# RTT TECHNOLOGY TOPIC
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# Quantum Telecom

Since 2008, the boundaries of the physical world have been explored under a mountain in Switzerland. The large Hadron collider research programme at CERN (the European Organization for Nuclear Research), has partly been about understanding the immediate aftermath of the Big Bang but is becoming increasingly relevant to device design as silicon scales to 22 nm and 14 and 7 nm. The physical oxide thickness needed for a 22 nm node is 0.5 nm, about twice the diameter of a silicon atom so an ability to harness rather than fight quantum physics at device level becomes progressively more important.

At the other end of the scale, mobile operators are beginning to invest in quantum time and quantum computing. The motivation is to gain visibility to next generation computing performance and its relevance to 5G physical layer delivery and storage efficiency.

**Read on**

Going back 100 years takes us back to Einstein in 1915 and his General Theory of Relativity. The relevance of the General Theory might seem initially remote to telecommunications but the General Theory was part of a wider body of work that began with Boltzmann's realization that the energy levels of a physical system such as a molecule could be discrete and Planck's realization that energy could be quantized.

The term quantum was first used in a paper by Max Bonn in 1924. Over the next twenty years there was continuous and often heated debate about how the General Theory and quantum mechanical theory could be reconciled, a debate that was not resolved until the 1960's when the process of entanglement became more fully understood.

Quantum mechanics has been credited as the basis for many of the most significant technology innovations of the twentieth century including semiconductors, microprocessors, lasers, nuclear energy and thermal imaging.

In the scientific community this is described as Quantum 1.0.

The expectation is that the next 100 years of scientific innovation (Quantum 2.0) will be defined by an emerging ability to harness quantum physics, the manipulation of sub atomic particles rather than transistors to perform a switch function.

**Quantum Computing in telecommunications**

Quantum computing similarly exploits a combination of quantum mechanical and quantum physical properties.

Classical computers based on Alan Turing's work in the 1930's, work on two logic states, a 0 or a 1. Quantum computing exploits the ability of quantum bits (qubits) to exist in three states, a 0 or a 1 or a superposition of 0 and 1.

Quantum bits are sub atomic particles in which a change in energy state can be stimulated and measured by a control device. The control device can be an ion trap using optical or magnetic fields or a combination of both, optical traps using light waves and microwave radiation, for example atomic clocks, quantum dots using semiconductor material to manipulate electrons, the use of semiconductor impurities to produce electrons from ‘unwanted’ atoms and or superconducting (atomic clocks again). Quantum dots are proposed as an alternative to LED and OLED light sources in large screen televisions.

Quantum computers exploit the property of entanglement in which the application of an external force on two atoms induces the second atom to take on the property (energy state) of the first atom.

If left on its own, a single atom will spin in all directions. If disturbed, it chooses one spin or one value at which apparently instantaneous moment the second atom adopts the opposite spin or value irrespective of how far the two atoms are apart.

Frustratingly, rather like 2D materials, these semi magical properties are hard to harness in real world low cost energy efficient computing devices. In terms of performance, the enemy of quantum computers is noise and what are known as quantum decoherence phenomena.

This influences both the hardware used and the maths used. The hardware can be exotic and unfamiliar and chemically or organically based. Quantum computers in the late 1990’s for example used amino acids to analyse quantum state decay and chlorinated hydrocarbon to spread out the qubits to make them more resistant to corruption.

Caesium, aluminium, niobium titanium nitride and diamond have all been researched as potential materials capable of sustaining particles in a state of superposition. Researchers at the University of South Wales (backed by Telstra) have also successfully constructed a quantum logic gate in silicon opening up the prospect of a silicon based quantum computer.

Over the last 15 years quantum computing research has been motivated by its potential application to cryptography and crypto analysis.

Theoretically, superposition and entanglement together enable quantum computers to perform massively parallel computing. A 30 qubit quantum computer would be equivalent to a conventional computer working at ten teraflops per second (trillions of floating point operations per second). This would allow existing factoring algorithms used in cryptography, for example RSA encryption, to be easily de encrypted. Inevitably much work is now ongoing on new cryptosystems that are secure from quantum computers. This is described as post quantum cryptography.

The applicability of quantum computing to 5G depends substantively on whether the hardware noise problems can be resolved and on cost and size issues.

But the associated maths is seductive. The ability to support three states rather than two allows quantum computers to run polynomial time algorithms (algorithms based on three or more state inputs).

Mathematical operations such as addition, subtraction, multiplication, and division, as well as computing square roots, powers, and logarithms, can be performed in polynomial time. Algorithms such as the Shor algorithm are efficient because of the efficiency of the quantum Fourier transform.

Present academic research suggests that an efficient quantum Fourier transform may not realise any improvement in the classical Fourier transform but there is clearly scope for further mathematical and algorithmic innovation. Research would appear to be coalescing around a sub set of algorithmic research known as adiabatic quantum computation.

The definition of adiabatic is a process that occurs without loss or gain of heat. Given that heat can be equated directly to noise, this is potentially useful but depends on a combination of hardware and innovation to which there is presently limited visibility.

Progress will also be dependent on different disciplines working together efficiently including physicists, chemists, hardware, software and system engineers and any physical layer applicability is likely to be in base station processing rather than user or IOT or MTC products.

Even in base stations it is worth remembering that mast mounted superconducting filters were promoted as a mechanism for achieving selectivity in larger macro cells but have to date not succeeded in achieving significant market uptake. Partly this is due to maintenance cost considerations in outdoor environments. Quantum computing will only be useful in telecoms if realised in robust low cost hardware capable of working in harsh operational conditions.

**Summary – quantum telecom**

**Quantum computing** promises a step function increase in processing capability.

The present focus is on harnessing this capability for cryptographic applications.

The application of quantum computing in telecoms could potentially deliver a transformative improvement in physical layer processing speed and power efficiency but will require hardware innovation to which there is presently limited visibility. The ability to manage and manipulate sub atomic particles in silicon would seem presently to be one of the most promising opportunities.

There are potentially three key enablers that could realise a 5G physical layer capable of delivering a step function performance improvement over existing and future 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, enhanced interference management (for capacity gain) and improved energy efficiency – see last month's technology topic , **Time for 5G** and next month's topic, a **Second Look at Time.**

**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 (next month's technology topic)..

**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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