Reference Architecture

Redis Enterprise In-Memory Database
Intel Optane Persistent Memory

Deploying Redis Enterprise Database with Intel® Optane™ Persistent Memory

> "Redis Enterprise in combination with Intel Optane persistent memory allows developers to simplify their database deployment and application development by keeping the entire dataset in a single multi-model database."
> – Yiftach Shoolman, Co-founder and CTO, Redis Labs

As an in-memory enterprise database gets larger, the amount of memory required to hold the entire dataset can become cost-prohibitive. A common way of addressing that challenge has been to split the data into multiple working sets, making sure that the most frequently accessed one always remains in system memory. While that arrangement requires accessing cooler data from slower storage, many organizations have been forced to accept the accompanying performance compromise. That tradeoff is becoming less tenable with the growing prevalence of use cases such as real-time analytics that require instant response times for complex transactions, using multiple data models such as key-value, JSON, time-series, graph, tensor, and others.

This new generation of applications requires the entire dataset to be available in memory, with typical baseline expectations of delivering 99th percentile (P99) latency under one millisecond (ms). Intel® Optane™ persistent memory is a breakthrough technology that packages Intel Optane media in a dual in-line memory module (DIMM) form factor. This innovation makes it affordable to configure servers with larger memory capacities than was previously feasible, so that systems can hold larger datasets closer to the processor. With latency that is similar to that of dynamic random-access memory (DRAM), Intel Optane persistent memory enables businesses to extract more value from data.

Intel Optane persistent memory empowers Redis users to achieve faster time to insights by enabling terabytes of memory per node while meeting sub-millisecond SLAs and simplifying and optimizing their hardware infrastructure investment. This reference architecture provides guidance and baseline performance examples for deployments of Redis Enterprise database with Intel Optane persistent memory.

1. Hardware and Software Building Blocks

Redis Labs has worked closely with Intel to optimize the Redis Enterprise database for Intel architecture. Optimization for 2nd Gen Intel Xeon® Scalable processors enables customers to match their implementation to the specific performance requirements of a given deployment. Enablement for Intel Optane persistent memory enables customers to cost-effectively deploy massive system memory, supporting full datasets instead of dividing them into multiple working sets. As a result, enterprises can achieve the high throughput and low latency needed to deliver compelling user experiences from real-time, data-driven applications.

Selection of hardware for Redis Enterprise implementations reflects both dataset size and performance requirements, as shown in Figure 1, with performance including both throughput and latency requirements. Workload type (heavy write versus heavy read versus random read/write) is another key consideration. Intel Optane persistent memory enables scale-out memory at lower cost per GB than DRAM.[1]

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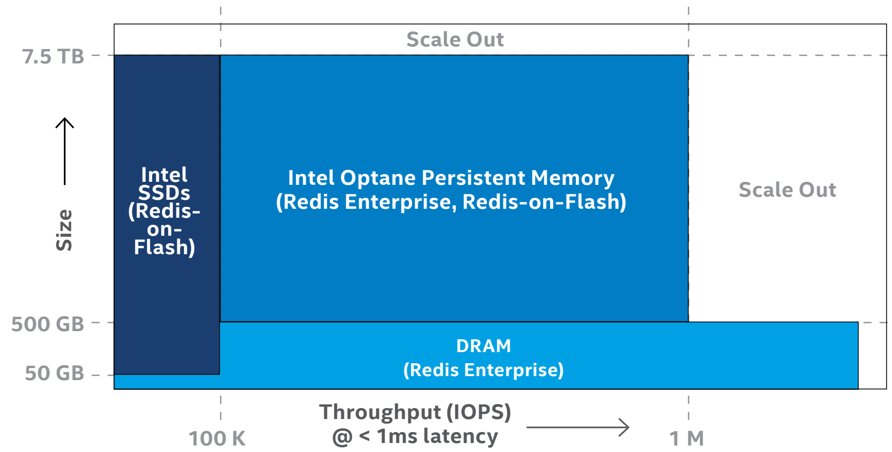

Figure 1. Memory/storage selection for large data sets in Redis.

