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Advancements in High Speed, In-Memory Systems

A New Approach to Mission Critical In-Memory Systems with Persistent Memory

White Paper

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Overview

For leading retailers, financial services providers, and IoT innovators, in-memory technologies long ago moved from the R&D lab to the frontline, customer-facing environments as critical business drivers. In-memory data grids and stream processing engines are the backbone to mission-critical applications such as e-commerce websites, payment processing infrastructure, and fraud detection systems.

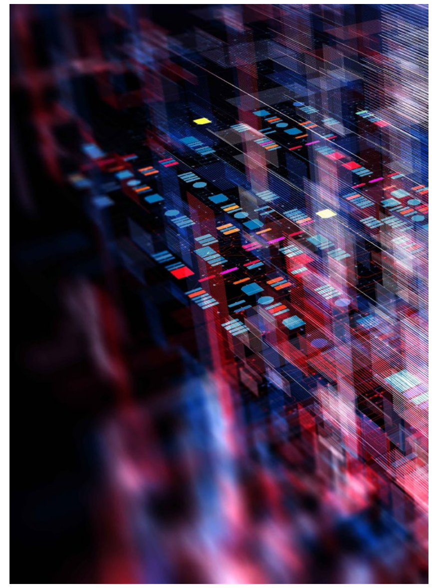
In-memory data grids reside entirely in random access memory (RAM), enabling developers to dramatically accelerate applications by placing all relevant data in memory rather than relying on access to slower disk-based databases. Stream processing engines collect data as it is generated, process that data, and deliver the result of any aggregations, calculations, or other processes, all in real time.

Considering the always-on, immediate-gratification demands of modern customers, it's clear why fast technologies are so important. And thus, these in-memory data grids and stream processing engines have become the bedrock for the applications that drive today's global economy.

Who uses these systems? As mentioned earlier, the top retailers address their customers' demands with high-performance, in-memory systems. But customer demands are not their only concern, as the massive volume creates an additional challenge. U.S. retail e-commerce sales were $146.2 billion in the second quarter of 2019.[1] That's $18,544 a second, or more than $1.1 million an hour. Zoom out to a worldwide view, and the global e-commerce market is projected at $4.9 trillion by 2021, with the B2B e-commerce market nearly four times as large.[2] Some of the biggest retailers contribute a significant portion to these collective numbers, so they depend on systems that can handle extreme loads.

Bank and card provider processing infrastructure and fraud detection solutions (which also serve the much larger traditional retail market) are also ideally suited to the capabilities delivered by in-memory data grids and stream processing technology. Major card providers are processing nearly 2000 transactions per second (over 150 million per day)—this level of volume is being enabled by in-memory solutions, as traditional disk based systems cannot operate at this speed.

1 https://www.census.gov/retail/mrts/www/data/pdf/ec_current.pdf
2 https://www.shopify.com/enterprise/global-ecommerce-statistics



With high customer expectations around speed, and the massive volume of transactions, minimizing downtime becomes especially critical. Even a few seconds of downtime can be impactful. This can mean a customer can walk away from an in-person purchase, or worse, a burst of thousands or millions of online orders get denied. So reducing downtime as much as possible has become a much more valuable strategy than ever.

The stakes are continually rising, and fortunately new technologies continue to emerge to meet the demand. While leading in-memory data grids and stream processing engines have been widely adopted in recent years, new opportunities are still being uncovered. A new breed of adjacent technology is entering the market with the ability to accelerate the processing paradigm even further.

A new class of memory hardware is opening doors for many organizations that previously chose to trade-off high performance (and thus competitive advantage) for the lower costs of SSDs. This new persistent memory technology costs less than RAM while providing much more storage capacity, and offers a significant speed boost over SSDs, creating the opportunity to move a variety of workloads into memory. It provides the combination of large capacity, fast operating speed, and lower costs compared to RAM.

