Dell Technologies and IonQ: Delivering Hybrid Quantum/Classical Solutions for Today's Key Workloads and Beyond

Sponsored by Dell Technologies and Intel
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EXECUTIVE SUMMARY

Quantum computing (QC) offers the promise of enhanced compute capability far beyond that possible on current classical binary computers for a range of critical applications and workloads. Quantum computers have already demonstrated impressive performance potential in key application areas including artificial intelligence (both machine learning and deep learning), cybersecurity, modeling/simulation, Monte Carlo processes, and optimization.

However, quantum computing is not a replacement for classical computing, nor is it a standalone compute solution. Instead, hybrid quantum/classical computing, where distinct QC systems and classical high performance computers (HPCs) work in concert to address a single programming job, show substantial promise to deliver significant performance capabilities. Such hybrid configurations allow both computer paradigms to be used for their unique, and distinct, performance advantages.

The partnership between Dell Technologies, a leader in developing and supplying some of the most advanced HPC systems in the world, and IonQ, a foremost provider of quantum computing systems, is one of the first commercial collaborations designed specifically to offer a truly integrated hybrid quantum/classical solution targeted for a wide range of hybrid quantum/classical algorithms, applications, and use cases.

The quantum computing sector is moving fast with new QC-related hardware and software developments announced on a near continual basis, complicating any efforts by current or potential QC end users to manage the daunting transition from early QC interest to the establishment of an integrated hybrid quantum/classical computing capability. Faced with such uncertainty in the sector, aspiring hybrid quantum/classical computing users can benefit significantly from partnerships such as the one that Dell Technologies is undertaking with IonQ to:

- Facilitate a quantum/classic solution that can be readily integrated within an existing HPC or enterprise facility without requiring the skills of an in-house or third-party quantum computing staff, a major concern of many current and potential quantum computing end users.
- Customize a vertical-specific solution for almost every academic, commercial, or government end user by drawing on Dell's global reach and experience with a wide range of advanced computing end user sites.
- Provide a more targeted hybrid quantum/classical offering based on Dell's long-standing classical computing expertise working in concert with IonQ designers and product developers, an option not generally available to counterpart QC suppliers that have yet to link up with commercial HPC suppliers.

QUANTUM COMPUTING: A GAME CHANGING NASCENT TECHNOLOGY

Users of high performance computers (HPC) have benefitted from the decades-long trend toward regular and notable increases in HPC performance to address their most complex computational requirements spanning traditional modeling and simulation jobs, big data analysis, and most recently, advanced AI problems including both machine learning and deep learning. However, continued performance gains in the sector are not assured due to the growing limitations levied by rising HPC system cost, more stringent requirements for chip and system level power and cooling, growing complexities in semiconductor logic and memory design and production, as well as increasingly complex HPC architectures necessary to manage a growing range of diverse of workloads. To that end, both HPC suppliers and end users are actively exploring new technologies to help them meet current and projected computational requirements, with many centered on the promising, albeit nascent, field of quantum computing.

Quantum computing, which leverages specific properties described by quantum mechanics to perform mathematical computations, has been a technology of increasing interest of late, offering the promise of enhanced compute capability far beyond that possible on the classical binary computers that form the basis of almost all major computing systems in existence today. The potential performance gains of any single job running on a quantum computer are evolving and a major source of research, discussion, and some conflict within the sector. Issues of algorithmic design, architectural specifications of a particular quantum system and, indeed, the composition, number, and topology of individual gates in a quantum processor all affect the overall performance of a QC system on any given application and have yet to be fully determined.

The ultimate QC system is envisioned to be capable of demonstrating quantum supremacy: delivering results in a timely manner that would otherwise take millions if not billions of years on a classical counterpart. A more attainable goal in the short term is quantum advantage: a clear demonstration of a quantum computer outperforming a classical counterpart on a real-world application.

- Progress in QC development has accelerated in the past few years, and the wide and increasing commercial availability and use of early stage quantum systems are already hinting at the full potential of these systems.
- Many QC experts believe that such a demonstration of quantum advantage could take place within the next two to three years.

THE PROMISE OF HYBRID QUANTUM/CLASSICAL COMPUTERS

Quantum computers have already demonstrated impressive performance potential in key application areas that include artificial intelligence (both machine learning and deep learning), cybersecurity, modeling/simulation optimization, and Monte Carlo processes. Recent surveys conducted by Hyperion Research reveal that almost every major advanced computing user base, spanning the academic, commercial, and government sectors, are interested in pursuing QC as an option to address some of their most vexing current classical computational problems as well as to explore new compute capabilities unique to the quantum computing realm.

- Some of the early explorers of QC potential include those in the advanced manufacturing, biosciences, energy, finance, telecommunication, and transportation sectors, particularly those

that are already long-time HPC users facing limits on their ability to meet the computational requirements of their existing workloads.