Note: Redis provides hardware recommendations for database deployments at **https://docs.redislabs.com/latest/rs/administering/designing-production/hardware-requirements/**.

1.1. Redis Enterprise

Redis Enterprise, the enterprise version of the popular Open Source Redis, is an in-memory database platform that is used by thousands of organizations worldwide as the basis for data-intensive business processes. It scales to multi-terabyte datasets, delivers hundreds of millions of operations per second with sub-millisecond latencies, and provides 99.999 percent availability when used as a fully managed cloud service.

Redis Enterprise extends the core data structures of Redis with modules such as RedisJSON, RedisGraph, RedisTimeSeries, RedisAI, and others. It also supports multiple, flexible deployment options and topologies including cloud, multi-cloud, on-premises, and hybrid using its Active-Active Geo-Distributed technology, which is based on conflict-free replicated data types (CRDT). This technology allows for multiple distributed replicas to be updated independently, without inconsistencies among replicas ever creating irresolvable conflicts.

In real-world implementations, Redis Labs found that many of its customers were splitting their datasets across multiple data services to reduce infrastructure costs, keeping only the most time-critical data in Redis. In addition to the performance limitations that this approach typically creates, it also adds a significant layer of complexity, making the environment more challenging to manage and maintain. In particular, developers must deal with multiple database engines and/or services when deploying applications.

With the combination of the Redis Enterprise database and Intel Optane persistent memory, customers now have a cost-effective approach to reunifying datasets, eliminating the performance impacts and complex architectures associated with splitting them out over multiple services. This solution stack offers throughput that rivals Redis database running on DRAM, but with cost and ROI advantages.

1.2. 2nd Gen Intel Xeon Scalable Processors

The Intel Xeon Platinum processor 8200 Series is built for demanding and mission-critical workloads with up to 28 cores per socket and operating at frequencies up to 4.0 GHz, with support for up to eight sockets per system. The Intel Xeon Gold processor 5200 Series offers workload-optimized performance and advanced reliability with up to 18 cores per socket and operating at up to 3.9 GHz, for up to four-socket systems. All 2nd Gen Intel Xeon Scalable processors offer foundational enhancements over their predecessors that include the following:

- **Per-core performance improvements** that deliver high throughput and scalability for compute-intensive enterprise database workloads.
- **Enhanced memory subsystem** with six memory channels compared to four in predecessor platforms, plus support for Intel Optane persistent memory, for a total of up to 36 TB system memory.
- **Expanded I/O with 48 lanes of PCIe 3.0** for the bandwidth and throughput to handle the data-transfer demands of I/O-intensive workloads.

1.3. Intel Optane Persistent Memory

Intel Optane persistent memory redefines the memory tier, with Intel Optane media packaged in a form factor similar to conventional memory modules, but at much larger capacities within common cost constraints. It is designed to provide performance similar to that of DRAM at lower cost per GB,[1] provided as 128 GB, 256 GB, and 512 GB modules that are socket-compatible with DRAM. The larger capacity allows architects to regard memory as the main data tier, eliminating I/O bottlenecks associated with conventional combinations of discrete storage and memory. Intel Optane persistent memory has distinct operating modes that place varying optimization requirements on software.[2]

Redis Enterprise operates with Intel Optane persistent memory in Memory Mode, which enables customers to benefit from expanded system memory by simply plugging Intel Optane persistent memory modules into slots on the system board and setting the resource to operate in Memory Mode. This mode does not take advantage of memory persistence, with the Intel Optane persistent memory behaving like volatile memory. Therefore, data is not retained during power cycles.