This new memory technology has also been proven to accelerate the recovery time of in-memory systems by as much as two thirds, effectively reducing downtime (either unexpected or scheduled) from minutes to seconds on systems that are now measured in terabytes. In a recent test, researchers compared the new persistent memory technology against a traditional solid-state drive (SSD) as the dual in-line memory module (DIMM) motherboard connection for a leading in-memory data grid. Recovery times were markedly faster for the persistent memory configuration (more information is included later in this paper). As researchers added parallel threads, the recovery time of the in-memory data grid with the persistent memory technology continued to decrease. For the SSD configuration, additional parallelism initially reduced the recovery time, but, unintuitively, the recovery time began to increase as researchers added even more parallel threads.

In a world where seconds of downtime equates to millions of dollars lost, the new persistent memory technology shows incredible promise for helping IT organizations meet strict SLAs and increase revenues by dramatically improving the uptime of in-memory data grids and stream processing engines at a fraction of the cost.

Use Cases for In-Memory Systems

In this section, we will begin by exploring some examples of in-memory data grids and stream processing engines. Then we will discuss the verticals that deploy these systems and the applications that they power. Finally, we will calculate the value of those applications—and the corollary, the cost of downtime—for the businesses that leverage these technologies.

The Need for Speed

Historically, in-memory computing was primarily the domain of specialists and researchers. Though business teams and IT organizations have always valued application performance, they found that the cost of memory prohibited them from making the technology core to almost all projects. Because memory was so expensive, it was only used for small or very high-value data sets.

But as we entered the age of big data, organizations realized that rapidly accessible memory would be key to processing the onslaught of streaming event data from websites, mobile applications, sensors, medical devices, and more. Developers turned to a new breed of in-memory technologies to enable them to keep up with the demands of their customers as well as the speed at which new data sources were generating data. In-memory data grids (IMDGs) such as Hazelcast IMDG and stream processing engines such as Hazelcast Jet became key components for many applications. IMDGs store data entirely in RAM, enabling developers to dramatically accelerate their applications by leveraging the low latency access of RAM rather than relying on slower disk-based systems. Stream processing engines collect data as it is generated, process that data—often in multiple ways—and deliver the results, all in real time.

With IMDGs and stream processing engines, organizations greatly increased their ability to handle both the speed and value of data for applications such as e-commerce websites, payment processing, fraud detection, and IoT data collection and analysis.

Almost all modern applications require fast performance and the ability to scale as real-time data volumes grow, making IMDGs and stream processing engines fundamental for a nearly limitless list of use cases.

The Impact of Downtime

We are all well aware of another trade-off when relying on data in volatile RAM. When an in-memory system shuts down—whether a server crashes or engineers are deploying new code, for example—all the data is lost and must be restored from a source system such as a disk-based database. As organizations and their customers have grown to depend on applications built on IMDGs and stream processing engines, the value of application uptime coupled with intolerance for downtime has dramatically increased.

For example, one of the busiest online stores in the United States (a Hazelcast customer) expect hundreds of millions of people to visit their website on the day they announce key new products. That's a rate of millions of people per hour, or thousands of new visitors per second. Hazelcast IMDG powers the inventory management behind their e-commerce application, scaling up for peak retail events and product launches while reducing application latency. The retailer's client-server architecture supports more than 2,000 application server clients to ensure a superior online customer experience. Imagine suffering from downtime during those peak times, or even at any time for their high-volume revenue-generating system. The fact that they rely on high speed means that many transactions are taking place, putting an even higher premium on uptime. They simply can not afford unplanned downtime.

In another example, when a visitor enters his/her credit card information to make a purchase on an e-commerce website, a payment processing system checks the merchant details by forwarding them to the card's issuing bank, and any downtime could cause lost revenue as the customer may use a different card. One such processing system, built on the Hazelcast 4.0 acting as the pipeline, processes tens of thousands of transactions per second every day. Downtime here would quickly add up to hundreds of thousands or even millions of transactions being delayed or not processed at all.

