RTT TECHNOLOGY TOPIC
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Space Time

We have been using celestial objects to determine time and position for thousands of years. The Sun, the North Star, the moons of Jupiter and events such as the transit of Venus have been used to determine latitude, direction of travel and time.

From the late 18th century onwards, the availability of stable and accurate time sources provided an effective and convenient way of calculating longitude.

Harrison's clock in 1764 survived the test trial trip to Barbados with an error of 39.2 seconds which translated into a positional error of less than ten miles, sufficiently accurate for Harrison to finally collect some of the Prize money owed to him.

Today we use GPS, Glonass, Galileo or Beidou to establish our location. These four MEO constellations between them provide an exquisite level of positioning and timing information and the ability to locate fixed and moving objects within a fraction of a metre.

Beidou is also being used for two-way messaging, opening up additional low cost IOT and user device applications.

Standard positioning from the four MEO constellations is realized by demodulating satellite specific codes that allow the receiver to determine which satellites are overhead and visible, referencing the measured signal against known ephemeris data stored in an almanac table which allows the device to calculate its position.

Three satellites in view will provide an accurate 2D location; more than three will provide an accurate 3D position.

Adding more constellations produces more accurate results but the device will consume more power and will take longer to calculate. This may or may not be acceptable depending on how fast the device itself is moving, the level of accuracy needed and the required battery life of the device.

Very high accuracy positioning (fractions of a metre, centimetre, and millimetre accuracy) does not use this code acquisition process but instead looks at the difference in received carrier frequencies between visible satellites.

The reference signals are at the transmission frequency, for example 1.5 GHz rather than the code rate of 1.023 MHz but the carrier difference is hard (expensive in terms of clock cycles) to calculate in real time so works for static objects, for example earthquake tremor sensors, but is non ideal for moving objects, particularly power constrained moving objects.

Carrier phase difference is a function of the Doppler signal from the satellite. The Doppler signal increases in strength as the speed of the satellite increases.

Satellite speed increases as orbit height reduces (Newton's Cannon Ball thought experiment circa 1687).

Iridium satellites in a low earth orbit of 700 kilometres travel at a speed of 27000 kilometres per hour compared to GPS satellites at 24000 kilometres which travel at 14000 kilometres per hour.

Low Earth orbit satellites therefore have stronger Doppler signatures than MEO satellites. They are also harder to jam due to higher flux density and a wider range of deployed frequencies (from VHF to V band). The use of low cost Cube SATS for example could provide a lower cost, more accurate and more robust timing and location platform than existing MEO constellations.

In 2016 Iridium turned this principle into practice by announcing the availability of their Satellite Time and Location (STL) System as a supplementary or complementary system to GPS.

Iridium's system combines carrier-phase ranging measurements from GPS and their recently refreshed NEXT L Band LEO satellite constellation to exploit the large geometry variations generated from their 'fast moving' satellites to allow the rapid resolution of 'cycle ambiguities'.

This is achieved by using newly created ionospheric models derived from the data sets generated from the Iridium satellites crossing large amounts of sky very quickly, (a seven minute transit time from horizon to horizon).

This modelling, based on ever more accurate error models over time, reduces the calculation overheads and therefore elapsed time of differential calculations.

This means that real time intercontinental tracking and aiming accuracy is improved by several orders of magnitude. Most of us can work out why that might be interesting and valuable to the US DOD.

The Iridium constellation also uses inter-satellite switching. The advantage of inter satellite switching is that it reduces the number of ground stations needed to communicate with the constellation but also reduces end to end latency and end to end delay variability

The absolute reduction in latency is a function of radio waves travelling faster in free space than in fibre which translates into lower end to end latency for any distance longer than 10,000 kilometres. End to end delay variability is reduced because the end to end routing is controlled by the constellation whereas most fibre links are subject to multiple and often random transit hops. These two mechanisms are the basis for LEOSAT'S 'faster than fibre' service offer.

Inter satellite switching using RF or optical transmission also means that satellites can calculate their relative distance from one another. This can provide the basis for autonomous station keeping where the satellites auto correct for any change in orbital position. This is used in Cube SAT constellations such as Sky and Space Global.

Essentially these are cooperative constellations which can either act autonomously or semi autonomously but importantly can maintain high levels of orbital accuracy.

They therefore potentially provide a highly accurate constellation clock source but also have the ability to track earth bound moving objects to a high level of precision.

Location information can then be messaged down to the device rather than the device needing to continuously calculate its position from an ephemeris almanac. This means that device duty cycle can be greatly extended to days, month or years for battery dependent IOT or user devices. Inter satellite communication within a LEO constellation can therefore support a range of potentially high added value applications

The same principle applies to inter constellation communication.

Inter constellation communications is already widely used in space, for example the Hubble telescope in low earth orbit talks up to a GSO satellite which then relays data back to earth. The International Space Station can similarly go up to go down as can many military satellite radio systems. The NASA Near Earth Network is the most widely established example of a communication system which links together LEO, MEO and GSO satellites and missions to the moon.

Inter constellation communication has the potential to provide a range of advanced communication, timing, tracking and location capabilities to and from devices on the ground or in the air. Hybrid constellation service offers already exist, SES for example operate GSO satellites and a MEO constellation acquired from O3B and Intelsat are invested in OneWeb but as yet there is no commercial operator combining GSO, MEO and high count LEO.

This is perhaps surprising given the performance advantages that could be achieved and the cost advantages that could be realised from co sharing spectrum across all of these satellite entities. The angular power separation now possible using passive and active fractional beam width antennas makes inter constellation spectrum sharing practical and easy to implement.

It also makes co sharing of satellite and cellular spectrum possible which could and probably should include scaling satellite down into existing cellular bands between 450 MHz and 3.5 GHz.

This would mean that 5G fixed access, progressive point to point, mobile access and in band backhaul could be extended across urban, outer urban, rural deep rural and maritime applications, transforming the sub 6G 5G business model. It would work for Ku and Ka band as well.

The world's most accurate clock and positioning, location and tracking system would be an added bonus.

New Book - 5G and Satellite Spectrum, Standards and Scale

Our new 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

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