RTT TECHNOLOGY TOPIC
September 2021

RF and Optical Network Integration

Last month's technology (Smart Servers from Space), this month's topic (RF and Optical Network Integration) and next month's topic (RF and Optical Device Integration) look at how the integration of RF and optical technology is changing the relative delivery and storage economics of terrestrial and non-terrestrial networks.

The three topics together provide background to a Cambridge Wireless Webinar being presented on the afternoon of Wednesday October 20th

Information on the webinar can be found here.
https://www.cambridgewireless.co.uk/events/rf-and-optical-integration/

It is a chargeable event for non-Cambridge Wireless members but you can book a free ticket by going to register here and quoting **'CWGV21'** when prompted.

We look forward to you joining us at this event.

Read on

In last month's (August) Technology posting, Smart Servers from Space, we argued that optical asset value would outpace RF asset value over the next twenty to thirty years and that space asset value would outpace terrestrial asset value over a similar time scale.

In this month's topic we look at the relative value of wireline assets (terrestrial copper, cable and fibre) and wireless assets, RF and optical terrestrial networks, RF and optical point to point, point to multipoint, multipoint to multipoint and RF and optical non terrestrial networks.

Making predictions is easy but to have validity need to be based on an understanding of past and present trends.

We can look for example at the first 100 years of telecommunications with 1870 as a nominal start date and use that to forecast the second hundred years of telecommunications from 1970 to 2070 with the present day as a half way mark point in this second century.

In the first hundred years, wireline assets are predominantly copper (plus some aluminium for cost and weight reasons) with radio as a complementary carrier, initially at long wave, medium wave and long wave then VHF and UHF and microwave. Satellites come into the mix in the final ten years (from 1960 onwards)

From 1970 multi-mode fibre begins to be introduced but is expensive and suffers from high loss and signal degradation. Material and manufacturing improvements over the next fifty years (1970 to the present) reduce this loss from 20 dB per kilometre to 0.2 dB per kilometre and costs (including termination cost) reduce by several orders of magnitude.

From the mid 1980's single mode fibre starts to be deployed (8-12 micron core with 125 micron of cladding) and is used for long distance links. Multimode (50 to 85 micron core with 125 to 400 micron of cladding) gradually starts to replace copper for local area connectivity. Today's hyper data centres (see last month's technology topic) are connected internally with multi-mode fibre.

Materials and manufacturing improvements make high fibre count single mode cables practical and economic. 864 and 1728 pair cables are now relatively common and 3456 and 6912 fibre cables are being introduced within 1.14 inch and or 1.3 inch form factors. The optical world still quirkily likes to mix metric and imperial measurements.

Wavelength division multiplexing with 100, 50 and more recently 25 GHz channel spacing increases available bandwidth combined with higher order modulation (as channel coherence improves over time). In subsea cables, optical amplifiers replace electric regenerators from the mid 1990's onwards reducing cost and improving end to end latency.

In parallel, various technologies are introduced to extend the life of copper and cable networks including ADSL in copper and DOCSIS Versions 1- 4 in cable. ADSL moves to 8.5 MHz, 17.7 MHz and 35.33 MHz using 1024 and 4096 level QAM. As late as 2014, BT announce new speed records over copper (10 Gbps ADSL) though only over short distances. DOCSIS 4.0 similarly extends cable bandwidth from 108 MHz to 1.8 GHz but deployments are typically between 10 metres and 100 metres with 10 Gbps downstream and 6 Gbps upstream.

CAT 6 and its successor (CAT 7) remain as the default cabling solution for smart homes but plastic fibre begins to take market share. Made of a mixture of acrylic, polystyrene and polycarbonate, usually an acrylic core surrounded by fluorinated cladding, plastic fibre has at present a propagation loss of 50 dB per kilometre but its weight and cost advantage make it a good choice for automotive connectivity and in the longer term, industrial connectivity. In domestic applications it will sooner be cheaper than co-ax with low cost easy to use connectors which means that you can have plastic fibre running round the house terminating in a USB port where the fibre signal is demodulated (fibre to the desk). For outdoor connectivity, low voltage power can be added as well, an ideal low cost simple way to upgrade the man shed.

Last but not least in the present wireline world we have RF over Fibre which starts to become practical from the mid 1990's onwards. RF over Fibre is now widely used to move L band, S band, C band and more recently Ku and Ka bandwidth within and between earth stations to support diversity transmit and receive. It is also used in radio astronomy to link multiple terrestrial antennas together often over hundreds of kilometres. Most systems use a distributed feedback laser operating between 1270 and 1610 nanometres with the fibre channel intensity modulated by the RF analogue carrier (known as a repeater in LTE and 5G). As with optical amplifiers in subsea cables, this avoids the latency introduced by a regenerative receiver (known as a relay in LTE and 5G) and explains why RF over Fibre is also used in latency sensitive 5G applications such as cell towers and distributed antenna systems.