The payment processing system also runs a series of anti-fraud measures. With five terabytes of customer data in Hazelcast, one bank can process 10,000 transactions per second while ensuring millisecond response times, by leveraging data-aware compute with in-memory processing. Their transaction processing rate was previously constrained by their legacy in-database solution. By running the processes in Hazelcast IMDG, the bank was able to identify hundreds of millions of dollars in would-be fraudulent transactions in their first year of using the new solution.

This entire workflow of payment verification and anti-fraud checks occurs in about seven milliseconds (plus allowances for network latency and bandwidth), thanks to Hazelcast. This is the performance that consumers have become accustomed to and now demand. Anything slower, and they could easily move on to a competitor's website.

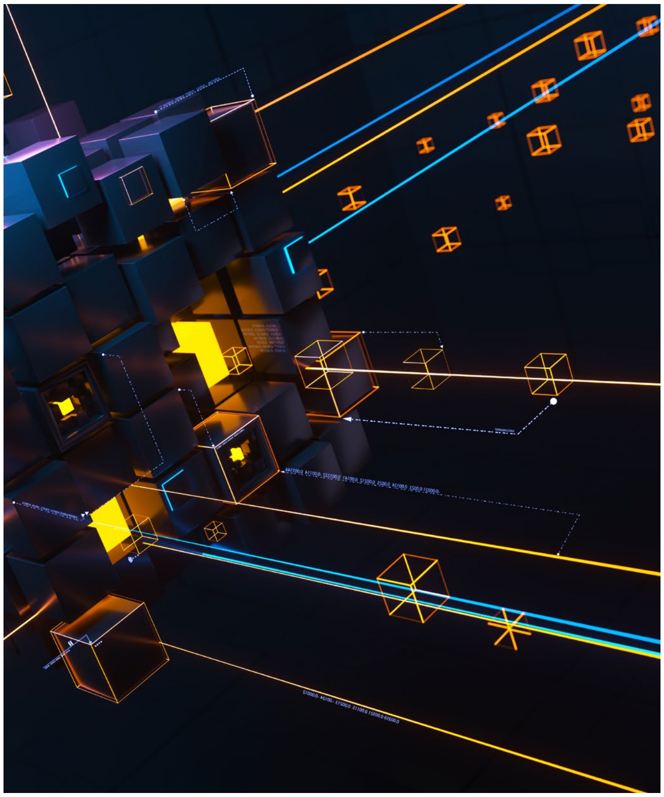
With the customer experience being so critical to every interaction, and the cost of downtime being so great, it's easy to understand the reticence of businesses for unplanned downtime. Even planned downtime—for upgrades, new code deployment, and other expected reasons—should be minimized. To mitigate the potential risk, organizations are regularly increasing the stringency of their service level agreements.

Increasing Uptime for In-Memory

Developers of in-memory systems are constantly working to improve their code bases to avoid bugs and crashes. But memory itself is volatile, so if anything happens, organizations must scramble to restore the data from elsewhere. These sources usually include disk-based systems that are much slower than in-memory solutions.

To overcome such challenges, Hazelcast introduced its Hot Restart Store feature that leverages a persistence store optimized for SSDs to accelerate restarts. Whether the restart is after a planned shutdown or a sudden cluster-wide crash, Hot Restart Store enables a much faster full recovery to the previous state of configuration and cluster data. And while the SSD optimization in Hot Restart Store significantly accelerates restarts, new memory technologies promise to take this capability to the next level, as described in the upcoming sections of this paper.

Introducing Intel® Optane™ DC Persistent Memory



Intel Optane DC Persistent Memory is a new memory technology that combines the performance of RAM with the scalability and persistence of storage at a significantly reduced cost when compared to traditional RAM at similar capacity. Intel offers a large and persistent memory tier at an affordable cost; thus changing the way that hardware and software developers think about memory, and ultimately enhancing data insights by redefining the memory and storage hierarchy.

