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QUANTUM COMPUTING
The Fifth Industrial Revolution (5IR)
Are We Ready?

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Abstract: **For decades, the technology is shaping from the first Mechanization and Steam Power to the second IR Mass Production and Assembly Line, evolving to the third IR Automation and Electronics reaching the 21th century fourth IR in Digitalization. So, what is the next big thing? Are we ready for the new technologies that next revolution brings? The future technologies are taking shape, and enterprises are preparing for the Fifth IR "Personalization" were man and machine co-operate the earth. Are we ready for such mass customization and personalization for customers, and putting human's intelligence back in industrial production and robots in front? One particular technology that will help us achieve such revolution balance is Quantum Computing, this technology touch base on many applications like Optimization, Simulation, Sampling, Artificial Intelligence, Advance Machine Learning and more. this paper will explain many aspects of this technology and how governments and enterprises are strategically planning and spending on such technology and its threats.**

Keywords: **Quantum Computing, Qubits, classical computing, supercomputers, Quantum-safe cryptography, cryptographic, computing algorithms.**

I. INTRODUCTION

What we know about computers is about to change with the era of Quantum Computing, for years computing served humanity advance and increase linearly in various areas like; Healthcare, Manufacturing, Chemicals, Mobility and Logistics. This advancement is about to increase exponentially with this new technology. Maybe a question crosses your thoughts, will quantum computing replace current computers, and what is quantum computing to begin with! We will step back and explain what is computing. Today classical computing is a represented logically by either a 0 (off) or a 1 (on) in form of bits, storing information in each bit. For eight decades this classical computing served its purpose of information processing. Now it is time to look for another alternative or maybe side by side to achieve ultimate results. So, going back to the question, what is quantum computing? To simplify the answer, the quantum computing is like a classical computing but with more open logical representation. It has a 0 (off), 1 (on) and both at the same time which referred to as superposition state, the information is stored in form of Qubits, the purpose of such invention is to solve complex problems that today's most powerful classical supercomputers cannot solve. In Figure 1 below, you will see a photo of what Quantum Computing looks like in compare to your known classical computing. Diving deep into technical quantum computing is not part of this paper rather than an informative explanation of this technology and how governments and enterprises are strategically planning and spending time and money on this emerging tech and its threats.

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Fig 1: Rigetti Quantum Computing (image courtesy Rigetti Computing)

II. QUANTUM COMPUTING IS COMING SOONER THEN FORETOLD

Quantum Computing concept began way back in the 80s, as a theoretical physics and a scientific research field, since then experimental labs continued this path until they reached to the first quantum computer (2-qubit) back in 1998 by MIT. From there the Quantum Computing topic increased in interest, new experimental labs established, research papers being published, new startups companies found headquarters in major countries, patents being filed from all over the world, Quantum hubs started forming to drive innovation. In a simpler word, the race has started the moment (2-qubit) were invented. This race is not just for quantum technology providers, public and private sectors in (Chemical, Oil & Gas) (Military infrastructure security) (Healthcare, Pharma & Life Sciences) (Banks and Financial Services) (Manufacturing) and more joined this race by aligning with Quantum Technology providers to run real business use cases and complex computing problems to benefit and surpass their peers. Energy enterprises aligning with Quantum providers to reduce carbon emissions and invent next-generation energy. Healthcare institutes partnering with Quantum providers to discover new drugs, accelerate diagnostics and personalize medicine for patient. Manufacturing enterprises developing inhouse Quantum Chemistry and fluid dynamics structuring using Quantum Computing. The list of examples goes on and on. The reason why quantum technology became so attractive to public and private sectors is because of two motives; supremacy or threat. To clarify in an example, see the below "Time to solve problem" illustration:

Type of scaling	Time to solve problem				
Classical algorithm with exponential runtime	10 secs	2 mins	330 years	3300 years	Age of the universe
Quantum algorithm with polynomial runtime	1 min	2 mins	10 mins	11 mins	~24 mins

Fig 2: Time to solve problem between Quantum Computing and Classical Computing

Quantum Computing has the ability to solve today's impossible complex problems in any field, thus it can be used to protect or attack a system. So, for Supremacy; Energy enterprises achieving carbon footprint reduction or invention on next-generation energy will put them ahead of their peers. Threat; Military defense upgrading their infrastructure will address a potential threat. With such technology, solving complex math computing problems are becoming easier and faster compared to classical computing. So, what are the first steps for adapting this new technology? Here are some essential steps for you to excel in Quantum Computing, first step is to understand the technology and how will it impact your sector in order to identify the right quantum provider to partner with your enterprise, this step includes educating your organization, reporting to senior management on latest changes in Quantum, injecting quantum technology in your business strategic objectives and how will your business benefit from such integration. Step two is to identify potential use cases that classical computing is so poor or unable to deliver valuable results, many opportunities could be invented at this stage, thus it will exponentially change the way you do your business in the future. Step three would be experimental lab stage, where quantum system specialist and your core business specialist join the same team to PoC idea turns into a reality, during this stage you will know quantum system fit or not in your business line. Next step is the real deal where

your business becomes ready for quantum computing, this fourth step includes creating Quantum computing roadmap and putting your strategy into action, here where Quantum hubs become valuable for your research labs and scientists. The last step would be shaping your quantum future and adopting any new changes related to quantum revolution, as you may remember this is an emerging technology and subjected to changes, so in your strategic and development plans, flexibility and revision is important due to technology evolvement, limiting your organization to classical computing or jumping full-fledged for quantum computing are not healthy for your organization, proper strategic execution for this emerging tech is critical for your organization's time and money.

III. QUANTUM COMPUTING THREATS

For years, classical computing encryption algorithm secured the communication between Alice and Bob devices, this is about to change with the quantum threat to computing ecosystem. Alice and Bob are fictional characters representing two machines and their way of communication. To send a private message over the network from Alice to Bob and vice versa, sealing the message with a special stamp or converting the message data to random code using classical computing algorithms, ensures confidentiality and integrity of that message, is now at risk, thus begun another race for Quantum-safe cryptography. Cracking a code require time and computing power that is measured in FLOPS (floating-point operations per second), today's most powerful supercomputing is producing 0.442 exa-FLOPS that has 7,630,848 Cores, researchers calculated with assumption analysis reaching 208 – 420 qubit equals the most powerful supercomputer of today, but it has been reported that a single quantum computer (100 qubit) would be more powerful than all the supercomputers. A Quantum vendor roadmap, promises for 430+ qubit milestone next year, 1000+ qubit milestone by 2023 and 1 million qubits in 2030. Putting today's assumptions into reality. So, is network communication security becoming vulnerable, with the growth of such technology, do we need to wait until this threat becomes definite, or join the race to be Quantum-safe. According to NIST (National Institute of Standards and Technology in USA) a new set of certified strong algorithms and controls are being evaluated and published for Quantum-safe. Public and private sectors are waiting to adopt these new cryptographic standards in their communication security, in the meantime, inventory of applications and infrastructure protocols, algorithm dependencies and cybersecurity tools are being reviewed and evaluated against the NIST cryptographic algorithm drafts. So, each sectors have a business decision to make, either to act and be ready, or wait and see your options in the future.

IV. CONCLUSION

To conclude this emerging technology topic; joining the Quantum Computing race would give an advantage whether in your plan is Supremacy or defend against the threat. Also, it is an opportunity for public or private sector to invest in such field. At this stage, reading, absorbing and learning about the technology is a key success for future business growth plans and avoid flying in fog with your business.

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