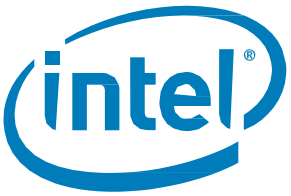

Intel® Memory Drive Technology

Set Up and Configuration Guide

July 2017
Revision 005

Document Number: 335666-004US

Revision History

Revision	Description	Date
001	• Initial release.	March 2017
002	• Revised Set Up and Configuration guidelines	April 2017
003	• Corrected Download URL & command line • Revised Recommended Configuration • Included UEFI boot support	May 2017
004	• Highlighted supported OS • Re-ordered installation steps 3 & 4	June 2017
005	• Added Common Error Code explanation • Added workloads classification for workload classes that do not benefit from Intel Memory Drive Technology • Added a section for performance data collection (using automatic anonymous periodic statistics collection) • Added details of supported processor models for Skylake-generation processors • Updates for Intel Memory Drive Technology version 8.2.1455.x.	July 2017

For copies of this document, documents that are referenced within, or other Intel literature, please contact your Intel representative.

All products, computer systems, dates, and figures specified are preliminary based on current expectations, and are subject to change without notice.

Contents

1 Introduction

Intel® Memory Drive Technology is a software-defined memory (SDM) product[1] that allows for the expansion of system memory beyond DRAM by defining some of the PCIe*-based Intel SSD capacity as memory, instead of as storage.

This document describes the setup, capabilities, and specifications of the Intel® Memory Drive™ Technology software.

The Intel® Memory Drive Technology implements software-defined memory (SDM) on-top of Intel® SSDs. Intel® Memory Drive technology is optimized to take advantage of the latest Intel processors, PCIe-based Intel® SSDs, and the latest memory technology of the Intel® Optane™ SSDs.

As shown in Figure-1, Intel® Memory Drive technology executes directly on the hardware, and below the operating system, and allows for system memory to be assembled from DRAM and the PCIe-based Intel® SSD. It leverages economic benefit of SSDs, and operates transparently as volatile system memory. With Intel® Optane™ SSDs, it is initially available in 320GiB capacity, but later will be offered at higher capacity points of 640GiB, and 1.28TiB.

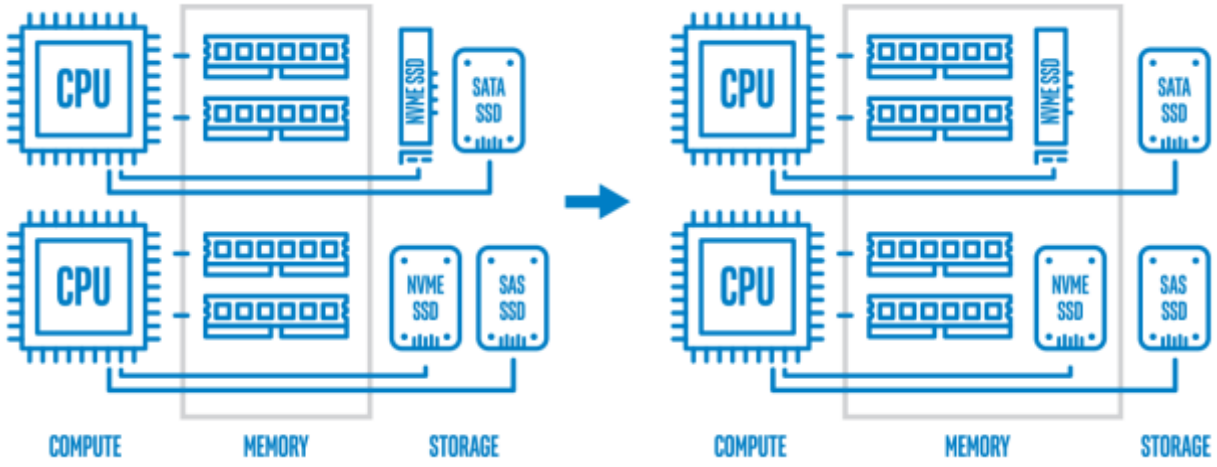

Figure-1: Memory Pool with Intel® Memory Drive Technology

Intel® Memory Drive Technology offers these key features:

- Optimized for up to 8x system memory expansion over installed DRAM capacity
- Ultra-low latencies and close-to DRAM performance for SDM operations
- Consistent and reliable SDM Quality of Service
- Very high endurance
- Designed for high-concurrency and in-memory analytics workloads

§

[1] Technology licensed from ScaleMP*

2 Set Up Overview

Overview of the setup steps covered in this guide:

1. Install supported PCIe-based Intel® SSD into the system.
2. Download and execute Intel® Memory Drive Technology software installer from https://www.memorydrv.com/downloads/latest. Initially run it to collect Intel SSDs license information:

   ```
   # ./imdt_installer-x.x.x.x.sh in -n
   ```

3. Install the Intel® Memory Drive Technology software and licenses received in email to the selected Intel SSDs.

   ```
   # ./imdt_installer-x.x.x.x.sh in -n FLX_Licenses-FLXxxxxxxxx.txt
   ```

4. If the system is capable of booting directly from the NVMe (using UEFI), skip to step 5. Otherwise, Install Intel® Memory Drive Technology software to local bootable flash media (such as USB/IDE drive).

   ```
   # ./imdt_installer-x.x.x.x.sh in -b
   ```

5. Set the system BIOS to boot from either the Intel SSD or the bootable flash media into which you installed the Intel® Memory Drive Technology software. Setup is complete. Reboot the system to expand system DRAM with Intel® Memory Drive Technology.

§

3 Installation and Configuration

3.1 Installing Intel® Memory Drive Technology Software

NOTE: Back up all data before beginning Intel® Memory Drive Technology Software setup. Intel® Memory Drive Technology configures PCIe-based Solid State Drive as a part of main (volatile) memory pool.

Following are the steps to set up Intel® Memory Drive Technology software for Linux*:

1. Before starting the installation, please make sure you have supported OS installed as explained in p3.2. Also, make sure you have the Intel-provided serial numbers available.
2. If you have not already done so, install certified PCIe-based Intel® SSD into the target server.
3. Log in to the system as root.
4. Download the Intel® Memory Drive Technology software installer from https://www.memorydrv.com/downloads/latest to a directory on the target Linux server (file name format: imdt_installer-x.x.x.x.sh). It can be downloaded using the wget command line utility as follows:

   ```
   # wget -N --content-disposition https://www.memorydrv.com/downloads/latest/imdt_installer.sh
   ```

5. Navigate to the directory that contains the files you downloaded in step 3.
6. Make the license installer file executable:

   ```
   # chmod +x imdt_installer-x.x.x.x.sh
   ```

7. Launch the license installation utility, and follow on-screen instructions. Intel® Memory Drive Technology software activation details for the selected Intel SSD are uploaded directly from the installer if the system is connected to the internet. If not connected to the internet, follow instructions to save the file and submit it at https://www.memorydrv.com/activate.

   ```
   # ./imdt_installer-x.x.x.x.sh in -n
   Intel Memory Drive Technology version x.x.x.x found the following NVMe SSDs:

   ##  Block Device   Vendor and Model Number  Serial Number       Size (GB/GiB)
   01  /dev/nvme0n1   Intel SSDPED1K375GA      FUKS70950005375AGN    375 /   349
   02  /dev/nvme1n1   Intel SSDPED1K375GA      FUKS7095000U375AGN    375 /   349

   Please select devices for license generation:
   - device list (1,3,4 or 1-3 or combination of both e.g. 1,2-4,5)
   - all devices (a or <ENTER>)
   Devices (q to quit):

   Please enter software serial numbers provided by Intel one at a time (press <ENTER> to finish):
   ==> 1234-12345678
   ==> 2345-23456789
   Please enter your email address (press <ENTER> to finish):
   ==> RobC@bigmemory.com
   Repeat your email address (press <ENTER> to finish):
   ==> RobC@bigmemory.com

   Selected NVMes, serial numbers, and email were saved to vsmp_nvmes.list.

   Would you like to submit this information for activation (requires Internet access)? [Y/n]
   Connecting to www.memorydrv.com... [OK]
   Sending vsmp_nvmes.list to www.memorydrv.com... [OK]
   Activation instructions will be sent to robc@bigmemory.com.
   ```