Intel spent 10 years developing its persistent memory technology. With breakthrough performance levels in memory intensive workloads, virtual machine density, and fast storage capacity, Intel Optane DC Persistent Memory—combined with 2nd Gen Intel® Xeon® Scalable processors—accelerates IT transformation to support the demands of data-driven users and applications.

Intel Optane DC Persistent Memory enables faster-than-ever-before analytics, cloud services, and next-generation communication services—along with increased uptime for mission critical in-memory systems.

By using Intel Optane DC Persistent Memory in a DIMM form factor, organizations can combine features found in both dynamic random access memory (DRAM) and SSD. This moves larger amounts of data closer to the CPU, so the data can be accessed, processed, and analyzed in real time without first being retrieved from storage. Organizations can keep more data closer to the CPU for faster processing, and that data will remain in memory when the system is power cycled.

The Hazelcast In-Memory Computing Platform, Powered by Intel Optane

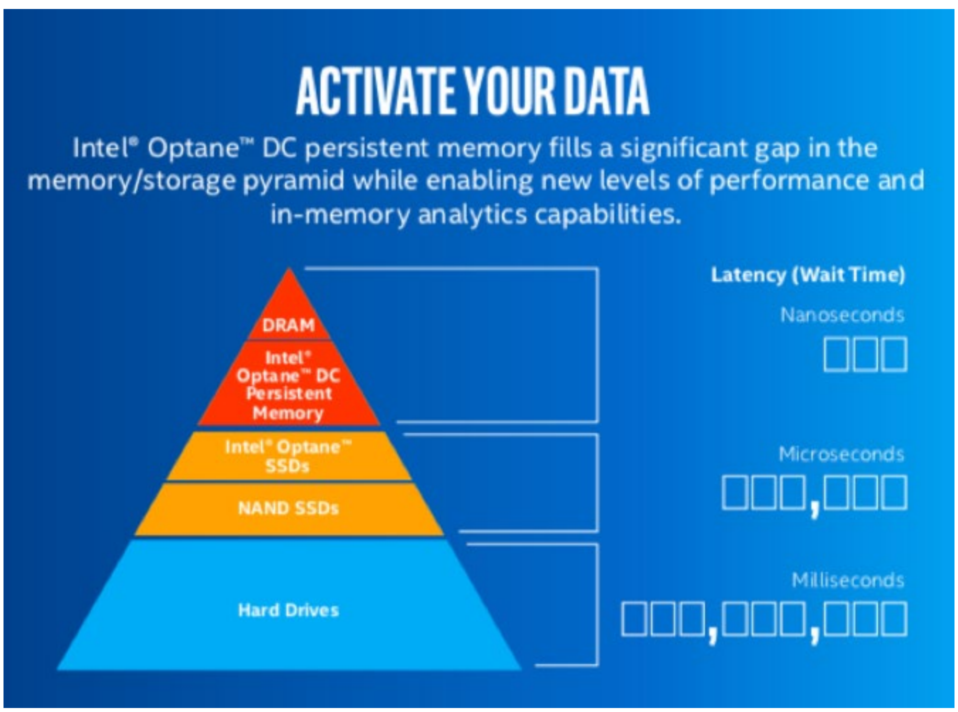
In this section, we will cover the benefits and use cases for the Hazelcast In-Memory Computing Platform powered by Intel Optane DC Persistent Memory.

