Cloud and infrastructure I Worldwide I 2019

Quantum computing state of the art

Part 3: Use cases & business models

SITSI I Market Analysis I InBrief Analysis

PREFACE

"In less than ten years quantum computers will begin to outperform everyday computers, leading to breakthroughs in artificial intelligence, the discovery of new pharmaceuticals and beyond.

The very fast computing power given by quantum computers has the potential to disrupt traditional businesses and challenge our cyber-security. Businesses need to be ready for a quantum future because it's coming."

Jeremy O'Brian, Professorial Research Fellow in Physics and Electrical Engineering at the University of Bristol, and director of its Centre for Quantum Photonics in the UK

Objectives of this three-fold series of reports

Those reports have three main objectives, each one being assigned to a specific report:

- Part 1: explain quantum computing & describe the different quantum technologies
- Part 2: analyze the quantum computing value chain and position the different actors of quantum computing
- Part 3: evaluate quantum computing use cases and business models

Methodology and resources

To create this report, teknowlogy consulted senior IT decision-makers from a number of medium- and large-sized companies and from the public sector around the world, as well as key executives responsible for practices at large or specialist technology providers and key quantum computing researcher. teknowlogy has also used its standard market studies and surveys to enrich the analysis.

TABLE OF CONTENTS

DOCUMENT INFORMATION

Author: Mathieu Poujol (mpoujol@teknowlogy.com)
Co-author: Wolfgang Schwab (wschwab@teknowlogy.com)

Publication date: March 2019
Modification date: n/a

Scope ID: Cloud and Infrastructure I Worldwide I 2019
Portfolio ID: SITSI I Market Analysis I InBrief Analysis
Related reports: Expert View: What is quantum computing and why should I care at this point?; Quantum Computing State of the Art – Parts 1 and 2

MANAGEMENT SUMMARY

Having overviewed and analyzed the technologies (Part 1) and the quantum value chain and its players (Part2), this last part of our Quantum series will focus on quantum use cases and business models.

Quantum computing is still deep in the research and development phase, currently with only 2 commercially available offers (D-wave & IBM), but it remains a very promising technology, mostly due to its expected huge computing capacities and the use cases it promises.

Quantum computing is strongly linked to quantum mathematical properties, so use cases are linked to physics, chemicals, materials, especially around real-time parallel computing for very complex systems simulation. At present, only around a dozen use cases are in proof of concept stage, essentially on the D-Wave technology, which is not believed to be able to reach quantum supremacy.

The next step in quantum computing will generate new use cases that are farther from quantum physics, but the complex systems will remain, in fields such as genomics, new materials, weather forecasting, and optimization of global financial models or new product marketing evolution.

The quantum computing market will enjoy huge growth in the coming years, and the ones who benefit from this will be the participants and the countries that host technology clusters which enable maximum collaboration between state-funded research, start-ups, major companies and venture capital.

QUANTUM COMPUTING USE CASES

Quantum computing is still in its infancy

Quantum computing is at the same level as classical computing was in the 1950s - still very mono-function and not very programmable. In these aspects, quantum computing and supercomputers are close, and this situation should continue in the medium term:

- As for supercomputers, which have an increasingly hybrid architecture (vector, parallel, graphic, etc.), quantum computers will be coupled with classical computing, in particular with the high-performance computers.
- In quantum computing, calculators and their programs are intrinsically linked, so the systems that are envisaged are and will be created in the medium term to perform specific tasks and specific calculations. They will not be generalist, as current classical computers are.
- By their architecture, they are useful for massively parallel calculations such as optimization problems, or molecular problems: chemistry, physics, biology, genetics, etc.
- Their design and the physical operational constraints present major restrictions to use cases: cryogenics (present in almost all types of quantum computing architectures) and the need for extreme isolation do not destine them for everyday use, but rather for shared use around a centralized system (on-premises or cloud), such as mainframes or high-performance computing.

The existing use cases

Quantum computing has just made it out of the labs, and many of its technologies are still in development or even in fundamental research. This explains why there are very few use cases, and why those use cases are essentially proof of concepts.

The following use cases are based on the first quantum computer to be put on the market, the D-Wave 2000Q, produced by the Canadian company D-wave with a catalog price of 15 million CAN$.

Daily movement simulation of 10,000 taxis in a large city based on their GPS positions

Optimize and shorten validation procedures from 8 months to 6 weeks using embedded software

Screening of molecules to identify additional uses of existing molecules and of their combinations

Exoplanet detection from analysis of telescopic observations, as well as optimization and planning problems.

High performance analytics to validate assumptions about the results of the last US presidential election.

Optimization of the operations of a fleet of electrical delivery vehicles.

Other possible uses cases

There are many use cases for quantum computing, especially based around quantum physics, simulations and optimization. The use cases presented below are the current uses cases on which quantum research centers and companies are currently working. Essentially, quantum computing allows faster multidimensional search functions to be created, such as query optimization, advanced mathematics and much better simulations on complex systems. Here is a list of the most common cases by business topic:

Improved automatic learning & artificial intelligence

Quantum computing allows for faster structured prediction. For example: Boltzmann machines, semi-supervised learning, unsupervised learning and deep learning. It also allows for faster calculations that could improve perception, comprehension, awareness of its condition and diagnosis of circuit errors & binary classifiers.

