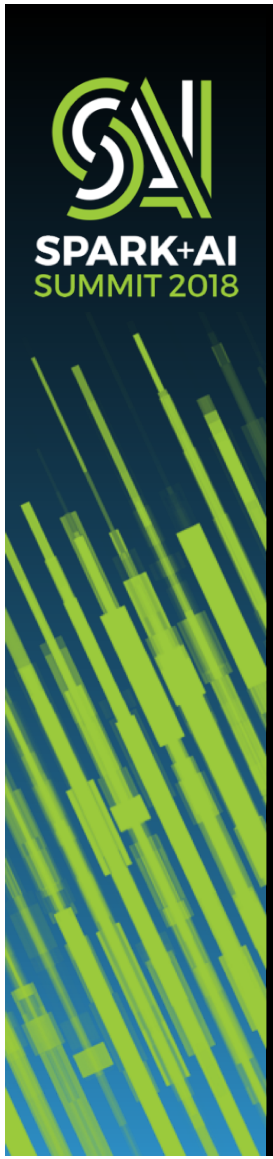

Optimizing Apache Spark* throughput using Intel® Memory Drive Technology

Ravi Durgavajhala
SSD Solutions Architect
Non-Volatile Memory Solutions Group (NSG), Intel

Ravikanth.Durgavajhala@Intel.com
@ravykanth

#HWCSAIS1

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Problem Statement

Optimize the performance of Spark* and get more out of my infrastructure while operating within the budget.

Assumptions

- **Extrapolate overall infrastructure set up.**
- **Match the individual system resources to that of real-world production, as much as possible.**
- **Come up with a representative workload.**
- **Identify a solution along with alternatives.**

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A quick overview of the K-Means workload

“Definition: K-Means clustering aims to partition n observations into k clusters in which each observation belongs to the cluster with the nearest mean.

Standard Algorithm: “Given an initial set of k means m1(1),…,mk(1), the algorithm proceeds by alternating between two steps:

1. **Assignment step**: Assign each observation to the cluster whose mean has the least squared **Euclidean distance**, this is intuitively the "nearest" mean.
2. **Update step**: Calculate the new means to be the centroids of the observations in the new clusters.

The algorithm has converged when the assignments no longer change.”

https://en.wikipedia.org/wiki/K-means_clustering

Hardware Configuration

	Master Node	Data Node (x3)
CPU	Intel® Xeon® Gold 6140 CPU @ 2.30GHz	Intel® Xeon® Gold 6140 CPU @ 2.30GHz
Cores per Socket	18	18
Sockets	2	2
Threads per Core	2	2
Total vcores	72	72
Memory	192GB	192GB
SSD	None	3.7TB Intel® SSD DC P4500 (x2)
		375GB Intel® Optane™ SSD DC P4800X (x2)
Network	10Gbps	

Software Configuration

Stack	Version
Distribution	HDP 2.6.4.0
HDFS*	2.7.3
YARN*	2.7.3
Spark*	2.2.0
OS	CentOS 7.4*
Kernel	4.14.16

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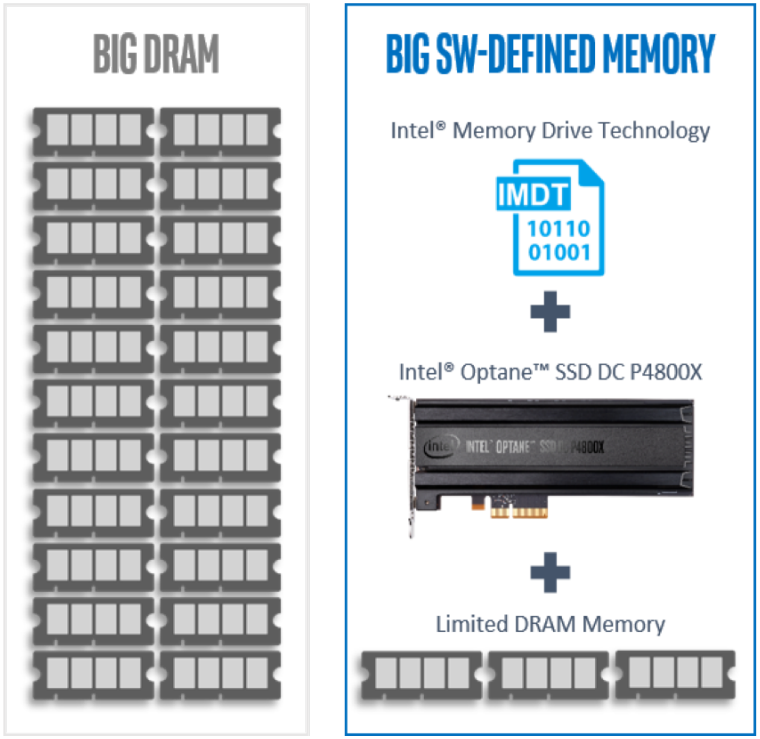
Introducing Intel® Memory Drive Technology (IMDT)

- Intel® Optane™ Technology - Write in place, Bit addressable, Low latency.
- Use Intel® Optane™ SSD DC P4800X transparently as memory.
- Grow beyond system DRAM capacity, or replace high-capacity DIMMs for lower-cost alternative, with similar performance.
- Leverage storage-class memory today!
  - No change to software stack: unmodified Linux* OS, applications, and programming.
  - No change to hardware: runs bare-metal, loaded before OS from BIOS or UEFI.