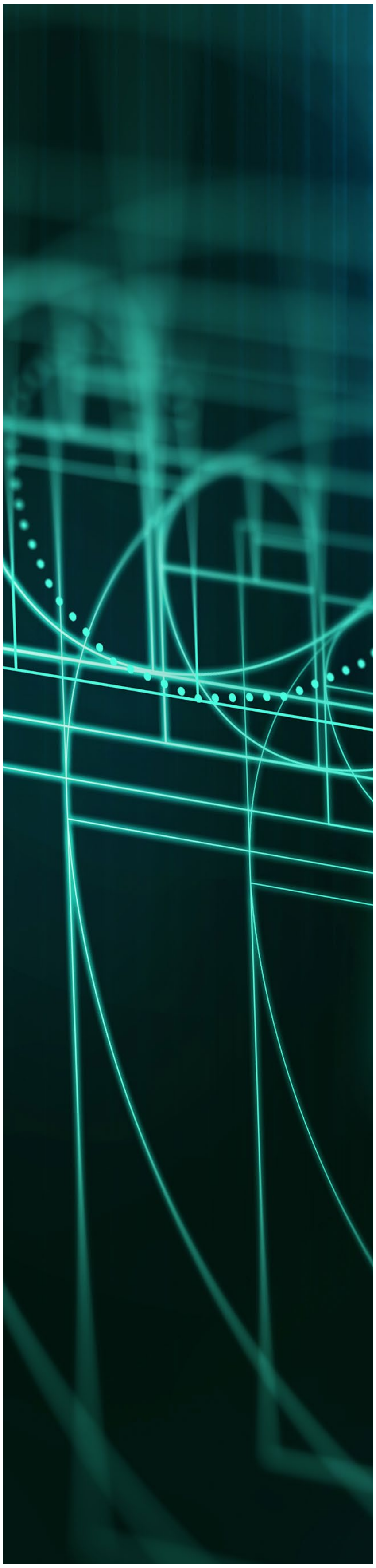
Reduced Costs, Increased Capacity

The value of Hazelcast powered by Intel Optane can be realized by a new range of users that were previously averse to the costs of hardware for in-memory solutions. In an upcoming release, joint customers will have the opportunity to reduce the cost of such a solution while increasing capacity.

Intel Optane DC Persistent Memory modules are typically competitively priced with respect to their traditional RAM counterparts but similarly performant. With the release of Hazelcast In-Memory Computing Platform 4.0, customers will be able to select modules in place of traditional RAM. This in turn will allow them to reduce the cost, or build solutions with much more capacity. At the same time, they can still leverage their RAM-based systems with Hazelcast in the same environment, allowing balanced hybrid deployments of RAM and Intel Optane DC Persistent Memory.

With Hazelcast IMDG Enterprise HD, developers can store more than 100GB of data in-memory on a single node. Because of the capacity of Intel Optane DC Persistent Memory modules, it will become cost-effective for many organizations to load as much as 256GB or 512GB on a single node. This greater data density will create new opportunities to bring in-memory performance to ever greater scale and meet the growth in data that is being driven by today's digital world.





The Performance Test: Increased Uptime

Another way Intel Optane DC Persistent Memory offers benefits to Hazelcast is by providing a persistent storage mechanism for systems that rely on the the ultra-high speeds of traditional RAM. By providing a highly performant non-volatile memory tier, Intel Optane DC Persistent Memory Modules can greatly improve the performance of recovery features such as Hazelcast Hot Restart Store. In a publicized test, Hazelcast integrated in DIMMs to fill the gap between DRAM, which is fast but capacity-constrained and volatile, and SSD, which has more capacity and is non-volatile but slower.

Because Hazelcast solutions are massively scalable, the amount of data held in RAM can be quite large. Typical customer deployments can be as small as tens of gigabytes or as large as multiple terabytes across dozens of machines. On restarts, Hazelcast IMDG pulls data from systems of record such as databases. If a restart is required, without Hot Restart Store a refresh could take days; even re-loading hundreds of gigabytes might take hours depending on the configuration.

Hot Restart Store is a log-structured storage engine that minimizes the time for Hazelcast IMDG to restart. Prior to the launch of Intel Optane DC Persistent Memory, the performance of Hot Restart Store was primarily constrained by the SSD serving as a persistent storage medium.