- As the technology to build and program increasingly capable QC systems progresses, a growing base of existing and new HPC users along with select enterprise IT users will bring new computation problems to the space, driving the creation of innovative quantum computing algorithms and applications that can address those challenges.

Despite its potential for addressing critical advanced computing workloads, quantum computing is not a replacement for classical computing nor is it a standalone compute solution. Instead, quantum computing systems serve as a key accelerator for HPCs. Indeed, quantum systems will likely work best when operating in a hybrid computing environment, where both quantum computers and classical counterparts work in concert, each bringing their unique and complementary performance capabilities to bear on the most ambitious advanced computing workloads.

Hybrid quantum/classical computing can, in reality, take on different forms. At the most basic level, any quantum system can be considered a hybrid quantum/classical system. Quantum computers rely heavily on classical systems to help prepare classically composed programs and data for quantum processing, oversee the technical operation of the quantum system, manage I/O and storage between the quantum computer and external devices, manage organizational tasking with counterpart classical computer processors and related accelerators, and regulate the overall job flow into and out of the quantum computer.

As a result, requirements for classical technology to support quantum computing development present significant opportunities for classical semiconductor part suppliers. For example, Intel, one of the world's largest semiconductor makers, offers its Horse Ridge II cryogenic quantum control chip that can support gains in quantum computing scalability due to its high integration potential with select quantum processors. In addition, Intel has developed a special-purpose high-volume chip testing device that can operate at near absolute zero temperatures, speeding the commercialization potential of select quantum computing systems.

- Classical computers are also required to support a range of quantum computing-related software functions including software development kits, compilers, debuggers, and optimizers, all critical elements of an overall efficient quantum computing stack necessary to extract the full performance potential of the quantum system.

However, for many advanced hybrid quantum/classical developers, hybrid quantum computing takes on a much more comprehensive and potentially rewarding perspective. Here, distinct quantum and classical systems are tied together to support a programming paradigm that enables a back and forth iterative process within a single job. The two computational paradigms work in concert to address a single programming task. Moreover, in most cases, to achieve the best overall performance of the hybrid quantum/classical system, the classical side needs to have HPC-class performance capabilities.

- One such example of an iterative quantum/classical algorithm is the Variational Quantum Eigensolver (VQE), a flagship algorithm for quantum chemistry used to find the optimal stable configuration of a complex molecule under consideration.
- The VQE cycles between the classical system for traditional computational processes to drive towards the best solution while using the quantum system to calculate the overall energy state of each classically suggested solution.

DELL AND IONQ: HARNESSING THE POTENTIAL OF HYBRID QUANTUM/CLASSICAL SYSTEMS

The partnership between Dell Technologies, a leader in developing and supplying some of the most advanced HPC systems in the world, with IonQ, a foremost provider of quantum computing systems, is one of the first commercial cooperative efforts to offer a truly integrated hybrid quantum/classical solution that promises significant performance potential on a wide range of hybrid quantum/classical algorithms, applications, and use cases.

Dell Technologies

Dell Technologies, as a world leader supplying advanced computing solutions to both the HPC and enterprise IT space, is in a strong position to help end users identify and integrate quantum computing solutions into their existing classical computational ecosystem, a task that requires considerable technical expertise in both classical and quantum computing.

- Dell Technologies offers a wide range of HPC options that can be configured to match a range of hybrid quantum/classical configuration requirements.

Dell Technologies has long and successful experience in placing leading-edge server systems across a wide range of industry verticals, each with unique and often diverse computational requirements. Building on that experience in the classical world, Dell Technologies is well positioned to customize a classical/quantum solution far more effectively than most standalone quantum computing firms that currently lack the experience and reach to address the specific but diverse use cases amenable to hybrid quantum/classical solutions.

- Likewise, counterpart classical server makers not up to speed on the most advanced developments in the quantum computing space will not be well suited to navigate the complexities of configuring, standing up, and supporting a hybrid classical/quantum system. Closing that knowledge gap will become only more difficult over time.

IonQ

IonQ, as a foremost developer of quantum computing technology, will be a strong partner for Dell Technologies, founded on more than 25 years of pioneering academic research. IonQ develops its own quantum computers based on trapped ion technology that can be operated at room temperature, and the company promises an impressive road map for future technology gains to better address use cases including chemistry, machine learning, materials, and optimization processes.

- IonQ supports most major quantum languages and SDKs including Qiskit, Cirq, and Pennylane. Additionally, IonQ has already established partner and customer relationships with Accenture, Airbus and Goldman Sachs.