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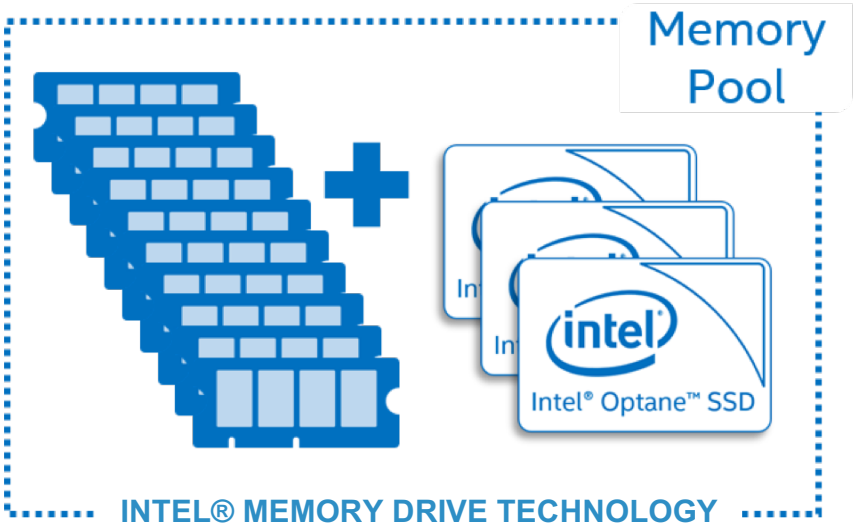
Intel® Memory Drive Technology delivers big, affordable memory

use case 1

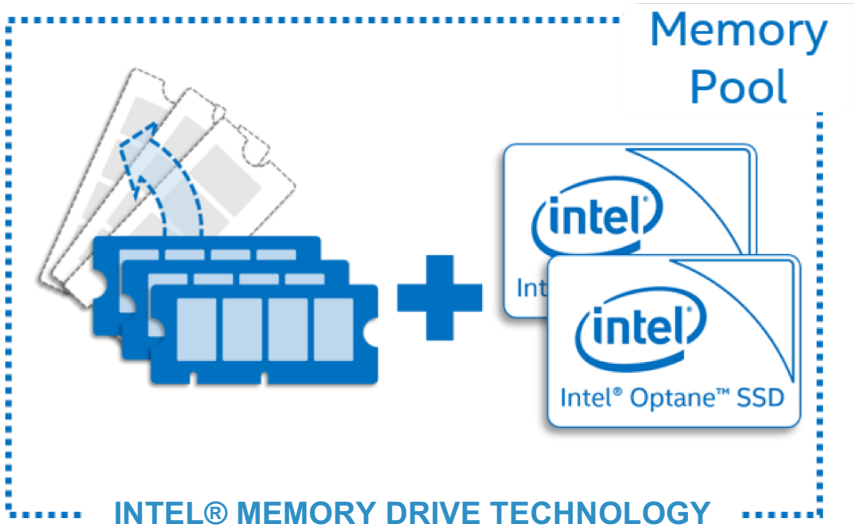
EXPAND beyond limited DRAM capacity



Expand Insights with Massive Data Pools

use case 2

DISPLACE DRAM with affordable SSDs



Reduce High-capacity DRAM CAPEX Expenditures

Note: Intel® Memory Drive Technology supports Linux* x86_64 (64-bit), kernels 2.6.32 or newer.

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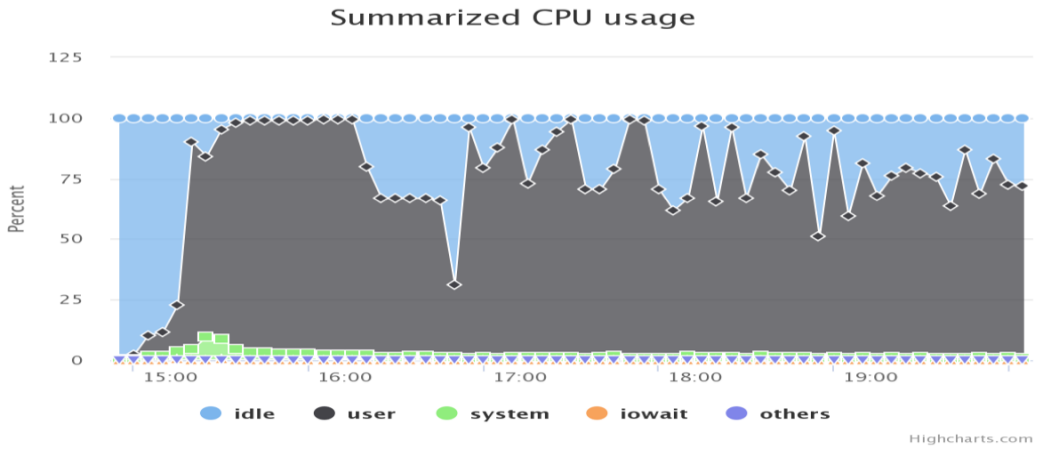
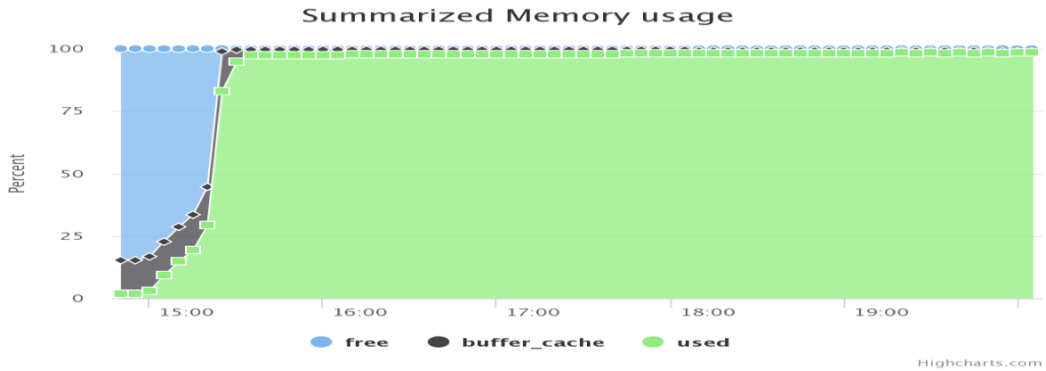
Workload that fits entirely into DRAM