Finance

Finance involves a large number of tasks that are very close to optimization, where quantum computing can allow faster and more complex "Monte Carlo" simulations, in areas such as trading, trajectory optimization, market instability, price optimization and hedging strategies.

Healthcare

Quantum computing could be used to accelerate the sequencing of DNA genes, the optimization of treatment in radiotherapy and better and faster detection of brain tumors, which could be done in seconds instead of hours or weeks. This could mean reduced exposure to X-rays by simulating and optimizing the movement of waves in the human body.

Manufacturing

One of the most promising uses of quantum computing is the simulation and discovery of the properties of new materials and active products (for chemistry and pharmacy), through the simulation of atomic interactions. Projects based around this notion are in progress at Dow Chemicals and at Airbus. Another interesting topic is the modeling, simulation and design of batteries, and other electrical equipment that is needed for green energy and electrical vehicles. Quantum computing could also help to validate the engineering and marketing feasibility of new concepts with complex simulation of marketing issues. In addition, Rayheon is currently experimenting around reverse engineering.

Weather forecasting

Weather forecasting relies heavily on high performance computing for some of the most complex simulation that exists. The computing capabilities, the management of the complexity of the assumptions and the speed of the predictions of the calculations of quantum systems could be significant.

Utilities and energy

Quantum computing simulation capacities could be used to improve oil exploration, and BP has a project ongoing on this topic. Dubai Electricity is experimenting around distribution and optimization of the water and electricity networks.

Transportation

The management and optimization of traffic (road, rail, air, etc.), the operation of vehicle fleets and the management of autonomous vehicles are promising fields where the inherent qualities of Quantum could well express their potential. Several companies are evaluating this around the optimization of filling of airline fleets in near real time and in a global way.

Cyber security

In theory, Cyber security is where quantum computing could cause the biggest disruption as it could be used to break the protection algorithms of the public key infrastructures (PKI). However, it could also be used to protect, by creating a new PKI system with quantum algorithms. The CGHQ (the British ANSSI) and the NSA have acquired a D-Wave machine to explore those issues.

These cases of theoretical use must take into account the economic realities. For example, is it more interesting to have a quantum cerebral scanner that is worth several millions, or several conventional brain scanners that are worth ten times less per unit?. These equations would need to be solved for quantum computing to establish itself as a viable cutting-edge way of doing computing.

Use cases by technologies

Hamiltonian calculators will be used for cases that are close to quantum mechanics and theoretically would solve problems that cannot be solved by classical computing in reasonable time. This is also the case for adiabatic calculators, but they can also have more varied uses as this document describes later in the D-Wave references.

Most use cases involve universal computers, and hybrid solutions (classical computing + quantum computing) will bring the largest number of scientific and business benefits. For example, BASF simulates polymers on a classic HP supercomputer, and then plans to use a hybrid (quantum/classical computing) solution to go further.

THE QUANTUM COMPUTING BUSINESS

Market size

In 2018, this is still a small niche market, and market size evaluations differ a lot because the segmentation of quantum still remains unclear:

- A market for quantum computing and communication technologies that would be around 50 M€ in 2017 globally.
- A market for pure quantum computation that could be a third of this market, considering the projects and the precedence of quantum communication.

All market studies show an explosion of the market in the future, some predicting X 55 in 7 years, but based on the hypothesis that quantum computing solutions are superior to the classical IT and are usable by businesses. Scientists tend to predict a timescale of 10 years for quantum computing to mature…. Anyway, even if it may be largely overestimated, a market of more than 2 billion euros which strongly impacts the rest of the economy is still a very important stake.

This is a critical market for the future - as shown by the involvement of many states - but the expected market volume will certainly be much smaller than the existing quantum market studies are predicting, mostly because many technological issues are still not resolved to date.

The market remains dominated by North America, with the United States and Canada riding the success of D-Wave. Asia is advancing rapidly with the Japanese well positioned throughout the chain, and the Chinese who are investing heavily and intend to take advantage of their strengths in quantum communication. The Chinese have this year surpassed the Americans in the registration of quantum patents. However, patents cover the entire value chain, while North Americans, Japanese and Europeans focus much more on the core quantum computing value chain.

Business model

The first quantum computing offers have been launched on the market only recently, and the business model is still not yet stabilized.

Delivery

The material problems of quantum computation require a specific mode of delivery, starting with a centralized computer architecture.

D-Wave is currently installed directly at its first customers with service support contracts associated with the operation of the machine. This is reminiscent of the delivery model of mainframes in the 70s and 80s. The price tag is 15MUSD.

The centralized cloud mode (which is close to the "office services" on mainframe of the 70s-80s) seems to be the way of the future and is displayed as such in the "road map" of many suppliers. This is to deliver computing capacity from a central and remote data center. The HPC (including Teratec of St-Quentin en Yvelines) and IBM's IA Watson are delivered in this way.