Database nodes that are equipped with Intel Optane persistent memory are also provisioned with a smaller amount of conventional DRAM (a ratio of 8:1 was used in this testing), as illustrated in Figure 2. Because the DRAM has slightly lower latency than the Intel Optane persistent memory, it can be effectively used as a cache to accelerate the memory subsystem as a whole.

The 2nd Gen Intel Xeon Scalable processor memory controller manages both DRAM as a near-memory performance tier for the hottest data and Intel Optane persistent memory as a far-memory capacity tier for the bulk of the operating dataset. Generally, the memory controller looks in the DRAM-based cache (near memory) first for a piece of data. If the required data is present in the cache, then the processor benefits from low-latency access to it. In the event of a cache miss (that is, when the data is not available in the cache), a fetch is triggered from the larger Intel Optane persistent memory tier (far memory).

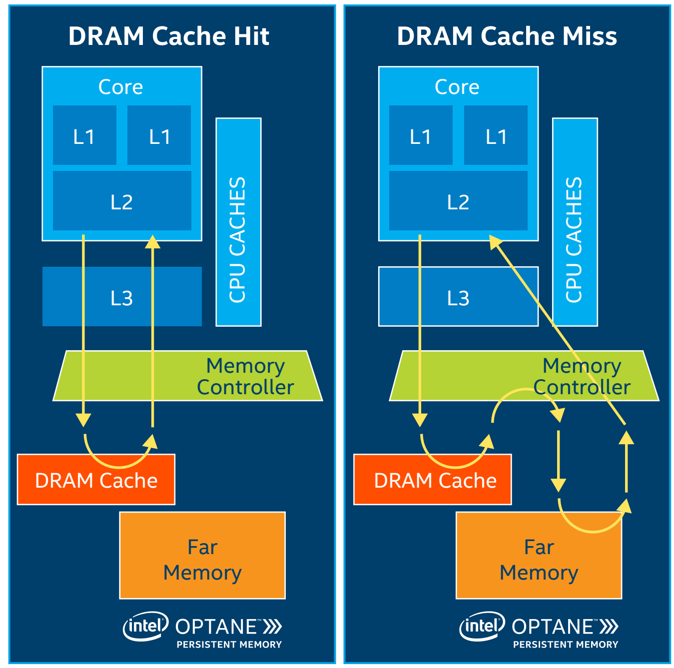

Figure 2. Intel Optane persistent memory interoperating with conventional DRAM.

Software interacts with Intel Optane persistent memory in Memory Mode just as if it were DRAM, meaning that no code optimizations or other application changes are required. Therefore, Memory Mode offers a rapid path to adoption of Intel Optane persistent memory for existing applications based on Redis Enterprise. Customers can cost-effectively provision servers with terabyte-scale system memory.

Developer Edge with Persistent Memory

Intel Optane persistent memory revolutionizes the performance equation with big, affordable, persistent storage on the memory bus. Use it to achieve lower latency, higher resilience, and more performance for your applications.

The Persistent Memory Development Kit (PMDK) provides libraries meant to make persistent memory programming easier. Software developers only pull in the features they need, keeping their programs lean and fast on persistent memory.

Learn more at **software.intel.com/pmem**.

2. Baseline Use Case Results

The benchmarking reported on here helps customers set a baseline for understanding the potential role of Intel Optane persistent memory in their environments. In addition, we examine a three-node configuration relevant to enterprise use cases such as fraud prevention scenarios with strict high-availability and P99 latency requirements. Three baseline use cases are reported on here:

- **Baseline Use Case 1:** Comparison of DRAM versus Intel Optane Persistent Memory
- **Baseline Use Case 2:** Load Testing Intel Optane Persistent Memory with Redis Enterprise
- **Baseline Use Case 3:** Recovery from One-Node-Down Scenario

2.1. Baseline Use Case 1 – Comparison of DRAM versus Intel Optane Persistent Memory

Use case goal: Demonstrate that Intel Optane persistent memory can be used in place of DRAM while continuing to meet a hypothetical customer service level agreement (SLA) of one million ops/sec at 1 ms average latency. Hardware and software configurations are given in Table 3, later in this document.