Spark* Workload Configuration	
# of Executors across all Nodes	42
# of Cores per Executor	5
Memory per Executor	12 GiB
Memory Overhead per Executor	3 GiB
Driver Memory	1 GiB
Driver Memory Overhead	1 GiB
K-Means workload Scale Factor	1.2 Billion samples
Time taken to run the workload is 5.3 min[1]	

- Spark* configuration is based on generally understood guidelines.
- Data set fits entirely into memory, without any spill.
- The objective is to utilize maximum available resources on the system to get best possible run-time.





[1] For system configuration details, please refer to Slide #5. Benchmark results were obtained prior to implementation of recent software patches and firmware updates intended to address exploits referred to as "Spectre" and "Meltdown". Implementation of these updates may make these results inapplicable to your device or system.

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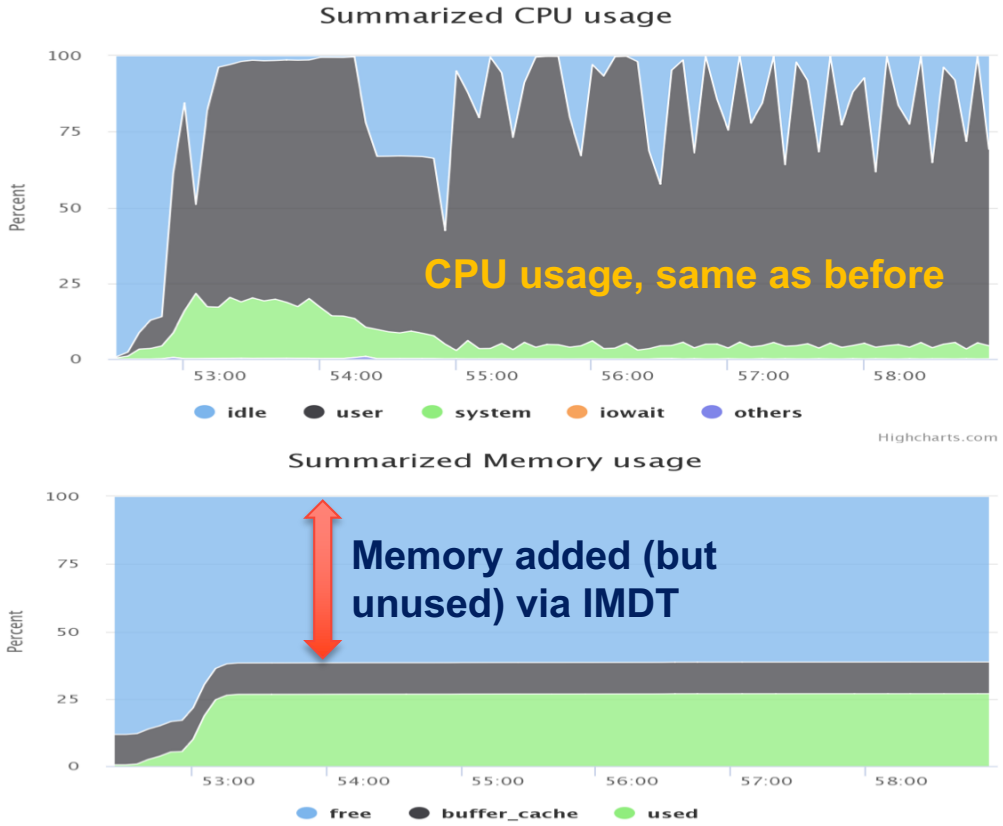
Workload that fits entirely into DRAM (+IMDT)

Spark* Workload Configuration	
# of Executors across all Nodes	42
# of Cores per Executor	5
Memory per Executor	12 GiB
Memory Overhead per Executor	3 GiB
Driver Memory	1 GiB
Driver Memory Overhead	1 GiB
K-Means workload Scale Factor	1.2 Billion samples
Time taken to run the workload is **5.3** min[1]	

- Objective is to ensure performance did not get impacted when running the same workload using same resource configuration, except for memory expansion using IMDT.



[1] For system configuration details, please refer to Slide #5. Benchmark results were obtained prior to implementation of recent software patches and firmware updates intended to address exploits referred to as "Spectre" and "Meltdown". Implementation of these updates may make these results inapplicable to your device or system.