8. Install the Intel® Memory Drive Technology software and licenses (received in email) to the selected Intel SSDs. The process may take few minutes as the SSDs will be formatted during this process.

```
# ./imdt_installer-x.x.x.x.sh in -n FLX_Licenses-FLXxxxxxxxx.txt
Intel Memory Drive Technology NVMe SSD licensing status:

##  Block Device   Vendor and Model Number  Serial Number       Size (GB/GiB)  License
01  /dev/nvme0n1   Intel SSDPED1K375GA      FUKS70950005375AGN    375 /   349  Available
02  /dev/nvme1n1   Intel SSDPED1K375GA      FUKS7095000U375AGN    375 /   349  Available

Press 'y' to install available licenses:
Starting license installation...
/dev/nvme0n1 (INTEL SSDPED1K375GA FUKS70950005375AGN): installing..
/dev/nvme1n1 (INTEL SSDPED1K375GA FUKS7095000U375AGN): installing..
/dev/nvme0n1 (INTEL SSDPED1K375GA FUKS70950005375AGN): done.
/dev/nvme1n1 (INTEL SSDPED1K375GA FUKS7095000U375AGN): done.
Done.
```

9. If the system is capable of booting directly from the NVMe (using UEFI), skip to step 9.
   In a case that booting directly from the NVMe is not possible, the Intel® Memory Drive Technology software must be installed to a local bootable flash media (such as USB/IDE drive).

```
# ./imdt_installer-x.x.x.x.sh in -b
Intel Memory Drive Technology version x.x.x.x found the following bootable media:

##  Block Device   Vendor and Model Number  Serial Number     Size (GB/GiB)
01  /dev/sdb        USB DISK 2.0            07A70E137CCCB815  0.957 / 0.979

Please select devices to install Memory Drive Technology:
- device list (1,3,4 or 1-3 or combination of both e.g. 1,2-4,5)
- all devices (a)
Devices (q or <ENTER> to quit): a
/dev/sdb (USB DISK 2.0 07A70E137CCCB815): installing..
/dev/sdb (USB DISK 2.0 07A70E137CCCB815): done.
```

10. Set the system BIOS to boot from either the Intel SSDs or the bootable flash media into which you installed the Intel® Memory Drive Technology software. Setup is complete. Reboot the system to expand system DRAM with Intel® Memory Drive Technology.

    Note: Installing Intel® Memory Drive Technology also installs the Intel® Memory Drive Technology Tools at /usr/local/{bin,etc}. If manual tools installation is required, use the procedure below.

```
# ./imdt_installer-x.x.x.x.sh in -t
Please enter absolute install path or press Enter to default [/usr/local]:
Installing...
```

3.2 Operating System requirements

Linux x86 64 bit, kernel versions 2.6.32 or higher. Linux OS must be installed in legacy (non-UEFI) mode.

3.3 Monitoring the System

1. To verify successful installation, and to check for the current running version of Intel® Memory Drive Technology software, run this command:

```
# vsmpversion
```

   More detailed information is available by adding the "-v" flag one or more times (as in -v, -vv or -vvv). An example for highest level of information with "-vvv" is:

```
# vsmpversion -vvv
Intel Memory Drive Technology: 8.1.1145.57 (Jun 08 2017 20:03:58)
System configuration:
    Boards:      3
       1 x Proc. + I/O + Memory
       2 x NVM devices (Intel SSDPED1K375GA)
    Processors:  2, Cores: 24, Threads: 48
        Intel(R) Xeon(R) CPU E5-2680 v3 @ 2.50GHz Stepping 02
```

```
    Memory (MB): 713728 (of 846498), Cache: 124490, Private: 8280
       1 x 122368MB   [131084/  644/8072]
       1 x 295680MB   [357707/61923/ 104]    07:00.0#1
       1 x 295680MB   [357707/61923/ 104]    82:00.0#1
```

Boot device: [HDD0] ATA INTEL SSDSC2BA01The total memory above is 713728MB (697GB), out of which part are contributed by DRAM (122368MB = 119.5GB, out of 131084MB = 128GB), and part by Flash (591360MB = 577.5GB, out of 715414MB = 698GB). The rest of the DRAM and Flash capacity are used for the Intel® Memory Drive Technology software itself, its data structures, cache and endurance protection. The vsmpversion output also displays the PCI address of the Optane devices in use.