Results: Single-node results, shown in Figure 3, demonstrate that both the DRAM server and the server with Intel Optane persistent memory easily exceed the 1 million ops/sec SLA, achieving 2.34 million and 2.13 million ops/sec respectively while maintaining 1 ms or less average response time. The performance of the server with Intel Optane persistent memory is 91 percent of that of the server with DRAM at its peak, with an average latency just three percent higher.

Takeaway: Intel Optane persistent memory enables businesses to achieve sub-millisecond latency and fast application response, using the Redis database across data-driven workloads and use cases, while providing a TCO advantage. By using a single durable database, customers streamline their infrastructures and trim costs.

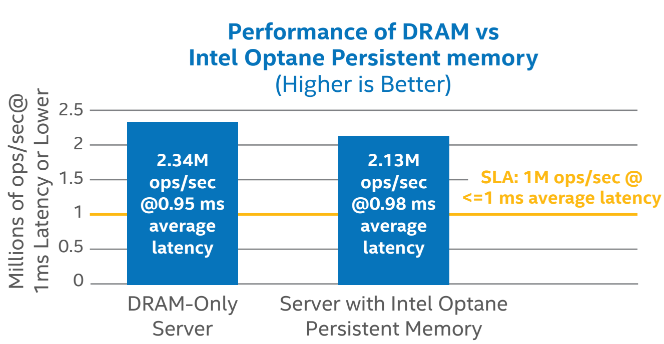

Figure 3. Intel Optane persistent memory maintains SLA in place of DRAM.

Note: Baseline use case 1 focuses on average latency only, while cases 2 and 3 also consider 99th percentile (P99) latency.

2.2. Baseline Use Case 2 – Load Testing Intel Optane Persistent Memory with Redis Enterprise

Use case goal: Benchmark Redis Enterprise with Intel Optane persistent memory, focusing on scalability across multiple nodes, as well as examining the performance with a stricter P99 latency in addition to the average latency reported by Redis Enterprise GUI. Hardware and software configurations are given in Table 4, later in this document.

Results: The cluster under test consists of three nodes, configured for high availability with replication enabled. Testing demonstrates that Redis Enterprise scales well with multiple nodes using Intel Optane persistent memory, reaching 4.52 million ops/sec across three nodes at 1 ms average latency. Using a stricter SLA of P99 at 1 ms, Redis Enterprise can achieve close to 1 million ops/sec across the cluster. At that throughput level, the average observed latency is only 0.06 ms. Summary output statistics for baseline use case 2 are shown in Table 1.

Table 1. Baseline use case 2 – Redis Enterprise scalability on three nodes with Intel Optane persistent memory.

Cluster SLA	Cluster Ops/sec	Average Latency (ms)	P99 Latency (ms)
1 ms average latency	4.52M	0.97	---
P99 latency under 1 ms	943K	0.06	99% < 1ms

In the Redis management UI performance graphs shown in Figure 4, the relatively straight lines for both average latency and throughput indicate a steady-state run, achieving 944 K ops/sec with an average observed latency of 0.06 ms.

Takeaway: Redis Enterprise with Intel Optane persistent memory delivers great performance and scalability at the cluster level.