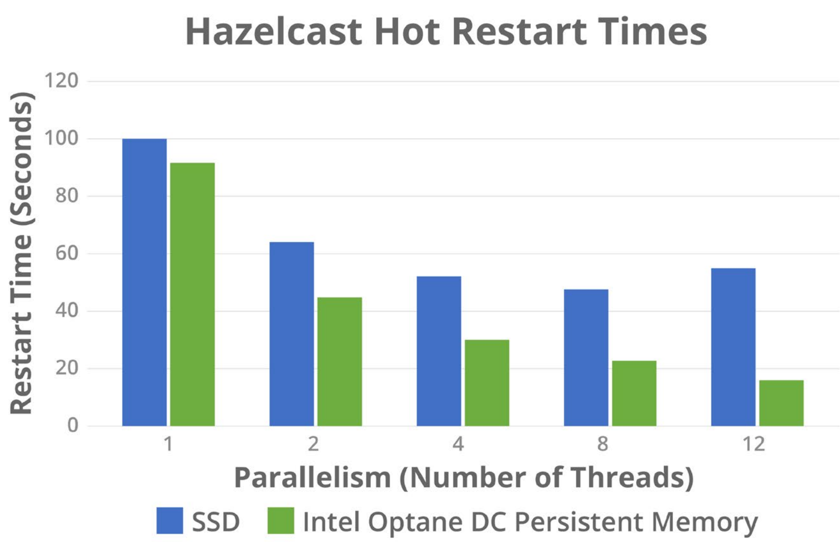
In comparing the SSD configuration of Hot Restart Store with an Intel Optane configuration, a researcher tested the settings on a single node of Hazelcast IMDG to control for any network issues..[3] The hardware is described below:

- **SSD**
  - 2x Intel® Xeon® E5-2687W v3 @ 3.10GHz
  - HP Fusion ioMemory™ 1.0TB HH/HL Light Endurance (LE) PCIe Workload Accelerator
- **Optane DC Persistent Memory**
  - 2x 2nd Generation Intel® Xeon® Scalable processors (56 cores total)
  - 6x Intel® Optane™ DC Persistent Memory (128GB each) connected to a single CPU in App Direct Interleaved mode

3 https://builders.intel.com/datacenter/blog/hazelcast-fast-restart-optane-dc-persistent-memory

The researcher loaded 5.5 million entries with values of 16K bytes each, for a total data size of about 87GB on this single node (in a 1TB cluster of 12 nodes). The researcher then shut down the instance and recorded the time it took to reload the data into memory, each time increasing the parallelism property. They recorded the measurement four times at each parallelism configuration and then logged the average restart time for each.

Results for both the SSD and persistent memory configurations are shown in the chart below.



The restart performance with Intel Optane DC Persistent Memory Technology became faster with every additional parallel thread. At 12 threads, the Intel Optane restore was less than 20 seconds, while the SSD restore was nearly 60 seconds. Because Intel Optane DC Persistent Memory performance scales as thread counts increase, it pairs perfectly with the higher thread and core counts of Intel's next-generation scalable Xeon processors.

Essentially, cut the restart time by two-thirds. When in-memory applications deliver millions of dollars of value every hour, customers demand an immediate response to every interaction; the value of such a dramatic reduction in downtime and the increase in uptime it generates is difficult to overstate.

Conclusion

In-memory technologies are mission critical, powering and accelerating the most valuable applications in modern businesses. With the introduction of persistent memory, and its ability to deliver RAM-like performance at a much lower cost with greater storage capacity, organizations have a significant opportunity to leapfrog competitors by making performance a key tenet of everything they build.

In-memory systems are on the verge of a major evolutionary step. Leaders will be wise to future-proof their in-memory data grids and stream processing engines by leveraging persistent memory to increase both their uptime and capacity. Joint solutions such as the Hazelcast 4.0 powered by Intel Optane have already proven the value of persistent memory, eliminating as much as two-thirds of downtime in test scenarios.

When minutes are worth millions of dollars, businesses can not overlook the potential to save more, do more, and go faster. It's time to not only increase the uptime of in-memory systems, but to rethink the memory and storage hierarchy.

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