2. NVMe* SMART attributes are accessible in-band using the command below. SMART attributes are also accessible out-of-band using IPMI.

```
# vsmpctl --pinfo
Device info:
        Board number: 0
        Device number: 0
        Device type: 0 (NVMe)
        Device address: 0007:00.0#1
        PCI VID:DID: 8086:2701
        PCI SVID:SDID: 8086:3904
Controller ID:
        Serial Number (SN): FUKS70950005375AGN
        Model Number (MN): INTEL SSDPED1K375GA
        Firmware Number (FR): E2010211
        Number of Namespaces (NN): 1
Namespace ID:
        Namespace Size (NSZE): 91573146
        Namespace Capacity (NCAP): 91573146
        Namespace Utilization (NUSE):  91573146
SMART / Health Information Log:
        Critical Warning: 0x0
        Composite Temperature: 23 C
        Available Spare:  100%
        Available Spare Threshold: 0%
        Percentage Used: 0%
        Data Units Read: 323800768
        Data Units Written: 417861353
        Host Read Commands: 40266157897
        Host Write Commands: 70671888170
        Controller Busy Time: 3133
        Power Cycles: 196
        Power On Hours: 1601
        Unsafe Shutdowns: 95
        Media and Data Integrity Errors: 0
        Number of Error Information Log Entries: 167
License info:
        End Of Support Date: 31 Jul 2017
        License: ZQE6E-R3V6N-PCG15-JR35K-1TNEU-PJKUM-H56DV-5MLMH-4QY2T-I6B9Y-44H22-8114Y-H29HZ-
I248I-248I2-48I24-YIJ68-P36DQ-H71H6-8DQQ6-5BN91-PC8YQ-PYVGY-WWQLH-4622N-JVH8C-B1HN2-BRH4T-K7JQS-
W1EYM-D5P49-7SGDB-255DL-B2NQ7-GKDKB-KBUFQ-L32TZ-9VS85-EF14E-C7748-9DA26-3BE1B-7AC55-EB935-C9K7
```

§

4 Optimizing & Troubleshooting

4.1 Workloads that Benefit Most from Intel® Memory Drive Technology

Intel® Memory Drive Technology takes advantage of one or more of the following workload attributes:

1. Predictable or probability-based memory access patterns, such as accesses to structured arrays - handled by *prefetch* algorithms. For example, row- or column-store in-memory databases used in analytics workloads.
2. Highly concurrent memory access such as parallel throughput workloads - handled through asynchronous memory load. For example, container-based virtual-shared web-hosting server, or a multi-threaded key-value cache such as *memcached*.
3. CPU intensive workloads - handled by optimizing the memory to CPU affinity throughout the run. For example, multi-threaded linear algebra workloads with large matrices, or parallel statistics calculations on large data.

4.1.1 Examples of applications best-fitting Intel Memory Drive Technology

1. Row- or column-store in-memory databases used in analytics workloads, such as SAP HANA, Oracle 12c, MySQL.
2. Different application classes which fit the high concurrency
    a. Multi-tenant workloads, such as Container-based virtual-shared web-hosting server, or Virtualization-based partitioning for example with KVM.
    b. Multi-threaded key-value cache such as *memcached.*
    c. Distributed/shareded data grids and frameworks such as Apache Spark, Apache Ignite, Aerospike, or Redis.
3. Multi-threaded or multi-process linear algebra workloads with large matrices, or high performance computing workloads using OpenMP, or parallel statistics calculations on large data

4.2 Workloads that do not benefit from Intel Memory Drive Technology

1. Low-concurrency workloads (e.g. serial workloads: single process, single threaded) - with low concurrency workloads, even if IMDT can prefetch or try asynchronous memory management, there is only one execution thread, and wait-time for memory will reduce the compute efficiency of the workloads.
2. Workloads bound by memory bandwidth - stressing the memory bandwidth, Optane's bandwidth of approximately 2GB/s would be reached. Even if four Optane SSDs are installed, the total aggregate bandwidth would be approx. 8GB/s. This would be much lower than two Xeon processors memory bandwidth of >100GB/s on their memory controllers' link to DRAM.
3. workloads with a high frequency of system calls may suffer from the virtualization overhead.