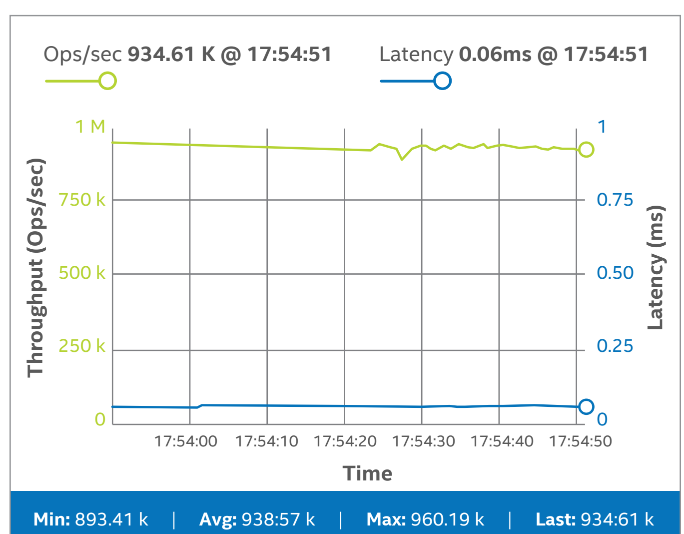

Figure 4. Baseline use case 2 – Throughput (ops/sec) and average latency (ms).

2.3. Baseline Use Case 3 – Recovery from One-Node-Down Scenario

Use case goal: Demonstrate that Redis Enterprise with Intel Optane persistent memory is able to maintain high-level throughput and P99 latency under 1 ms, while recovering from a one-node-down scenario. Hardware and software configurations are given in Table 4, later in this document.

Results: The cluster under test consists of three nodes, configured for high availability. During the benchmarking run, one of the nodes was rebooted. The plotted benchmark output in Figure 5 shows a five-minute period during which just two of the three physical Redis Enterprise nodes are running (the [Node down, Node Up] time interval in Figure 4). When the rebooted node comes back up (labeled as "Node Up / Resync start" in Figure 5), it has lost the contents of its memory and thus it must resync with the cluster and re-populate its shards (about 480 GB of data). The re-synchronization lasts about six minutes (the [Resync start, Resync finish] time interval in Figure 5). Throughout the entire process of the node going down and re-synchronizing, the remaining two nodes continue to serve requests and maintain the P99 latency of 1 ms. Summary output statistics for baseline use case 3 are shown in Table 2.

Table 2. Baseline use case 3 – Memtier output overall statistics.

Cluster SLA	Cluster Ops/sec	Average Latency (ms)	P99 Latency (ms)
P99 latency under 1 ms	851K	0.31	99% < 1ms

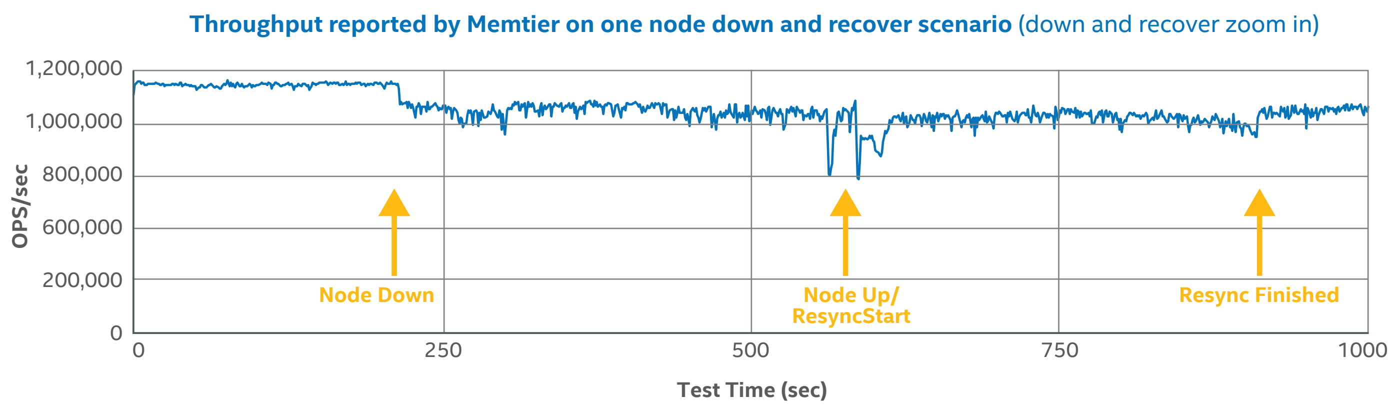

Figure 5. Baseline use case 3 – Throughput reported by Memtier benchmark during one-node-down and recover scenario.

