The Geographic Dividend

The economics of terrestrial mobile broadband are determined by a combination of technical, demographic, geographic and regulatory factors with cost, capacity, coverage and customer value as metrics which determine operator EBITDA and enterprise value.

In the early years of the cellular industry (AMPS and TACS and ETACS), coverage was a key competitive differentiator.

The commercial success of GSM made coverage less of an issue partly because the RF performance of the networks improved steadily on a year by year basis but also because volume manufacturing delivered performance gain for handsets yielding an improvement of 1dB a year in the GSM link budget from the mid 1990's onwards.

For countries like Australia it was possible to build 100 kilometer radius cells (albeit using adjacent time slots as time domain guard bands) which delivered good voice quality and messaging in deep rural, rural and outer urban areas at low cost. These were profitable networks delivering customer and corporate value.

As subscriber numbers grew, the focus shifted from coverage to capacity. This was delivered by increasing the number of bands and channels supported in user devices and by increasing network density.

Adding extra bands into the phones made them less efficient due to a lack of space for antennas and their ground planes and losses in the multiple switch paths. This reduced coverage in rural areas.

Additional network density in urban areas meant that interference noise floors started to rise.

In parallel, phone designers had to accommodate 3G which produced additional digital baseband noise which compromised the receive path. On the transmit path, symbols needed to be received at an equal power level which required an energy hungry and bandwidth hungry power control loop which reduced RF performance at both ends of the link. The upper layer protocol stack was also less than optimal. Something as apparently simple as Voice over IP subtracted 3dB from the link budget.

In 2007, the first iPhone was introduced; a great product but the layout constraints of the mechanical design compromised antenna and front end performance. Adding Wi-Fi and Bluetooth didn't help either. The end result was a capacity hit in urban areas and a coverage hit in rural areas.

The iPhone also started to increase the data load on the network and operators began to realise that as data rates increased, data reach reduced (for the reasons outlined above).

Fortuitously 4G mitigated most of these effects. The physical layer was (and still is) more bandwidth and power efficient than 3G and the RF component supply chain bent over backwards to recover some (or for the better designed phones, most) of the RF efficiency loss.

However no one can pretend that coverage is perfect and we still see people searching for a 3G or 4G signal in areas which should be covered.
This brings us to 5G and the satellite service offer.

The vendor community point to a number of factors that suggest that 5G could improve coverage and capacity when compared to existing 4G networks. Coverage gain will (we are told) be realised from accessing additional sub 1 GHz spectrum including Band 71 in the 600 MHz band and from beam forming at higher frequencies with beam forming also delivering capacity gain.

Luckily, smart phones have become larger making antenna and ground plane design easier but it is still difficult to produce an efficient antenna at 600 MHz (a half metre wavelength). At the base station, beam forming below 1 GHz (practically below 2 GHz) would take up too much space on most sites and add weight and wind loading to already fully loaded towers. Nortel failed to implement smart antennas at 1800 MHz twenty years ago and the underlying physics hasn't changed.

Adding millimetre band support into smart phones and millimetre band beam forming introduces additional challenges. Public domain design notes presently suggest that integrated antennas on a beamforming chip will be positioned at the four corners of a 5G phone and or half way along the side but it is hard to see how this will realise consistent or effective beam forming due to the variable capacitive effects that will be dominant at these higher frequencies.

Coverage and capacity gain could alternatively be delivered by adding satellite connectivity.

There is however a classic chicken and egg problem. Terrestrial network vendors see satellite as a threat to rural site hardware sales. Handset vendors do not want to add additional switch paths into user hardware unless there is an established global demand for devices with satellite connectivity at a price that consumers can afford. Operators are not going to consider adding satellites to the delivery mix unless they have confidence that networks and user devices will be available.

The additional switch path issue (cost and space) in user devices and base stations would be made easier if satellite and 5G signals shared the same bands. For example, 5G satellite connectivity could be added to existing FR1 and FR2 3GPP 5G bands (see our September 2018 technology topic, Massive Multiplexing for a list of these bands) and 5G connectivity could be added to satellite bands for example at 28 GHz.

However the satellite bands are realised as FDD with typically 3.5 GHz pass bands with 250 MHz sub channels. This is significantly different from the 5G radio layer. Satellites also use power efficient PSK rather than bandwidth efficient higher order modulation. There would also be higher layer protocol issues to address particularly at the MAC layer so coexistence and compatibility would be problematic.

If these issues could be overcome it would be feasible to embed an 8 or 16 or 32 element phased array active antenna in a smart phone screen which would mean a user could have satellite connectivity to a mix of LEO, MEO and GSO constellations by pointing the screen at the sky.

Alternatively as and when the mega LEO constellations are deployed, a simpler fixed fractional beam width aperture antenna would be effective given that there will nearly always be a satellite nearly overhead. (The NANO access model).