4.2.1 Examples of workloads which do not fit the Intel Memory Drive Technology

1. A serial program using an interpreted language, traversing a graph data structure with less than 1K of data for each vertex or edge.
2. A program resembling the "stream" memory bandwidth benchmark, constantly accessing memory and doing little compute on the fetched memory before moving over to consume new memory

4.3 Recommended Configuration

1. Strongly recommended: Attach equal number of drives to each socket (consult system manual for PCIe to socket mapping). Less than one drive per socket would result in inferior performance.

2. Multiple SSDs can be installed with Intel® Memory Drive Technology software, and can be aggregated to improve performance (optimize for the highest aggregated 4K IOPS across all devices used by Intel® Memory Drive Technology).
3. One smaller capacity drive per each socket will yield better performance than a single larger capacity drive attached to one of multiple sockets. For example, in a dual socket system, two SSD drives with Intel® Memory Drive Technology with capacity of 320GiB attached to each socket, would perform better than a single 640GiB SSD drive attached to one of the sockets.

4.4 DRAM to SSD Ratio for Intel® Memory Drive Technology

Intel® Memory Drive Technology uses part of the overall capacity (DRAM + Intel® Memory Drive Technology) for caching, prefetching, and endurance protection. Thus, adding capacity in either DRAM or Intel® Memory Drive Technology may result in lower increase or no increase at all in the system memory available for the OS. This can be overridden by changing Intel® Memory Drive Technology system memory settings at boot time (F5 – system settings) from Automatic to Manual. For example, when set to Automatic:

1. With two 320GiB drives on a system with 128GiB of DRAM, a DRAM capacity increase to 192Gib, will result in improved performance, however the system memory available for the OS will remain the same.
2. With 128GiB of DRAM on a system with three 320GiB drives, an increase in number of drives to four, will result in improved performance, however the system memory available for the OS will remain the same.

Tables 1 and 2 indicate the total SDM capacity for specific DRAM and Intel® Optane™ SSD configurations, optimized for performance. Using a higher number of devices for the same total capacity increases performance. Actual system memory capacity may vary by ±3% compared to the tables below. Some valid, but less frequent, configurations are not listed above. For example, it is allowed to have a quad-socket system with less than 2TB system memory, or an octa-socket system with less than 8TB system memory.

Table 1: Performance-optimized Software-defined Memory (SDM) capacity for Intel® Optane™ SSDs