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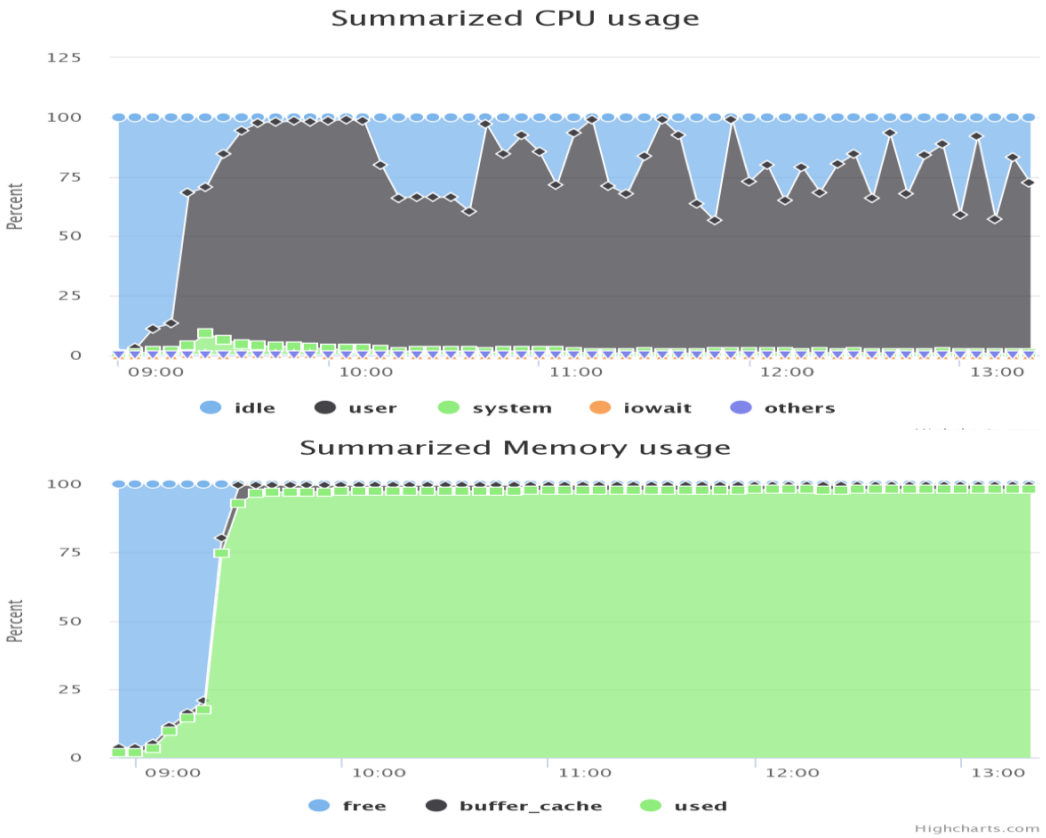
Workload that fits entirely into DRAM – fine tuned

Spark* Workload Configuration	
# of Executors across all Nodes	30
# of Cores per Executor	7
Memory per Executor	17 GiB
Memory Overhead per Executor	3 GiB
Driver Memory	1 GiB
Driver Memory Overhead	1 GiB
K-Means workload Scale Factor	1.2 Billion samples
Time taken to run the workload is **4.5** min[1]	

- Spark* configuration is fine tuned based on Memory and CPU utilization.
- Not all workloads are alike, so each workload needs to be custom-adjusted for better resource utilization.



[1] For system configuration details, please refer to Slide #5. Benchmark results were obtained prior to implementation of recent software patches and firmware updates intended to address exploits referred to as "Spectre" and "Meltdown". Implementation of these updates may make these results inapplicable to your device or system.

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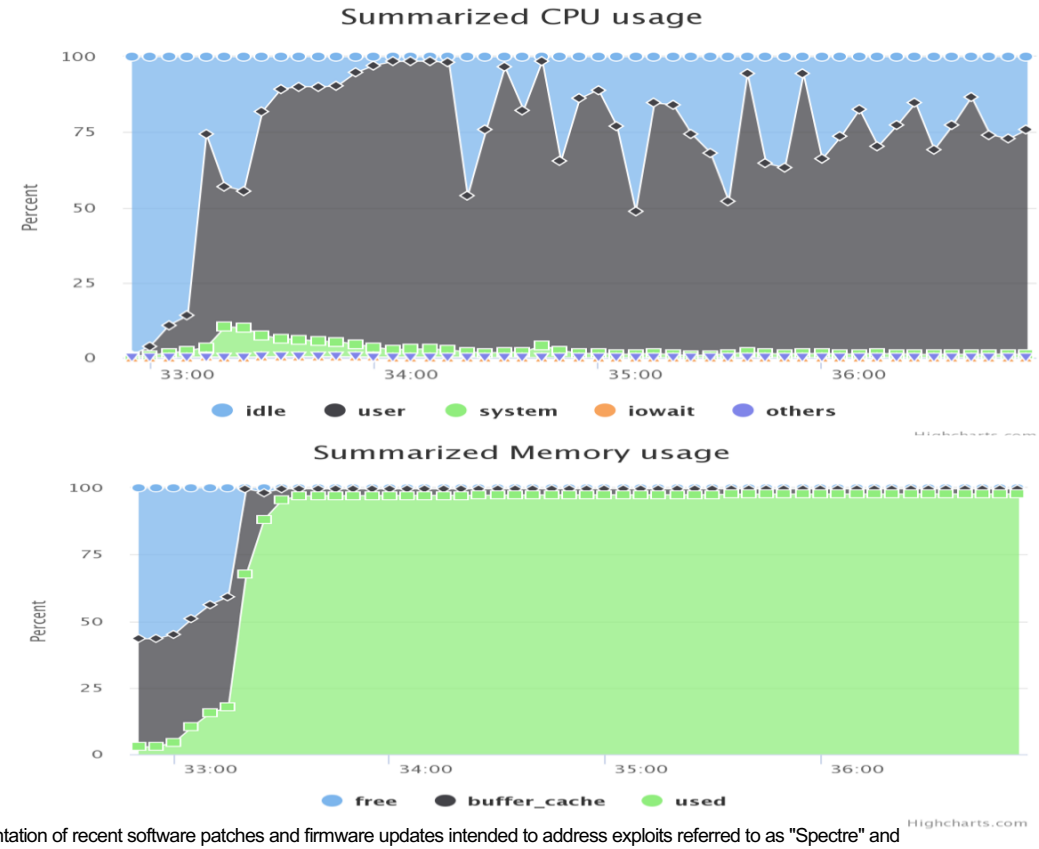
Workload that fits entirely into DRAM – fine tuned

Spark* Workload Configuration	
# of Executors across all Nodes	30
# of Cores per Executor	5
Memory per Executor	17 GiB
Memory Overhead per Executor	3 GiB
Driver Memory	1 GiB
Driver Memory Overhead	1 GiB
K-Means workload Scale Factor	1.2 Billion samples
Time taken to run the workload is **4.1** min[1]	

- Utilizing max of resources available does not always yield best possible performance.
- Performance varies based on memory and other resource utilization within the application code.



