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QUANTUM COMPUTING WILL MOVE INTO THE REAL WORLD

Can you imagine massive computing power that can operate one million times faster than any device you have in your office or home? That's the promise of quantum computing. Over 50 years of advances in mathematics, materials science, and computer science have transformed quantum computing from theory to reality.

All computing systems rely on a fundamental ability to store and manipulate information. Modern computers manipulate individual bits, which store information as binary 0 and 1 stateswith equal probability. At the same time,a quantum computer uses a quantum bit, or "qubit" as its computing unit. Qubits can represent 2 to the power of *n* (where *n* is the number of bits) states at the same time.

Quantum computers leverage different physical phenomena — superposition and entanglement— to manipulate information

Superposition refers to a combination of states we would ordinarily describe independently. To make a classical analogy, if you play two musical notes at once, what you will hear is a superposition of the two notes.

Entanglement is a counter-intuitive quantum phenomenon describing behavior we never see in the classical world. Entangled particles behave together as a system in ways that cannot be explained using classical logic.

There are many challenges to quantum computing that are pushing out the availability of quantum computing systems and applications. For example:

1. Keeping larger number of qubits stable for longer periods of time.

We need a lot of qubits to solve meaningful problems, which translates into moving from single-digit qubits on a single chip to tens and potentially hundreds of qubits. Intel has verified package designs and fabrication on 17- and 49-qubit chips. But one needs to have thousands of qubits in order to build meaningful applications. In addition, qubits are very sensitive to temperature and operating conditions in and around the quantum computer, causing their state to change in just a matter of microseconds. As a result, qubits need to be super cooled to remain stable and operate.

2. Interconnecting quantum computers.

Currently, there is no “quantum network” for connecting quantum computers outside of research labs. A lot of qubits will be required to implement error correction codes for long distances across quantum computers.

3. Creating design of quantum computing algorithms.

A quantum computer can simultaneously be in many states at the same time, one has to fundamentally design algorithms in a new way to take advantage of quantum computers. In simple terms, one can think of designing massively parallel algorithms using this new computing model.

The practical applications of quantum computing are as follows.

Quantum computing is already getting a lot of attention from the private and public sectors in some key markets:

1. **Security:** When it comes to security, quantum computing can be a double-edged sword. On the positive side, it can help create systems that are fortified against quantum cyberattacks. For example, an enterprise could deploy quantum cryptographic key distribution to protect its customer data. But it can also potentially help bad actors crack vulnerable security and encryption systems.

2. Healthcare: In the areas of medicine and drug development, healthcare and pharmaceutical companies could use quantum computing to model complex molecular interactions, such as simulating chains of chemical reactions to create new ways to cure cancer.

3. Energy: Increased data analysis can help companies better optimize oil and gas extraction processes and improve real-time monitoring of their equipment to reduce accidents.

4. Aerospace: Commercial aerospace and defense industries can develop more efficient aircraft navigation patterns by calculating multiple simulations based on various traffic scenarios and weather conditions.

IBM established a landmark in computing in November 2017, announcing a quantum computer that handles 50 qubits.

As silicon transistors have reached the limits of what they can handle, technology must adapt. **Intel** combines silicon with existing technologies to produce the world's smallest quantum chips. Taking these so-called "spin qubit" chips to market will require further research.

Google has also been working together with NASA and the Universities Space Research Association (USRA) to operate D-Wave system processor.

Due to these complex issues, we are realistically another 7-10 years away from having quantum computing systems and applications that are solving meaningful problems. Initially we will have hybrid computers that will be a combination of classical and quantum computers.