Optimized	DRAM	Sockets	2	2	2	2	2	2	2	2	2	4	4	4	4	8	8
		Channels	4	4	4	4	4	4	4	4	4	8	8	8	8	8	8
		DPC	1	2	3	2	3	2	3	2	3	2	3	2	3	2	3
		DIMM size (GiB)	8	8	8	16	16	32	32	64	64	32	32	64	64	64	64
Devices	Device Size (GiB)	Total size (GiB)	64	128	192	256	384	512	768	1024	1536	2048	3072	4096	6144	8192	12288
1	320	320	349	349	512	576	704	832	1088	1344	1856	2368	3392	4416	6464	--	--
2	320	640	512	698	698	698	1024	1152	1408	1664	2176	2688	3712	4736	6784	8832	12928
3	320	960	512	1024	1048	1048	1048	1472	1728	1984	2496	3008	4032	5056	7104	9152	13248
4	320	1280	512	1024	1397	1397	1397	1397	2048	2304	2816	3328	4352	5376	7424	9472	13568
5	320	1600	512	1024	1536	1746	1746	1746	1746	2624	3136	3648	4672	5696	7744	9792	13888
6	320	1920	512	1024	1536	2048	2095	2095	2095	2944	3456	3968	4992	6016	8064	10112	14208
7	320	2240	512	1024	1536	2048	2445	2445	2445	2445	3776	4288	5312	6336	8384	10432	14528
8	320	2560	512	1024	1536	2048	2794	2794	2794	2794	4096	4608	5632	6656	8704	10752	14848
1	640	640	512	698	698	698	1024	1152	1408	1664	2176	2688	3712	4736	6784	--	--
2	640	1280	512	1024	1397	1397	1397	1397	2048	2304	2816	3328	4352	5376	7424	9472	13568
3	640	1920	512	1024	1536	2048	2095	2095	2095	2944	3456	3968	4992	6016	8064	10112	14208
4	640	2560	512	1024	1536	2048	2794	2794	2794	2794	4096	4608	5632	6656	8704	10752	14848
5	640	3200	512	1024	1536	2048	3072	3492	3492	3492	3492	5248	6272	7296	9344	11392	15488
6	640	3840	512	1024	1536	2048	3072	4096	4191	4191	4191	5888	6912	7936	9984	12032	16128
7	640	4480	512	1024	1536	2048	3072	4096	4889	4889	4889	4889	7552	8576	10624	12672	16768
8	640	5120	512	1024	1536	2048	3072	4096	5588	5588	5588	5588	8192	9216	11264	13312	17408
1	1280	1280	512	1024	1397	1397	1397	1397	2048	2304	2816	3328	4352	5376	7424	--	--
2	1280	2560	512	1024	1536	2048	2794	2794	2794	2794	4096	4608	5632	6656	8704	10752	14848
3	1280	3840	512	1024	1536	2048	3072	4096	4191	4191	4191	5888	6912	7936	9984	12032	16128
4	1280	5120	512	1024	1536	2048	3072	4096	5588	5588	5588	5588	8192	9216	11264	13312	17408
5	1280	6400	512	1024	1536	2048	3072	4096	6144	6985	6985	6985	6985	10496	12544	14592	18688
6	1280	7680	512	1024	1536	2048	3072	4096	6144	8192	8382	8382	8382	11776	13824	15872	19968
7	1280	8960	512	1024	1536	2048	3072	4096	6144	8192	9779	9779	9779	9779	15104	17152	21248
8	1280	10240	512	1024	1536	2048	3072	4096	6144	8192	11176	11176	11176	11176	16384	18432	22528
10	1280	12800	512	1024	1536	2048	3072	4096	6144	8192	12288	13970	13970	13970	13970	20992	25088

12	1280	15360	512	1024	1536	2048	3072	4096	6144	8192	12288	16384	16764	16764	16764	23552	27648
14	1280	17920	512	1024	1536	2048	3072	4096	6144	8192	12288	16384	19558	19558	19558	19558	30208
16	1280	20480	512	1024	1536	2048	3072	4096	6144	8192	12288	16384	22352	22352	22352	22352	32768