IonQ supports a wide range of cloud-based options through cloud services available from Amazon Braket, Azure Quantum, and Google Cloud as an effective way to lower the barriers to entry for potential quantum computing end users and to provide a consumption-based pricing scheme for more committed longer-term users.

- Although it is unclear exactly when IonQ will begin to market an on-premises version of its quantum system, end users could soon have the choice of using running hybrid quantum/classical code either in the cloud, on-premises, or some mix of the two as Dell Technologies also provides capabilities for both on-premises and cloud access.

THE ROAD TO BECOMING A QUANTUM COMPUTING ADOPTER

Recent Hyperion Research studies indicate that there is widespread interest within the advanced computing user base to explore the potential of quantum computing as a solution to their most vexing current workloads and to access new computer capabilities engendered by quantum computing. At the corporate level, the advantages of quantum computing are seen as improving research capabilities and increasing revenue as well as driving innovation, achieving competitive advantage, and enhancing business process efficiencies. Likewise, of the nineteen commercial verticals contacted to assess general interest in quantum computing, spanning advanced manufacturing, aerospace, chemical, defense, healthcare, insurance and pharmaceuticals, and telecommunication, each had a sizable number of organizations already involved in some level of QC activity.

- On-going efforts that were noted spanned entry-level activities such as exploring options and monitoring technology development all the way to the use of QC technology for one or more business processes.
- Similar interest from both the academic and government sectors are evident.

Despite the promise of quantum computing, there are vexing roadblocks on the horizon for aspiring quantum computing end users. Chief hurdles include the high commitment of existing classical budget/IT resources that could complicate quantum computing funding efforts, the complexity of integrating quantum computing technology into an existing IT infrastructure, and the lack of in-house QC-related expertise and domain knowledge.

- In addition, some potential quantum computing end users are concerned with the current shifting state of the quantum computing sector writ large composed of a wide range of aspiring quantum hardware and software vendors, many with unproven track records, a profusion of diverse, novel, and untested quantum systems designs, a lack of demonstrated return on quantum computing investment, and perhaps most important, a shortage of clearly demonstrated performance gains on key applications in the near term.

TURNING TO THE DELL TECHNOLOGIES/IONQ PARTNERSHIP

Despite these concerns, the necessity for almost every advanced computing site user to at least begin exploring the potential advantages of quantum computing is here today. The quantum computing sector is moving fast and the potentially daunting process of transitioning from early exploration to establishing an integrated hybrid quantum/classical computing capability will take time. Well considered hybrid quantum/classical computing plans should include examining current and planned computation needs to expose the key workloads that can benefit from quantum capability, quantifying the potential benefits of a hybrid quantum/classical capability from both a technical and ROI perspective, selecting the mix of appropriate quantum and classical vendors, and identifying the most effective systems configurations, software suites and enterprise-wide ecosystem integration requirements.

- Despite these challenges, early adopters of the technology already recognize that an initial lead in the use of hybrid quantum/classical technology could make it be difficult for later adopters to readily close any computational capability gap.

Faced with such uncertainty in the sector, aspiring hybrid quantum/classical computing users can benefit significantly from partnerships such as the one that Dell Technologies is undertaking with IonQ to help address many of these of these issues, or at least offer some key insights on how best to navigate this complex process in the near-term.

Specifically, the Dell Technologies/IonQ partnership can:

- Facilitate a quantum/classical solution that can be readily integrated into an existing HPC or enterprise facility without requiring the skills of an in-house or third-party quantum computing staff, a major concern of many current and potential quantum computing end users.
- Customize a vertical-specific solution for almost every academic, commercial or government end user site by drawing on Dell's global reach and experience with a wide range of advanced computing end user sites.
- Provide a more targeted hybrid quantum/classical offering based on Dell's long-standing classical computing expertise working in concert with IonQ designers and product developers, an option not generally available to counterpart QC suppliers that have yet to link with commercial HPC suppliers.

Ultimately, Dell Technologies' presence as a trusted source of advanced computing technology with the help of IonQ, a leading-edge QC supplier, can significantly mitigate some of the risk -- and confusion -- surrounding the rapidly evolving quantum computing sector today, easing the burden for end users looking to incorporate hybrid quantum/classical solutions into their classical advanced computing ecosystem.

About Hyperion Research, LLC

Hyperion Research provides data-driven research, analysis and recommendations for technologies, applications, and markets in high performance computing and emerging technology areas to help organizations worldwide make effective decisions and seize growth opportunities. Research includes market sizing and forecasting, share tracking, segmentation, technology, and related trend analysis, and both user and vendor analysis for multi-user technical server technology used for HPC and HPDA (high performance data analysis). Hyperion Research provides thought leadership and practical guidance for users, vendors, and other members of the HPC community by focusing on key market and technology trends across government, industry, commerce, and academia.

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