In the longer term it is hard to see why fibre will not become ubiquitous. The scrap value of legacy copper networks is significant. 75 million miles of copper land lines in the UK is a valuable asset if it can be recovered economically. In terms of relative performance, high quality glass fibre supports many tens of terabits of throughput over many tens of kilometres (thousands of kilometres with the occasional optical amplifier) compared to 10 Gbps over cable or copper over at most tens of metres.

Fibre is an order of magnitude lighter than cable and consumes 2 watts rather than 10 watts per user. Fibre has lower maintenance costs and is immune to EMC interference and is faster. Electrons in copper travel at less than 1% of the speed of light, photons in fibre travel at 70 % of the speed of light.

This brings us to RF and optical wireless networks which operate in free space at the speed of light, no faster, no slower.

In some ways the story of wireless is similar to wireline. The evolution of the microprocessor from 1970 onwards transforms switching efficiency and the DSP does the same for bandwidth efficiency though with some associated power efficiency costs.

Satellite and terrestrial TV provide an example, initially with 2K carriers, then 4K and now, at least within Japan and parts of Asia, 8K carriers supporting a 120 fps frame rate, perfect for that 65 inch screen television you bought to watch the summer Olympics. As a matter of record, even with advanced compression, the bit rate of these systems has increased from 2.5 Mbps for 2K to 65 Mbps (OTT) or 85 Mbps from a GSO satellite.

It is therefore not surprising that satellite TV operators are happy to take large amounts of cash from the 5G community for C band (and soon Ku and Ka band) to move their service offer to terrestrial fibre where someone else is picking up the cost of delivery.

It is of course not a certainty that 5G operators will be able to find a way of using this higher frequency spectrum cost efficiently particularly if they continue to invest tens of billions of dollars in the auction process.

The idea that high count LEO constellations could become an economic alternative for universal broadband connectivity has so far been largely discounted by the 5G operator community.

While acknowledging, quoting the late Donald Rumsfeld, the known unknowns and unknown unknowns of the 'new space' economy we can say with certainty that there are many ways in which LEO satellites can deliver revenue and through life cost recovery including sub metre imaging, GNSS and end to end latency and security benefits over and above terrestrial networks. All sorts of tricks can also be deployed to increase in orbit life from a few years to twenty years or more and reduce other associated costs.

But the sparkling jewel in the space crown is arguably optical cross connect in space coupled to optical uplinks and downlinks

This is relatively easy to achieve with GSO satellites which obligingly stay in the same place at least as we see them from earth and relative to one another. High bandwidth laser links of 60,000 kilometres link GSO satellites together integrated with high bandwidth optical downlinks coupled to aberration corrected uplinks delivering a step function improvement in cost per bit with parallel improvements in power efficiency and reduced launch weight. For lower orbit options, optical hardware is also more space resilient than RF hardware which is useful if your satellites are flying through the Van Allen belt in orbits above 600 kilometres.

Optical cross connect for LEOS is trickier due to the need for dynamic pointing but DOD spending on space weapons has turbo charged research and low cost imaging can now be used to scan and align inter satellite LEO links. In their initial filings to the FCC, Starlink stated that each of their satellites would have five inter satellite links, two links to satellites in the same orbital plane, two to satellites in adjacent orbital planes and one to a satellite in a crossing plane. Initial satellites did not have optical cross connect capability which tells us that this is hard to do but not impossible. The latest Starlink satellites launched into the polar orbital shell have optical capability with an assumed ability to link in the longer term with satellites in inclined orbits. The proposed Telesat LEO constellation has a similar optical architecture.

In the middle of this space and terrestrial sandwich are below the cloud and above the cloud RF and optical systems.

HAPS systems can comfortably support 25 kilometre high data rate links with clear atmosphere attenuation close to terrestrial fibre (0.2 dB per kilometre). Turbulence induced loss, scintillation loss and below the cloud fog can add several tens of Db's to this loss figure and the same constraints apply to point to point terrestrial optical free space communication but in the right conditions, these low cost flexible inter connections are hard to beat technically and commercially.

To use a rain analogy, it would be precipitate to say that RF in space is going to disappear any time soon and a similar assumption can be made for terrestrial RF networks or below and above the cloud atmospheric free space communication.

But as with radio astronomy, RF and optical systems make perfect partners and over the next fifty years we will see ever more optical systems providing communication in space, communication to and from space in terrestrial links and in free space above the ground (within the atmosphere) communication systems.

Shame some of us will not be around to enjoy the experience.

Ends

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RTT, and **Niche Markets Asia** 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.

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