Table 2: Maximum Software-defined Memory (SDM) capacity for Intel Optane SSDs

Max DRAM	Sockets	2	2	2	2	2	2	2	2	2	4	4	4	4	8	8
	Channels	4	4	4	4	4	4	4	4	4	8	8	8	8	8	8
	DPC	1	2	3	2	3	2	3	2	3	2	3	2	3	2	3
	DIMM size (GiB)	8	8	8	16	16	32	32	64	64	32	32	64	64	64	64
Devices	Device Size (GiB)	Total size (GiB)														
1	320	320	384	448	512	576	704	832	1088	1344	1856	2368	3392	4416	6464	8512	12608
2	320	640	704	768	832	896	1024	1152	1408	1664	2176	2688	3712	4736	6784	8832	12928
3	320	960	1024	1088	1152	1216	1344	1472	1728	1984	2496	3008	4032	5056	7104	9152	13248
4	320	1280	1344	1408	1472	1536	1664	1792	2048	2304	2816	3328	4352	5376	7424	9472	13568
5	320	1600	1664	1728	1792	1856	1984	2112	2368	2624	3136	3648	4672	5696	7744	9792	13888
6	320	1920	1984	2048	2112	2176	2304	2432	2688	2944	3456	3968	4992	6016	8064	10112	14208
7	320	2240	2304	2368	2432	2496	2624	2752	3008	3264	3776	4288	5312	6336	8384	10432	14528
8	320	2560	2624	2688	2752	2816	2944	3072	3328	3584	4096	4608	5632	6656	8704	10752	14848
1	640	640	704	768	832	896	1024	1152	1408	1664	2176	2688	3712	4736	6784	8832	12928
2	640	1280	1344	1408	1472	1536	1664	1792	2048	2304	2816	3328	4352	5376	7424	9472	13568
3	640	1920	1984	2048	2112	2176	2304	2432	2688	2944	3456	3968	4992	6016	8064	10112	14208
4	640	2560	2624	2688	2752	2816	2944	3072	3328	3584	4096	4608	5632	6656	8704	10752	14848
5	640	3200	3264	3328	3392	3456	3584	3712	3968	4224	4736	5248	6272	7296	9344	11392	15488
6	640	3840	3904	3968	4032	4096	4224	4352	4608	4864	5376	5888	6912	7936	9984	12032	16128
7	640	4480	4032	4608	4672	4736	4864	4992	5248	5504	6016	6528	7552	8576	10624	12672	16768
8	640	5120	4032	5248	5312	5376	5504	5632	5888	6144	6656	7168	8192	9216	11264	13312	17408
1	1280	1280	1344	1408	1472	1536	1664	1792	2048	2304	2816	3328	4352	5376	7424	9472	13568
2	1280	2560	2624	2688	2752	2816	2944	3072	3328	3584	4096	4608	5632	6656	8704	10752	14848
3	1280	3840	3904	3968	4032	4096	4224	4352	4608	4864	5376	5888	6912	7936	9984	12032	16128
4	1280	5120	4032	5248	5312	5376	5504	5632	5888	6144	6656	7168	8192	9216	11264	13312	17408
5	1280	6400	4032	6528	6592	6656	6784	6912	7168	7424	7936	8448	9472	10496	12544	14592	18688
6	1280	7680	4032	7808	7872	7936	8064	8192	8448	8704	9216	9728	10752	11776	13824	15872	19968
7	1280	8960	4032	8064	9152	9216	9344	9472	9728	9984	10496	11008	12032	13056	15104	17152	21248
8	1280	10240	4032	8064	10432	10496	10624	10752	11008	11264	11776	12288	13312	14336	16384	18432	22528
10	1280	12800	4032	8064	12096	13056	13184	13312	13568	13824	14336	14848	15872	16896	18944	20992	25088
12	1280	15360	4032	8064	12096	15616	15744	15872	16128	16384	16896	17408	18432	19456	21504	23552	27648
14	1280	17920	4032	8064	12096	16128	18304	18432	18688	18944	19456	19968	20992	22016	24064	26112	30208
16	1280	20480	4032	8064	12096	16128	20864	20992	21248	21504	22016	22528	23552	24576	26624	28672	32768

Note: Higher capacity drives (640 GiB, and 1280 GiB) will be added in the future.

4.5 Optimized Workload Settings

This section lists generic recommendations for software stack setup in an environment using Intel Memory Drive Technology. Intel may publish application-specific guidelines in “Application Notes” documents; consult the support library for the same.

4.5.1 Operating System

1. Intel recommends using recent builds of supported popular Linux distributions (or clones) such as Redhat 7.x / CentOS 7.x or SLES 12.x
2. Intel Memory Drive Technology also supports Open Source hypervisors such as KVM and Xen, as shipped with the major Linux distributions

4.5.2 Memory Settings, Memory allocators

It is recommended that memory allocators be configured to use large pages (as example Linux Transparent Huge Pages (THP)), while correctly configuring them to (1) save on memory use, and (2) avoid memory fragmentation. For example, if your application was precompiled with the default libc allocator or with jemalloc, or makes use of them using the OS dynamic linker, please use the following guidelines:

1. For jemalloc, ensure THP operation is maintained by running the command:

```
# ln -sf 'lg_dirty_mult:-1' /etc/malloc.conf
```

2. For libc, the following environment variables may be useful to increase memory allocation size by the application, and to reduce virtualization overheads:

```
# export MALLOC_TOP_PAD_=$((16777216))
# export MALLOC_TRIM_THRESHOLD_=$((16777216))
```

4.5.3 Application Settings

Parallelism or concurrency yield great benefits with Intel Memory Drive Technology. Make sure your application is configured to use many threads where available, in order to process data. CPU over-subscription increases the throughput of the product, as it allows issuing multiple fetch requests from the Optane SSD concurrently.

4.6 4.7 Performance Data Collection

Intel Memory Drive Technology provides tools for collecting performance-related statistics. The tools are installed into /usr/local/{etc,bin} on the machine the installer was running on, at stages 3.8, 3.9 and 3.10.