[1] For system configuration details, please refer to Slide #5. Benchmark results were obtained prior to implementation of recent software patches and firmware updates intended to address exploits referred to as "Spectre" and "Meltdown". Implementation of these updates may make these results inapplicable to your device or system.

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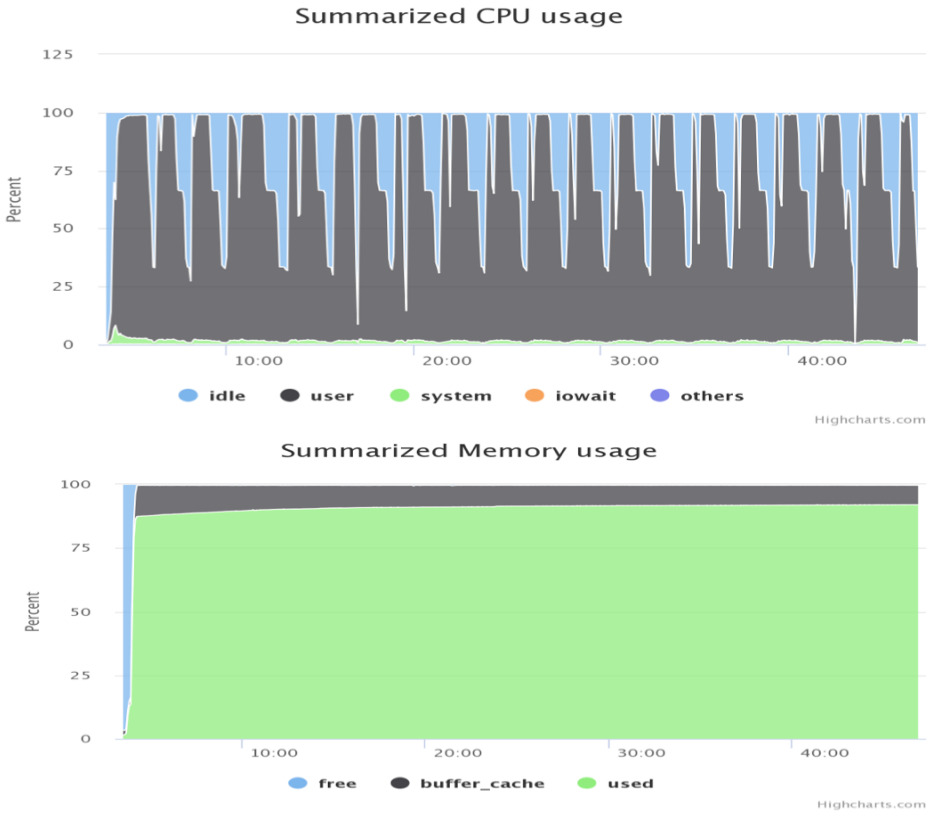
Bigger Workload using DRAM

Spark* Workload Configuration	
# of Executors across all Nodes	30
# of Cores per Executor	7
Memory per Executor	17 GiB
Memory Overhead per Executor	3 GiB
Driver Memory	1 GiB
Driver Memory Overhead	1 GiB
K-Means workload Scale Factor	2 Billion samples
Time taken to run the workload is 43 min[1]	

- Spark* shuffles the data between memory and storage when dataset does not fit entirely in memory.
- If the workload is large enough that it cannot fit with fully populated memory channel, the next logical move is to scale out and add more nodes.
- Storage: 2x Intel® Optane® SSD DC P4800X (375GB)



[1] For system configuration details, please refer to Slide #5. Benchmark results were obtained prior to implementation of recent software patches and firmware updates intended to address exploits referred to as "Spectre" and "Meltdown". Implementation of these updates may make these results inapplicable to your device or system.