Note: After the resynchronization completes ([resync finished] in Figure 5), the throughput of the cluster returns to the original, pre-node-down levels. This is not visible in Figure 5 due to a benchmark tool limitation.

Takeaway: Redis Enterprise with Intel Optane persistent memory maintains high throughput and P99 latency under 1 ms even during a node failover and re-synchronization—a necessary capability for mission-critical enterprise deployments.

Business Application: Fraud Prevention in the Financial Services Industry

A common type of fraud prevention measure currently in widespread use by the financial services industry applies machine learning algorithms to detect anomalies in customer behaviors that could indicate criminality. While the algorithms are far more adept than humans could be at sorting through massive data streams in real time to find these exceptions, they are limited by definition. Specifically, they are rules based, and the rules they follow must be decided upon and coded by humans. Moreover, attackers are getting more adept at deducing the logic of these rules and using that insight to defeat them.

The emerging next generation of this technology incorporates deep learning models that expand on the capabilities of current machine learning mechanisms by recognizing more complex and novel patterns, as well as deducing information from incoming data streams. Increasing the amounts of data that deep learning models can draw on enables them to make more sophisticated inferences about the fraud potential of transactions in real time. The memory capacity to support large-scale ingest of real-time data while holding the large historical dataset in memory is critical to these capabilities.

Intel Optane persistent memory provides Redis Enterprise with the capacity and performance to eliminate data-access bottlenecks in these massive, data-driven workloads. That ability helps make them more effective at detecting and responding to fraud, reducing the potential for financial losses and reputation damage, and improving ROI.

3. Baseline Use Case Hardware and Software Configurations

3.1. Baseline Use Case 1 Configurations

Server configurations for use case 1 are shown in Table 3. The servers are identically configured except for memory: The DRAM-only server contains 1.5 TB of DRAM, while the server with Intel Optane persistent memory is configured with 1.5 TB of persistent memory in Memory Mode, as well as 192 GB of DRAM that is used as a cache. A separate client node is used to drive the workload.

Table 3. Hardware and software configurations for baseline use case 1.

			DRAM-Only Server	Server with Intel Optane Persistent Memory
Database Node (One Node)	**Software**	**OS**	CentOS 7.5 with kernel upgraded to 4.19.8	
		Database Details	Redis Enterprise 5.4.0-26 • Dataset size: 1 TB (6 billion key-value pairs, 100 byte values) • Dataset split into 40 shards; shards are pinned to NUMA nodes using taskset • Redis Enterprise configured with 28 proxy server threads	
	Hardware	**Processor**	2x Intel Xeon Gold 6252 processors @ 2.10 GHz: • 24 physical cores per socket • 96 hardware threads total per node with Intel Hyper-Threading Technology enabled	
		DRAM	Total 1.5 TB - 24x 64 GB DDR4-2666	Total 192 GB - 12x 16 GB DDR4-2666
		Persistent Memory	---	Total 1.5 TB - 12x 128 GB (Memory Mode)
		Network Connectivity	2x Intel Ethernet X710 Converged Network Adapters (40 Gb)	

Client Node (One Node)	**Hardware**	**Processor**	2x Intel Xeon Platinum 8180 processors @ 2.50GHz: • 28 physical cores per socket • 112 hardware threads total per node with Intel Hyper-Threading Technology enabled
		DRAM	384 GB
		Network Connectivity	1x Intel Ethernet X710 Converged Network Adapter (40 Gb)

3.2. Baseline Use Case 2 and 3 Configurations

The test configuration for use cases 2 and 3 uses three Redis Enterprise database nodes and one client node, as detailed in Table 4. The database nodes are equipped with 1.5 TB of Intel Optane persistent memory, along with 192 GB of DRAM (a ratio of 8:1).