Most of the specialists agree that quantum computing capacities will be delivered as a part of High-Performance Computing (HPC), to complement, expand and extend the reach of those machines.

Resources

The Anglo-Saxon countries face increasing concerns regarding physics skills and are fearing an imminent shortage similar to that affecting cyber security with the advent of quantum computing *(Source: US Department of Education).* Quantum computing specialists remain relatively rare, for both the physical part and the computer part. Universities and research centers have understood this and bought quantum simulators to train the human resources of tomorrow.

In some other countries, such as France, physics research education is doing rather well (*Source: Ministry of Higher Education, Research and Innovation)*, with around 1000 doctors per year, but competition for talent will most certainly gain momentum if quantum computing achieves its theoretical qualities.

Public policies

Public policies are essential, as quantum computing is based on fundamental research with a very long technology readiness level that very few companies want to assume. In most of the countries this role is devoted to the public research labs.

Americans are clearly ahead of the game with already existing quantum computing support programs, powerful, collaborative ecosystems, boosted by a strong clustering culture and very powerful venture capital. The United States is benefiting from its unique computer industry, and Canada's public research is ahead of schedule.

Public investment programs in the US and the EU are currently similar in volume, around one billion euros. The involvement of the private sector makes the difference in the maturity of the sectors.

The Japanese have diversified conglomerates (Fujitsu, NTT, NEC, Toshiba) which are investing heavily in the subject, strong expertise in quantum and HPC, and also a good culture of "clustering": they are well positioned in the race. Chinese investments are accelerating and their focus on the subject is reported to be as important as that of the US. They have made several announcements on their investments in quantum, but they are less focused on quantum computing.

The importance of clustering is a major advantage for the North Americans and the Japanese. The combination of public research and private development is essential.

Europe has strong expertise, a strong pool of public and university research but too few advanced industrial players on the subject, as well as a relatively small number of start-ups, and venture capital that is not dynamic enough. In Europe, Germany, Great Britain and Austria seem to be the best positioned countries on the subject.

Financing

Quantum computing is currently entering its development phase, but remains highly dependent on basic research (technologies, processes, materials, chemistry, physics, etc.). This implies a strong mix of different types of financing:

- Basic research remains very largely state-funded, even though some countries (in particular the Anglo-Saxon countries) have a strong patronage with private foundations, or even very active companies in the field (such as IBM, for example). This part remains closely linked to research laboratories and universities. The aid is detailed in the public funding section.
- Aid from military institutions in China and the United States is substantial.
- R & D is most often funded by large companies and / or start-ups with an association with academic research centers in most cases.
- Most of the start-ups are from university research centers, funded by venture capital, a critical element of success in North America.

The biggest start-ups that build quantum computers, at the core of the quantum computing value chain, need a lot of financing, like D-Wave or Rigetti Computing. These are the most important recipients of fundraising. Investors also recognize that this core value chain is the most important element in quantum computing. It represents approximatively the 2/3 of funding, and as funding is concentrated on few targets, that funding tends to be big, normally well over 10 million and sometimes in excess of 100 million euros. This funding more closely resembles that of hi-tech industries such as healthcare or green techs than IT.

In the future, Cyber security applications such as PQ Solutions or Quintessence Labs will be increasingly interesting for investors due to the potential impacts of quantum computing on cyber security.

Business angels are also important, and they are most often found in the research, academic and start-up ecosystems. As an example, the Institute of Quantum Computing (IQC) was born of a massive personal investment by Mike Lazaridis, founder of BlackBerry, who felt that quantum was an opportunity for him to play a central role in the next technological revolution. Since 2002, Lazaridis has invested more than $ 100 million in IQC to conduct interdisciplinary research and create an ecosystem ready to support early, high-risk, and highly profitable opportunities.

Venture capital remains interested in the sector, but it now seems to be waiting for the first returns on investments. For the first half of 2018, according to the latest data available from Tackxn, venture capitalists started to reduce their (nevertheless huge) investments is quantum computing. It is too early to assess if it is a trend, but it is still a warning signal.

ABOUT TEKNOWLOGY GROUP

teknowlogy Group is the leading independent European research and consulting firm in the fields of digital transformation, software, and IT services. It brings together the expertise of four research and advisory firms, each with a strong history and local presence in the fragmented markets of Europe: Ardour Consulting Group, BARC (Business Application Research Center), CXP and PAC (Pierre Audoin Consultants).

We are a content-based company with strong consulting DNA. We are the preferred partner for European user companies to define IT strategy, govern teams and projects, and de-risk technology choices that drive successful business transformation.

We have a second-to-none understanding of market trends and IT users' expectations. We help software vendors and IT services companies better shape, execute and promote their own strategy in coherence with market needs and in anticipation of tomorrow's expectations.

Capitalizing on more than 40 years of experience, we operate out of seven countries with a network of 150 experts.

For more information, please visit www.teknowlogy.com and follow us on Twitter or LinkedIn.