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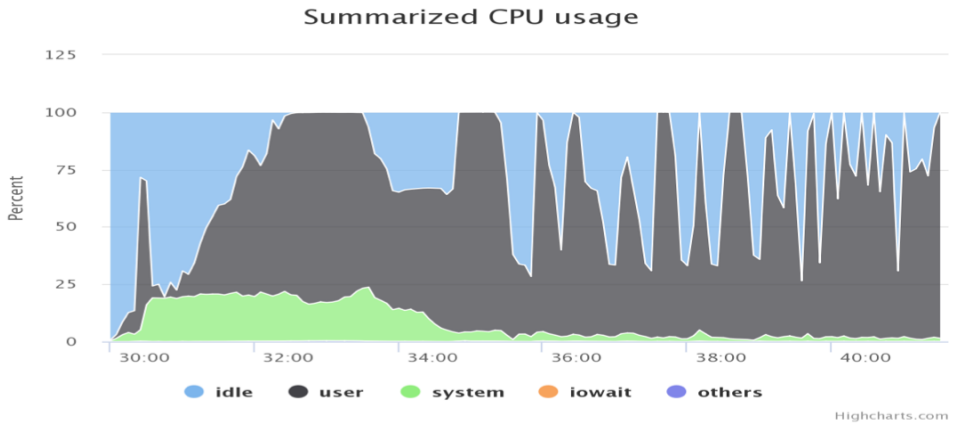
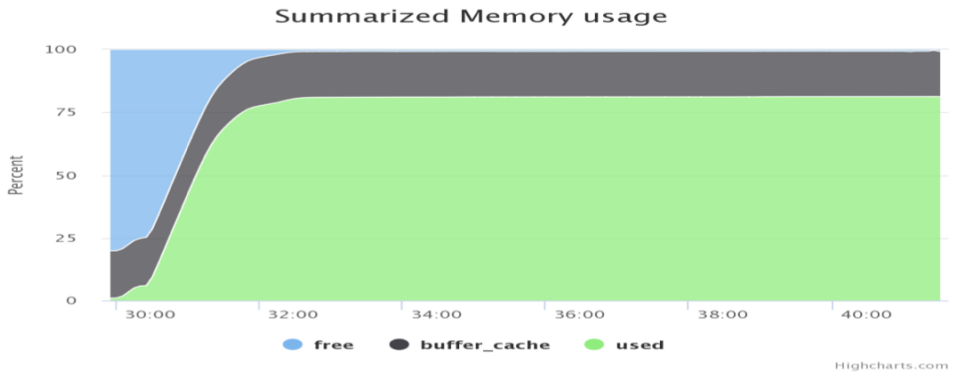
Bigger Workload using IMDT

Spark* Workload Configuration	
# of Executors across all Nodes	42
# of Cores per Executor	10
Memory per Executor	40 GiB
Memory Overhead per Executor	3 GiB
Driver Memory	1 GiB
Driver Memory Overhead	1 GiB
K-Means workload Scale Factor	2 Billion samples
Time taken to run the workload is 12 min[1]	

- IMDT helps to bring more memory resources without having to scale out.
- IMDT can expand memory capacity to grow x8 beyond system spec.
- That directly translates to more Spark* executors that can run in parallel.





[1] For system configuration details, please refer to Slide #5. Benchmark results were obtained prior to implementation of recent software patches and firmware updates intended to address exploits referred to as "Spectre" and "Meltdown". Implementation of these updates may make these results inapplicable to your device or system.

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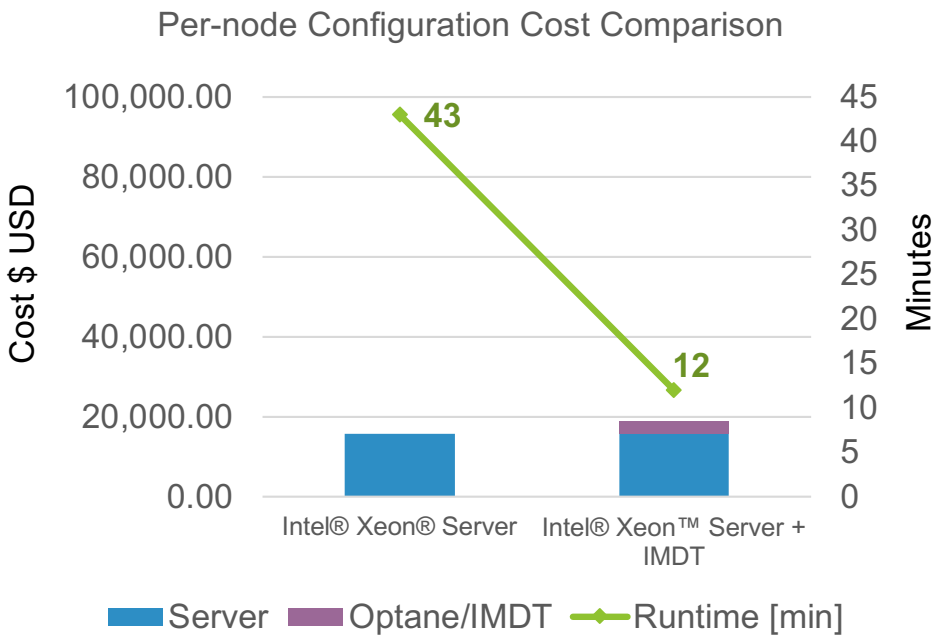
Solution Economics



	Master Node	Data Node (x3)
CPU	Intel® Xeon® Gold 6140 CPU @ 2.30GHz	
Cores/Socket	18	
Sockets	2	
Threads per Core	2	
Total vcores	72	
Memory	192GB	
SSD	None	3.7TB Intel® SSD DC P4500 (x2)
		375GB Intel® Optane™ SSD DC P4800X (x2)
Network	10Gbps	

20% added cost[1] → reduce runtime by factor of x3.5[2]