To activate periodic statistics data collection, use the following command, which records the counters every 60 seconds into an /tmp/stats (make sure this directory is not ramfs/tmpfs, but rather a directory located on a direct-attached storage device):

```
# cd /tmp/stats; vsmpstat --outfile 60
```

To start the performance collection at boot, add the following to your crontab file (with crontab -e):

```
@reboot     (cd /tmp/stats && vsmpstat --outfile 60)
```

After workload is completed, share a zipped/tar archive of the files collected, or the target directory (/tmp/stats in the example above), and share it with the Intel support team.

4.7 If Installation Fails

Please ensure that you are using a supported OS distribution and certified Intel NVMe SSDs. See Specifications in Section 5.

4.7.1 Common Installation Error Codes

During the boot process, Intel Memory Drive Technology may issue warnings and errors to the console, in many cases using error codes. Table 1 below lists the most common error codes, their explanations, and suggested path to resolution.

Error Code	Error Description	Proposed process for handling
279 / 700	Boot devices is not detected	Contact Intel Support

500	Intel Memory Drive Technology license not found	Reinstall licenses per Section 3.1 If licenses expired - obtain new licenses
70x	More than one USD/IDE Flash device found to have Intel Memory Drive Install. This error only happens when booting in Legacy mode.	Remove all moveable media that includes Intel Memory Drive software, and reinstall it again one device only.
1311	Legacy VGA BIOS not found. This error only happens when booting in UEFI mode.	Change BIOS configuration change allowing Legacy VGA support in UEFI

§

5 Specifications

Capacity	320 GiB[1,2,3]
Form Factors	PCIe® 3.0 x4 Add-in-Card (AIC)[4]; Half-height, Half-length, Low-profile
Operating Systems	RHEL* 6.5, 6.6, 6.7, 6.8 ,7.0, 7.1, 7.2, 7.3 SLES* 11 SP4, 12, 12 SP1, 12 SP2 Intel® Memory Drive Technology software[5] supports UEFI boot, or alternatively requires a bootable media. Supported protocols: IDE, UHCI, and EHCI. Linux OS must be installed in legacy (non-UEFI) mode
Supported Processors	Intel® Xeon® E5-x6xx v3 or later, E7-x8xx v3 or later Intel Xeon Bronze, Silver, Gold, or Platinum
Maximum Processor Sockets	8
Maximum Software-defined Memory	64 TiB[1]
Recommended DRAM Expansion	Up to 8x[6]
Power	AIC: 12V (3.3V Aux) Supply Rail Active/Idle: Up to 18 W/5 W (TYP)
Temperature Specification	Operating: 0-50° C ambient with specified airflow Airflow requirement to prevent throttling: Local Ambient T[7,8] 35° C 100 LFM/drive 50° C 400 LFM/drive Non-Operating[9]: -55 to 85° C
Data Retention	Shipping – 3 days for up to 85° C Storage – 3 months for up to 60° C Power off – Not Applicable
Hot-plug	Hot-plug is not supported
Compliance	PCI Express® Base Specification Rev 3.0 Enterprise SSD Form Factor Version 1.0a PCI Express Card Electro-Mechanical Specification Rev 2.0 and 3.0
Certifications and Declarations	UL*, CE*, C-Tick*, BSMI*, KCC*, VCCI*, CAN/CSA*
Product Ecological Compliance	RoHS*, WEEE*

1. GiB = 1,073,741,824 bytes, TiB = 1,099,511,627,776 bytes
2. Total physical capacity is 375GB. Total usable capacity towards Memory Drive is 320 GiB.
3. Intel® Memory Drive Technology software will be offered on higher capacity Intel® Optane™ SSDs at a later date.
4. Intel® Optane™ SSDs with Intel® Memory Drive Technology software will be offered in the U.2 form factor at a later date.
5. Technology licensed from ScaleMP*
6. For example: 128GiB DRAM can be expanded up to 1024GiB based on the capacity of NVMe media installed. Higher expansion ratios may be supported, with possibly suboptimal performance.
7. Local ambient temperature is measured at the inlet to the SSD.
8. LFM (Linear Feet per Minute) airflow measured at the approach area of the SSD.
9. Please contact your Intel representative for details on the non-operating temperature range.

§