network investment. An increase in radio network efficiency is therefore needed in order to ensure that present and future mobile broadband data volumes can be viably supported.

Key findings by industry sector

For operators and carriers - the study and economic model validate that a move to LTE, if coupled with investment in band flexibility and improved year on year user equipment efficiency yields sufficient radio network efficiency gain and incremental user value to provide a positive and improved return on present and future spectral and radio network investment, or put another way, allows operators and carriers to make money out of data volume growth.

We argue that the combination of user equipment efficiency and extended multi band support which we define as more than the standard 5 bands presently supported and the eight bands presently on most vendor road maps, will have a more positive impact on mobile broadband radio access economics than commonly assumed or presently modelled. Implementing additional bands should however only be considered if performance in existing bands is maintained. Conformance specifications are already being degraded to accommodate multi band designs. The goal should be to exceed existing requirements rather than maintain par with requirements that are getting laxer over time.

Over and above this, a year-on-year performance improvement of 1dB over and above the single band baseline but applied to multi band and extended multi band user equipment would yield year-on-year user experience gain (user value) and a reduction of direct and indirect radio network cost, delivering a positive investment cycle even if additional user equipment BOM costs are factored in to the equation.

A 3 dB improvement over three years would double the average data rate per user or double the user data duty cycle, a combination of link budget and scheduler gain. This translates directly into additional realisable user experience value and reduced network cost per subscriber and device supported.

For infrastructure hardware and software vendors

We show how improving user equipment performance transforms scheduler efficiency and by implication the ROI model for infrastructure hardware and software investment.

For user equipment hardware and software vendors

We argue the case for a shift from user equipment cost optimisation to a combination of cost and performance optimisation and show how this yields a positive EBITDA return.

For component hardware and software vendors and the test equipment hardware and software community.

We identify presently under exploited opportunities to add value to the whole industry supply chain.

For industry, financial and investment analysts

We demonstrate that provided certain preconditions are met, the demand side growth potential of mobile broadband is capable of delivering much greater fiscal returns than presently reflected in mobile broadband industry equity valuation.

Implications of future mobile broadband data demand
The measured growth suggest that the present rate of increase of data traffic on mobile broadband networks is increasing over time, a function of the growth in subscriber numbers, number of attached devices including connected machines and the volume of data generated per device, particularly from smart phones, tablets/slates and lap tops with dongles or embedded mobile broadband connectivity.

We forecast 87 exabytes of offered traffic data volume in 2015. This is in line with other **higher end industry estimates.** On the basis of present growth trends, and the trend of the trend (increasing over time), these projections would prove to be conservative**.** On the basis of present tariff trends, over the same period data revenues will have increased by at most a factor of 3, an income/cost disparity which must be regarded as a major challenge for the industry.

Delivery cost is a function of the type of data traffic. Conversational, interactive and streamed traffic is more expensive to deliver in terms of bandwidth and power consumed than best effort traffic. This mix is also largely determined by the hardware and software form factors of user devices but it seems very possible that average application latency both in terms of first order latency (end to end delay) and second order latency (worst to best difference) will need to be more closely controlled. This effectively means that radio bandwidth and power will need to be over provisioned in order to meet user experience expectations. These are all factors that together add to the cost of delivery.

While the demand projections and data revenue forecasts could well be realistic, there are two reasons why the growth in demand and revenues might be slower than anticipated and costs may be greater than expected (the downside equation).

1)The relatively slow rate of revenue growth relative to traffic growth will mean that operators will find it hard to raise the capital needed for the network density and or spectrum required to meet user experience expectations. This will result in poor voice quality, poor coverage, high blocked call rates, high dropped call rates, unacceptable application and task latency, high session failure rates and unacceptably short mobile broadband session duty cycles (time between battery recharge). This will result in high product returns and high churn rates introducing additional delivery and support cost and making it hard/impossible to realise any relative income gain on a per subscriber per device basis.

2) Battery capacity and heat density constraints will make mobile broadband duty cycles even shorter, choking offered traffic volume and value. While some users will be connected to a mains supply for example in trains, these applications are by definition portable rather than mobile broadband.

This study directly addresses these interrelated challenges of delivery cost, delivery value and mobile user experience expectations. We show that the solution (the upside equation), not surprisingly, is a function of mobile broadband radio network efficiency improvement. User equipment performance is a more important part of this efficiency equation than commonly assumed.

Our data volume forecasts are based on a year on year improvement in the user experience which in turn delivers a 1% uplift in ARPU which in turn yields the additional EBIDTA needed to justify the investment required to sustain the year on year user experience gain - a positive investment cycle for operators and the whole of the industry supply chain.

To achieve this, however, implies an associated need for materials and process innovation particularly in the radio front end. **Antenna design** for example is crucial to getting optimum performance out of SISO, SIMO and MIMO techniques and is a defining component in wide area and local area access economics. Antenna design and the associated matching requirement, is apparently simple but actually complex and dependent on the application of a mix of material and algorithmic innovation, knowledge and expertise. Similarly **Silicon on Sapphire** based components and systems provide an example of materials and algorithmic innovation applied to realise efficiency gain in switch path and adaptive tuning applications but with wider application potential. The study discusses and quantifies other similar innovations including RF power amplifiers and related enabling components.

Generally it is also important to address the growing disparity between bench top measurements and real life user equipment performance. This is resulting in best to worst differences of 7 dB in user equipment performance. A network cannot be dimensioned to meet defined user experience expectations with this degree of performance uncertainty. RF and baseband innovation help to reduce this difference. Changes to conformance and performance measurement methodologies are also required to reduce the gap between what is measured on the bench and real world performance.

There is clearly a demand side opportunity if delivery cost, investment, innovation and test issues can be addressed.

The study can be downloaded **HERE**

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

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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.

There are a number of sponsorship opportunities available linked to the new web site and related Science Museum telecom industry educational initiatives.

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