[1] Cost estimates based on quote from Colfax International as of May 27, 2018
[2] For system configuration details, please refer to Slide #5. Benchmark results were obtained prior to implementation of recent software patches and firmware updates intended to address exploits referred to as "Spectre" and "Meltdown". Implementation of these updates may make these results inapplicable to your device or system.
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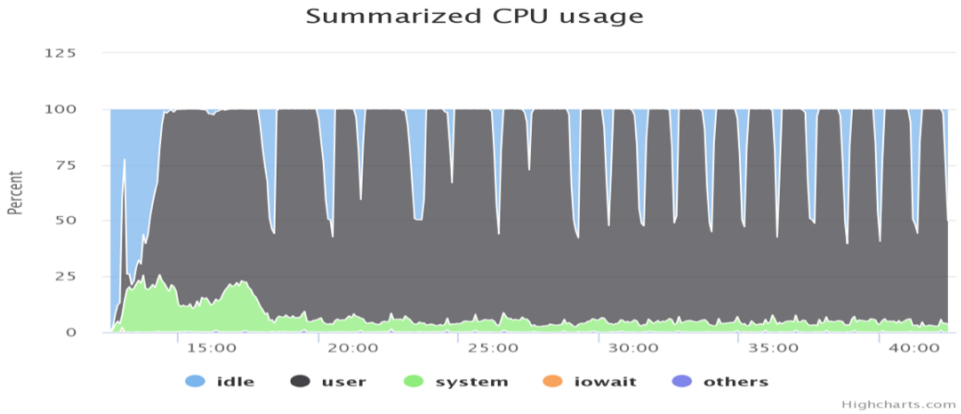
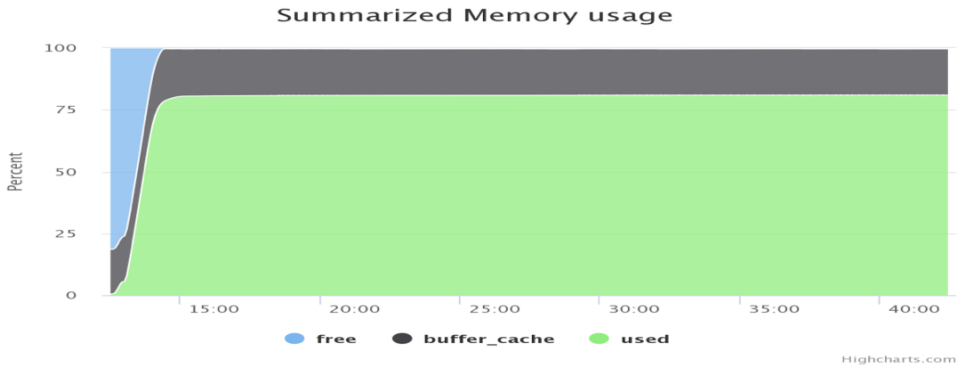
Bigger Workload using IMDT and fewer nodes

Spark* Workload Configuration (2 Data Nodes only)	
# of Executors across all Nodes	28
# of Cores per Executor	10
Memory per Executor	40 GiB
Memory Overhead per Executor	3 GiB
Driver Memory	1 GiB
Driver Memory Overhead	1 GiB
K-Means workload Scale Factor	2 Billion samples
Time taken to run the workload is 30 min[1]	

- For workloads that are not fully utilizing CPU resources in a given infrastructure, IMDT can help increase CPU utilization.
- Increasing CPU utilization allows for savings on data center footprint by reducing node-count, with larger memory per node.
- Savings can be put back into improved networks, higher-core-count CPUs, etc.





[1] For system configuration details, please refer to Slide #5. Benchmark results were obtained prior to implementation of recent software patches and firmware updates intended to address exploits referred to as "Spectre" and "Meltdown". Implementation of these updates may make these results inapplicable to your device or system.

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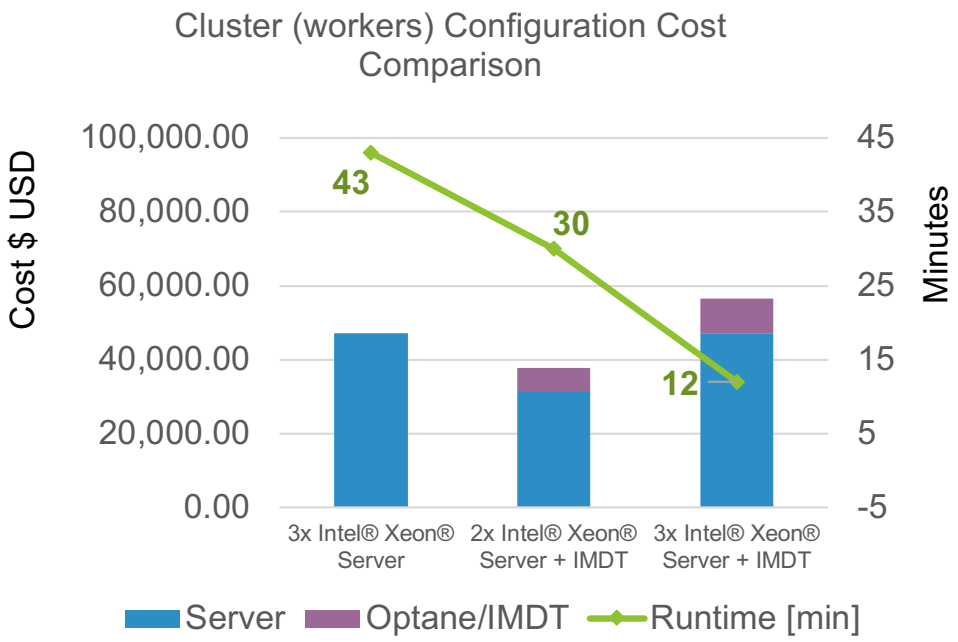
Solution Economics



	Master Node	Data Node (x2)
CPU	Intel® Xeon® Gold 6140 CPU @ 2.30GHz	
Cores/Socket	18	
Sockets	2	
Threads per Core	2	
Total vcores	72	
Memory	192GB	
SSD	None	3.7TB Intel® SSD DC P4500 (x2)
		375GB Intel® Optane™ SSD DC P4800X (x2)
Network	10Gbps	

20% cost reduction[1] → reduce runtime by 30%[2]