Table 4. Hardware and software configurations for baseline use case 1.

Database Node (Three Nodes)	**Software**	**OS**	CentOS 7.6, Linux Kernel 5.12
		Database Details	Redis Enterprise 5.4.4-7 • Dataset size: 1.5 TB / 3 TB with replication (1.8 billion key-value pairs, 750 byte values) • Dataset split into 90 shards / 180 with replication across the three nodes • Redis Enterprise configured with 28 proxy server threads per node
	Hardware	**Chassis**	HPE ProLiant DL380 Gen10 server
		Processor	2x Intel Xeon Platinum 8276M processors @ 2.20 GHz: • 28 physical cores per socket (112 hardware threads total with Intel Hyper-Threading Technology enabled) • Two NUMA nodes
		Storage	6x HPE 1.6 TB SSD - MO001600KWSJN
		DRAM	Total 192 GB - 12x 16 GB DDR4
		Persistent Memory	Total 1536 GB - 12x 128 GB DDR4-2666 Intel Optane persistent memory (Memory Mode)
		Network	HPE InfiniBand EDR/Ethernet 100 Gb 2-port 841QSFP28 Adapter

Client Node (One Node)	**Software**	Memtier version 1.2.12	
	Hardware	**Chassis**	HPE ProLiant DL380 Gen10 server
		Processor	2x Intel Xeon Gold 5118 processors @ 2.30 GHz: • 12 physical cores per socket (48 hardware threads total with Intel Hyper-Threading Technology) • Two NUMA nodes
		Storage	2x HPE 1.92 TB SSD - MK001920GWHRU
		DRAM	Total 256 GB - 8x 32 GB DDR4
		Network	HPE InfiniBand EDR/Ethernet 100 Gb 2-port 841QSFP28 Adapter
		Operating System	CentOS 7.6, Linux Kernel 5.12

3.3. About Memtier_benchmark

Redis Labs developed memtier_benchmark (commonly referred to simply as "memtier") to measure system performance of Redis Enterprise. The benchmark is used to verify and track ongoing system performance, as well as to assess the performance effects of various system changes. It provides an open source, readily customizable tool for generating traffic patterns against Redis Enterprise as well as Memcached instances. More information is available at https://github.com/RedisLabs/memtier_benchmark.

4. Conclusion

Using Intel Optane persistent memory in Memory Mode dramatically increases the size of datasets that Redis Enterprise can cost-effectively hold in memory. This capability removes the need to split databases into smaller working sets and keep only part of the data in active memory. The solution stack thereby provides better support for the instantaneous demands of applications such as real-time analytics.

The results presented here demonstrate the ability of Intel Optane persistent memory to be used for a large majority of the system memory deployed in the database servers, at lower cost than DRAM. That arrangement helps drive up ROI, while meeting SLAs of approximately one million ops/sec at under 1 ms latency.

By giving the data engine the ability to move, store, and process large working datasets close to the processor, this breakthrough memory architecture enables Redis Enterprise to make actionable insights available rapidly and cost-effectively, extracting previously untapped value from business data.

Take the Next Steps

- Learn more about Intel Optane Persistent Memory: **www.intel.com/OptanePersistentMemory**
- Learn how Intel Optane Persistent Memory gives developers the edge: **software.intel.com/pmem**
- Learn more about the latest 2nd Gen Intel Xeon processors: **www.intel.com/XeonScalable**
- Contact Redis Labs: **www.redislabs.com/company/contact**

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[1] Intel Optane persistent memory pricing & DRAM pricing referenced in TCO calculations is provided for guidance and planning purposes only and does not constitute a final offer. Pricing guidance is subject to change and may revise up or down based on market dynamics. Please contact your OEM/distributor for actual pricing. Your cost and results may vary.

[2] For more on Intel Optane persistent memory operating modes, see https://itpeernetwork.intel.com/intel-optane-dc-persistent-memory-operating-modes/.

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