RTT TECHNOLOGY TOPIC
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STEAMSHIPS AND SPACE SHIPS
A new golden age of connectivity?

Mr Brunel and his very big ship - Physical Scale and Efficiency

In 1859, a few months before his premature death, Isambard Kingdom Brunel was photographed on the deck of the Great Eastern, his final project and at the time the largest ship ever built, 700 feet long with a displacement of 22,500 tons and the first ship built entirely of iron. It was potentially capable of carrying 4000 passengers from the UK to Australia on a single load of coal.

In practice the ship had a chequered history and lost money for several owners but finally found its niche laying transatlantic cables including the first transatlantic cable from Britain to America in 1866 and over the next eight years another six cables from Europe to America and a cable across the Indian Ocean.

The point of the story is that as with commercial scale, physical scale can deliver improved performance, in this example speed and efficiency and tonnage capacity, but the end application is not always the one originally intended. Telecommunication is essentially a transport system and Brunel would have been undoubtedly proud of his posthumous maritime role in enabling the global undersea cable network.

Mr Musk and his very big rocket

The same scale effect applies to rockets. In our November Technology Topic, **Red Rockets Yellow Rockets** we made the point that larger rockets are more efficient than smaller rockets. The SpaceX Falcon Heavy Rocket for example is capable of taking a 16,000 kilogram payload to Mars or alternatively can lift over 60,000 kilograms of payload into low earth orbit, that's one hundred and twenty 500 kilogram micro satellites or six thousand ten kilogram pico satellites all for a launch cost of $90 million dollars.

The number of options for sending images and data around the world could therefore increase exponentially but only if the economics of these new high count constellations are better than existing terrestrial networks.

Mr Metcalf and the magic of numbers

Sceptics doubt whether these new networks in the sky will ever approach the delivery cost economics and value proposition of terrestrial networks. There must however be a generalized methodology we can use to test the break point at which satellite networks deliver more value per MHz of spectrum at a lower opex and capex.

As a starting point we can revisit Metcalf's Law which states that the value of a network grows by the square of the size of the network. If five network nodes expand to ten network nodes, the combined value is equivalent to twenty five network nodes.
https://www.computerhope.com/jargon/m/metcalfe.htm

If Metcalf's law is applied to high count LEO constellations it also needs to account for the ability of satellites to route traffic and signalling to and from terrestrial networks, to route traffic and signalling across satellites in the same constellation and other constellations in LEO orbits and to route traffic and signalling to constellations in other orbits including MEO and GSO constellations.

Adding network nodes could therefore potentially create a cube root rather than square root increase in isotropic routing opportunities, a uniform gain in all orientations.

As a reminder, performance gain is realized from high count constellations because they can be nearly always nearly overhead with a close to 90 degree elevation producing the shortest possible path length , the best possible link budget and minimum interference with other space and terrestrial systems including space and terrestrial systems deployed into the same spectrum.

A new generation of FLAT VSAT antennas (see December Technology Topic **FLAT VSATS**) potentially maximize in band and out of band performance. This makes co sharing with other satellite constellations and 5G sub 6 GHz spectrum plausible and possible.

Mr Moore and his law of processing scale and efficiency

However we also need to consider the impact of Moore's Law on satellite delivery economics and terrestrial network delivery economics. Moore's Law, as we probably all know, states that the number of transistors per square inch doubles every 18 months.
Moore's Law https://www.investopedia.com/terms/m/mooreslaw.asp#ixzz52rpeZojC

Moore's Law therefore applies equally to satellite networks and terrestrial networks apart from the fact that Moore's Law does not apply to terrestrial wayleave agreements or trench digging or metal and concrete structures. Terrestrial network densification therefore has irreducible capex and opex cost multipliers which are increasing over time. Space network densification has capex and opex costs which are reducing over time.

The rate at which this cost reduction occurs and the possible economic cross over points are however dependent on satellite networks working together more efficiently and coupling more efficiently with terrestrial networks.

Inter satellite switching and inter constellation switching as a way of improving coupling efficiency

One way of improving coupling efficiency is to use intersatellite and inter constellation switching.

Existing constellations such as Iridium have used inter satellite switching successfully for over twenty years. Some of the new constellations inter satellite switch (Space X and LEOSAT for example) but none of the proposals so far support inter constellation routing and switching.

This is surprising given that the technique is widely used in military systems. The International Space Station and the Hubble telescope also talk up to a GSO and back to GSO earth station gateways.

There is of course a latency cost but it seems contrarian to deliver a low cost high satellite count network into space and then load it with expensive terrestrial assets. The alternative would be to deliver traffic from and to space from cellular base stations which would also have the benefit of transforming 4G and 5G backhaul economics. Intersatellite switching also potentially allows satellites to manage their own station keeping which further reduces terrestrial cost.

Summary - Steam Ships and Space Ships – a new golden age of connectivity?

Brunel was a brave and brilliant man working in a golden age of innovation and infrastructure investment. He built boats and bridges and tunnels and viaducts on a scale never previously attempted. Many of the projects were regarded as financial failures and only delivered economic gain years after their completion. Many of us still commute by train on bridges and viaducts built by Brunel - 160 years of engineering added value.

The SS Great Eastern combined steam and sail power with material and manufacturing innovation to create a vessel that could outperform every other ship in the world but was never used for its intended purpose.

The big rockets being designed and built today combine liquid fuel and solid fuel engines with material and manufacturing innovation to provide the power needed to take people to Mars or alternatively launch thousands of satellites into near earth orbits. The satellites scale from a few kilograms to thousands of kilograms and can sail through space using solar powered ion thrusters to maintain and change orbit.

Instead of shipping people to Australia, the SS Great Eastern cabled the world, enabling the Victorian internet to achieve global scale. 160 years on the world is being connected from space in ways that Brunel could never have imagined but would have completely understood – a new golden age of connectivity based on innovation and space infrastructure investment.

5G and Satellite Workshop in the Caribbean- April 23-25 2018

We are pleased to announce that our next 5G and Satellite workshop, presented in association with Niche Markets Asia will be held in the Caribbean in April. For details, including the early bird registration booking offer, **follow the link.**

New Book with Artech House - 5G and satellite spectrum, standards and scale

RTT, The Mobile World and Policy Tracker are working on a new book project on 5G and Satellite Spectrum and Standards and Scale and related regulatory and competition policy issues prior to WRC 2019. The book will be published by Artech House in June this year.

If you are interested in knowing more about this project or are developing products and services that you feel should be included or a regulatory and advocacy position that you feel should be reflected then please e-mail us for more information.

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