Another option is to admit defeat and deliver satellite connectivity through a separate device connected via Bluetooth or Wi-Fi to the user or IOT device.

Satixfy and Hiskysat both support this approach initially targeting OneWeb (Ku band 11-12 GHz receive and 13.75-14.5 GHz transmit) with a product range of integrated modems and tracking antenna arrays.

Given that we seem to have acquired the habit of carrying extra devices such as power blocks with us, a separate satellite modem is probably no big deal but it will have a higher cost floor than an integrated device.

Either way, a case needs to be made that satellite connectivity adds sufficient value to the 5G business model to be worth adding to the network and device product and service offer.

There are arguments for and against and the answer will not be the same for all terrestrial mobile broadband operators or all markets but some present assumptions need to be tested.

The first of these assumptions is that 5G coverage and capacity should be concentrated on urban hot spots, or in other words, demographic demand.

Demand for internet access is typically modelled by measuring existing demand for social media and rich media interactions by volume and value.

Unsurprisingly these show that this demand is overwhelmingly urban but there are several counter arguments.

The first is that there is minimal demand in rural areas (geographic demand) because there is limited coverage from existing terrestrial mobile broadband networks. Sort out the coverage and the demand may be higher than expected by volume and value. Agrarian IOT and remote working are components of this rural satellite added value connectivity story.

The second counter argument is that urban 5G and indoor 5G will be competing directly with evolved versions of Wi-Fi including Wi-Fi 6.00. Bluetooth 5.0 also now has a long distance option providing another no cost or lower cost (compared to 5G) connectivity option.

Another assumption is that satellite has a limited role to play in urban 5G connectivity due to building blocking but this only applies to sparse constellations and not to high count LEO and mixed LEO/MEO/GSO connectivity where satellites are nearly always nearly overhead. Satellites could therefore improve the delivery economics of direct access urban 5G. Satellite is not just a back haul option.

Counter intuitively, satellite also has a role to play in delivering ultra-low latency urban connectivity. One of the issues of ultra-low latency ultra-reliable radio links in any topology (urban or rural) is that the network has to be over provisioned. Any contention in a ULLC radio connection will destroy the service level access guarantee either because of the first order delay or because of the second order effect of delay variability. Over dimensioning network capacity to meet these latency and reliability requirements increases capex and opex costs to an unsustainable level.

Offloading latency insensitive traffic to satellite therefore becomes an important part of the urban delivery economic model.

For long distance intercontinental or transcontinental path lengths over 10,000 kilometres, inter satellite switched LEOS will beat fibre both in terms of end to end delay and delay variability, a performance metric that will be important for many transactional supply chains.

So the argument is that there is a potential urban connectivity gain which can be added to the geographic dividend that satellite 5G would deliver.

Even if you discount the urban gain, the rural connectivity gain from satellite connectivity is compelling both at device and network level.

Give me a choice of a next generation Huawei 5G smart phone which will work anywhere in the world including at sea or in deepest darkest somewhere or another vendor 5G smart phone that will only work in urban environments where Wi-Fi is either a lower cost or no cost option then (given an equivalent price) which device would I choose? The same argument applies to the handset manufacturer. If satellite can be added without a real estate or hardware cost (in band satellite) then the added subscriber value equates to competitive differentiation.

This is the geographic dividend. Add on the additional operator EBITDA and it becomes an even more compelling proposition.

Industry analysts are fond of pointing out that alternate generations of cellular technology are alternately successful, 2G good, 3G bad, 4G good, 5G?

Why not break the sequence and sort out satellite as a connectivity option that is embedded into the 5G standards and spectrum story? The EBITDA and enterprise value gain could be substantial.

5G and Satellite Spectrum, Standards and Scale

Our latest book, **5G and Satellite Spectrum, Standards and Scale** is available from Artech House. You can order a copy on line using the code VAR25 to give you a 25% discount.

http://uk.artechhouse.com/5G-and-Satellite-Spectrum-Standards-and-Scale-P1935.aspx

---

About RTT Technology Topics

RTT Technology Topics reflect areas of research that we are presently working on. We aim to introduce new terminology and new ideas to help inform present and future technology, engineering, market and business decisions.

The first technology topic (on GPRS design) was produced in August 1998. 20 years on there are over 240 technology topics **archived on the RTT web site**.

Do pass these Technology Topics and related links on to your colleagues, encourage them to join our **Subscriber List** and respond with comments.

Contact RTT

RTT, and **The Mobile World** are presently working on research and forecasting projects in the mobile broadband, public safety radio, satellite and broadcasting industry and related copper, cable and fibre delivery options.

If you would like more information on this work then please contact **geoff@rttonline.com**
00 44 7710 020 040