RTT TECHNOLOGY TOPIC
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Time for 5G

The role of big clocks and small clocks in next generation mobile broadband networks

Problems with ground software uploaded to the GPS constellation on January 26 caused a 13 microsecond error in the GPS universal timing message. This in turn compromised the timing data on legacy L band signals and the time base from GPS receivers.[1] A similar error had occurred on the Russian Glonass system in April 2014.

The problem lasted about twelve hours. While not having a major impact on positioning and navigation systems it was noticed by most telecommunication networks and highlighted the importance of having back up timing references either at system level, the restoration of the Loran system being one option, and/or using high stability atomic oscillators for one to one redundancy.

Accurate timing is needed in all telecommunication networks both in and between the core network and radio access layer and is critical to the management of end to end delay and delay variability and cell to cell and network to network interference.

In 4G mobile broadband, localised and large scale time coordination is made more complex by the need to manage interference through mechanisms such as Intercell Interference Coordination (ICIC) and to manage link budgets through mechanisms such as Coordinated MultiPoint (CoMP) transmission.

For 5G, safety critical applications in automotive intelligent transport systems, energy grid applications, e-health applications and factory of the future requirements specify end to end latency of less than 5 milliseconds and packet loss thresholds equal to or lower than 10^{-5}

This performance can only be achieved by increasing the accuracy and resilience of timing in next generation networks.

In this month's technology topic we review the role of big clocks and small clocks in this process.

Read on

Big Clocks in telecommunication networks

Big atomic clocks are used in the telecommunications industry to provide an additional reference source to GPS and other GNNS systems (Glonass and Beidou).

Legacy cellular networks such as GSM have relatively straight forward timing and synchronization requirements with frequency synchronization provided via asynchronous Ethernet backhaul using the IEEE 1588 Precision timing protocol and or synchronous Ethernet (Sync E).

[1] http://www.insidegnss.com/node/4831

Distributed timing using Sync E results in frequency synchronization with an accuracy of 50 parts per billion at the air interface which in turn requires 16 ppb at the base station interface to the backhaul network.

The introduction of CDMA in the US introduced an additional need for phase synchronization. This is implemented by using GPS as a frequency and phase reference to an accuracy of between +- 3 to 10 microseconds depending on the cell radius.

In common with CDMA, LTE TDD and LTE Advanced networks also require phase and time synchronization.

In frequency synchronized networks, pulse transitions happen at the same rate but not at the same time.

In phase synchronized networks, the leading edge of the pulses occur at an identical moment.

In phase and time synchronized networks, the leading edge of the pulses occur at an identical moment and identical time.

The time and phases reference in LTE TDD and LTE Advanced has to be traceable back to Coordinated Universal Time and requires a phase accuracy of +- 1.5 microseconds for cell radii of up to 3 kilometres and +- 5 microseconds for cell radii over 3 kilometres.

This is defined by the ITU standard ITU-T G.8272 and needs to compensate for variable delay introduced by router hardware and routing flexibility.

The base unit of Coordinated Universal Time is the SI (International System of Units) second. The Si second is defined by a caesium fountain atomic clock.

A fountain atomic clock works on the principle of firing lasers at a group of caesium atoms. This creates an optical trap in which the caesium atoms are pushed closer together to the point at which they more or less stop vibrating at which point they become very cold, a tiny fraction of a degree above absolute zero (-273.15 degree Celsius).

The lasers above and below the optical trap launch the caesium atoms upwards into a microwave chamber and the atoms fall back down under gravity. Microwave radiation makes the electrons in the caesium atoms move between energy levels as they move up and down and the energy levels are measured through fluorescence. This ‘fountain’ process takes approximately a second and is repeated with different microwave frequencies until the frequency that causes the maximum number of caesium electrons to change level is realised. This is the resonant frequency that defines a second as the amount of time it takes for the radiation from the transition to compete 9,192,631,770 full wave transitions.

These caesium clocks lose than a nanosecond per day but are the size of a small car and can draw up to a kilowatt of power.

Small clocks in telecommunication networks

An accurate reference is not useful if the path between the reference and the timing requirement passes through router hardware and routing options with unknown delay and delay variability.

Using GPS as an alternative or supplementary reference to clock both ends of a communications link provides a solution but GPS signals are susceptible to jamming, hardware failure and software errors. A loss of GPS system integrity is not just a problem for telecommunications systems but a risk for any system relying on GNSS signals for timing and positioning. This includes drones and weapons systems. This provided a high value justification for a development project called the

Chip Scale Atomic Clock Programme financed by DARPA with the mission to produce a miniature atomic clock.

The principle of miniature atomic clocks is based on a technique known as Coherent Population Trapping using a compact sealed vacuum cell of a few cubic millimetres which contains an alkali vapour which is illuminated by a high frequency modulated laser beam.

Practical clocks are now available. A present device, produced by Symmetricom, uses caesium 133 and a buffer gas in the resonance cell. The vapour is illuminated with a semiconductor laser modulated at a frequency close to the natural oscillation frequency of the caesium atoms, about 9.192 GHz.

As the caesium atoms start to oscillate, they absorb less light and the photons transmitted through the cell are used to determine when the modulation frequency of the laser beam coincides with the resonant frequency of the atoms. It is effectively an atomic phase lock loop.

The Symmetricom clock weighs 35 grams and draws 115 milliwatts of power and measures 4 by 3.5 by 1.1 centimetres. It is accurate to within less than half a microsecond a day and can work across a -10 to +70 degree Celsius operating range.

This makes it useful for a whole range of applications including back pack military radios, military GPS receivers, unmanned aerial vehicles, back pack IED jammers and marine geophysical sensors (GPS doesn't work under the sea!).

At around $1500 dollars it has not yet achieved consumer price levels but as prices fall and accuracy improves these miniature clocks will become significantly useful in 5G mobile broadband and telecommunications timing and positioning systems.

Summary

There are potentially three key enablers that could realise a 5G physical layer capable of delivering a step function performance improvement over existing 4G systems

Super accurate super small clocks – to enable the improved frequency, phase and time referencing needed for high throughput low latency low packet loss connectivity and enhanced interference management (for capacity gain).

Supercomputing including quantum computing **–** to enable cost efficient and energy efficient spatial processing.

Superconducting materials including single atomic layer 2D materials such as graphene, silicene and germanane - to enable the ultra-low loss transfer of heat and energy.

Learn more about these topics

All three topics are covered in a new study on ***5G Vertical Markets*** co-authored by Geoff Varrall to be published by Policy Tracker – if you would like to know more about this study contact **martin@policymaker.com**

Geoff Varrall is also presenting two ninety minute modules on the Policy Tracker 5 day Training Course ***Understanding Modern Spectrum Management*** *at the* LS Telcom Training Centre in Central **London April 18-22 –** to book a place follow the link

http://www.policytracker.com/training/understanding-modern-spectrum-management-london

The three topics (and many others) are also covered in Geoff's new book, 5G Spectrum and Standards to be published by Artech House in May

More details are available here

http://www.rttonline.com/news.html

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