[1] Cost estimates based on quote from Colfax International as of May 27, 2018
[2] For system configuration details, please refer to Slide #5. Benchmark results were obtained prior to implementation of recent software patches and firmware updates intended to address exploits referred to as "Spectre" and "Meltdown". Implementation of these updates may make these results inapplicable to your device or system.
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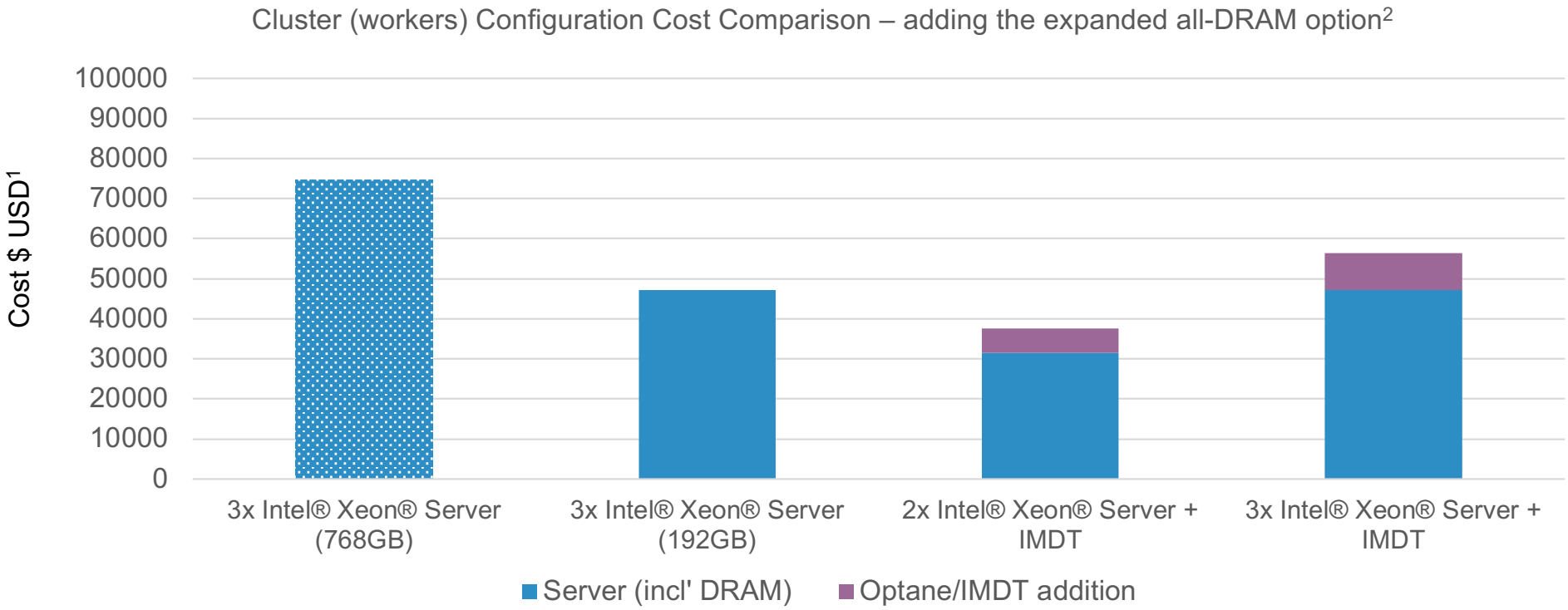
Solution Alternatives



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[2] For system configuration details, please refer to Slide #5. Benchmark results were obtained prior to implementation of recent software patches and firmware updates intended to address exploits referred to as "Spectre" and "Meltdown". Implementation of these updates may make these results inapplicable to your device or system.
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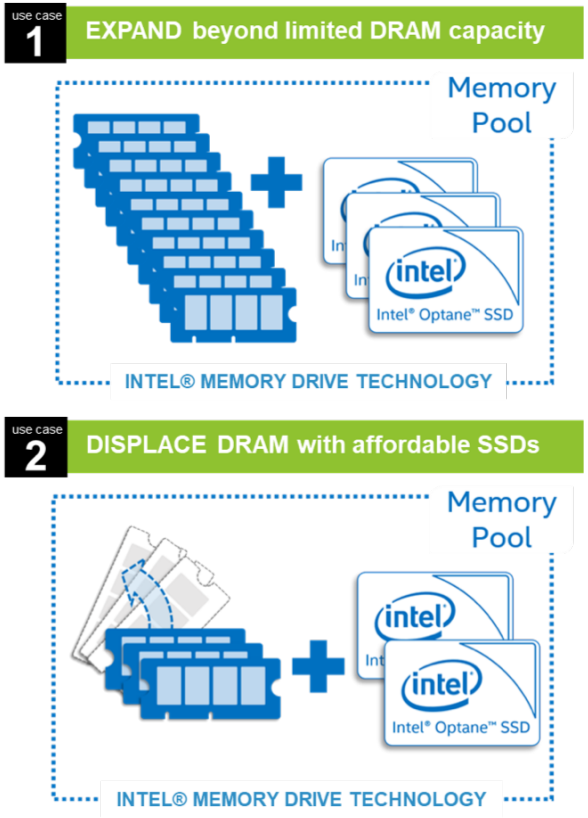
Summary - Optane/IMDT Benefits for Spark*



- Reduce manual optimization work by having more memory available
- For workloads with underutilized CPUs:
  - Significantly reduce runtime
  - Increase CPU utilization
  - Reduce cluster node-count. Reinvest free budget in higher-core-count processors

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Resources

- www.intel.com/optane
- www.intel.com/imdt
- https://www.intel.com/content/www/us/en/software/apache-spark-optimization-technology-brief.html

QUESTIONS?