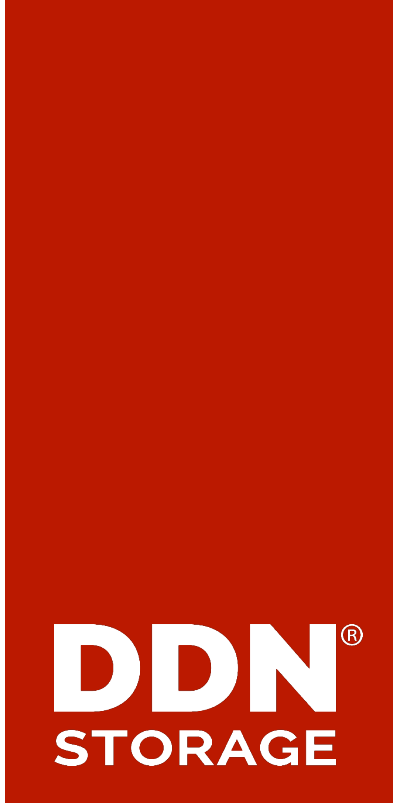

Lustre Data on MDT – an early look

LUG 2018 - April 2018
Argonne National Laboratory

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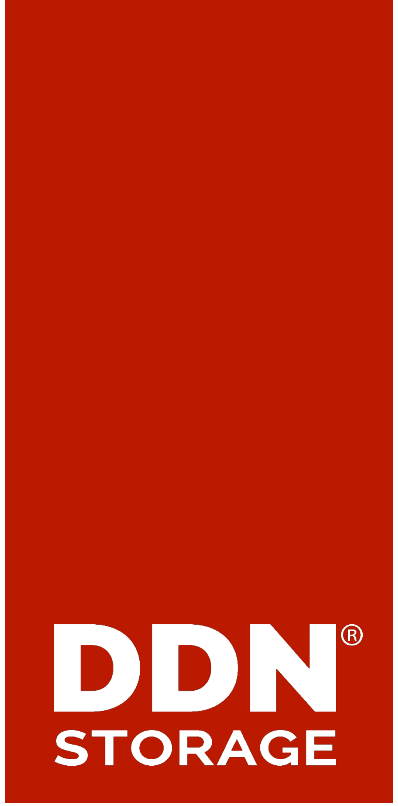
DDN Performance Engineering

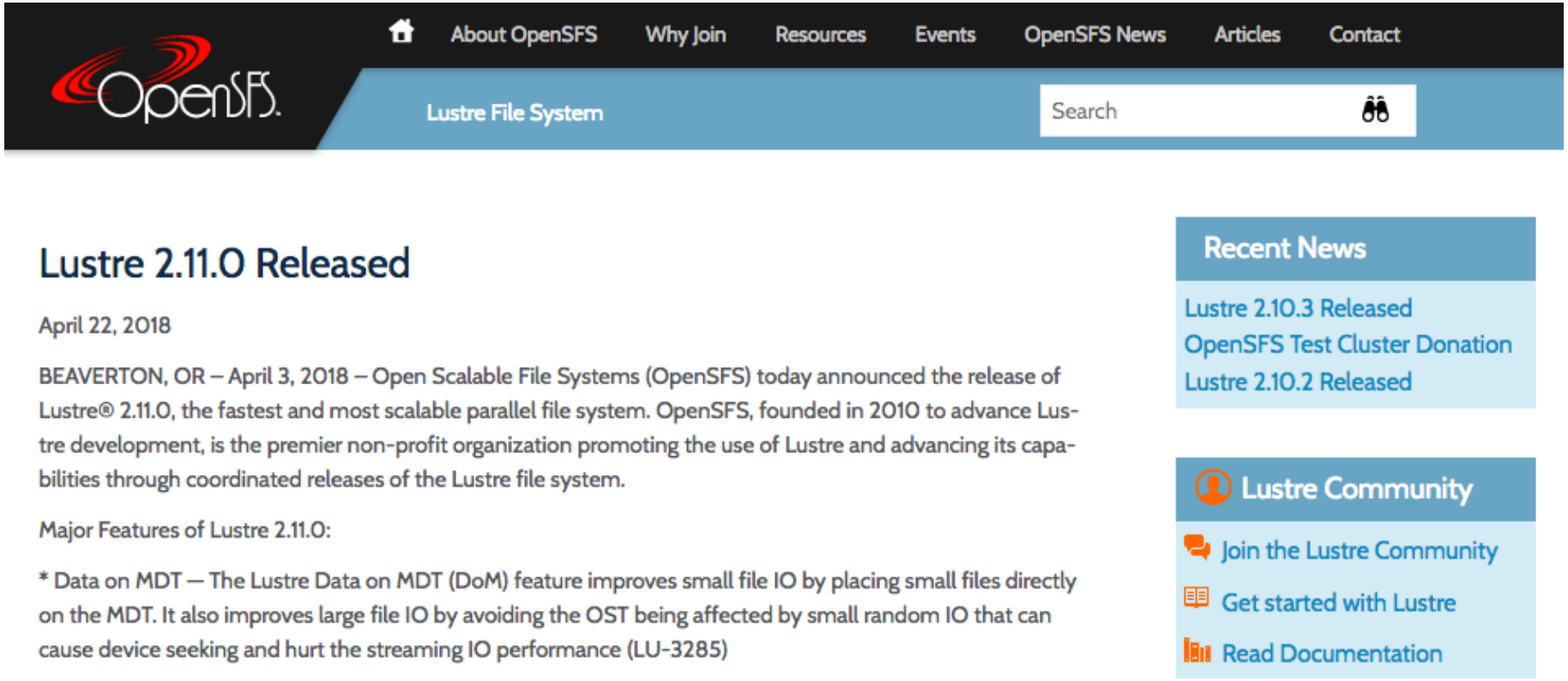
Agenda

- DoM Overview
- Practical Usage
- Performance Investigation
  - Test Environment
  - Test Cases
- Next Steps



Data on MDT Overview

DoM Overview – Release Announcement



"The Lustre Data-on-MDT (DoM) feature improves small file IO by placing small files on the MDT.

DoM also improves large file IO by avoiding the OST being affected by small random IO that can cause device seeking and hurt the streaming IO performance."

DoM Overview – Benefits and Definition

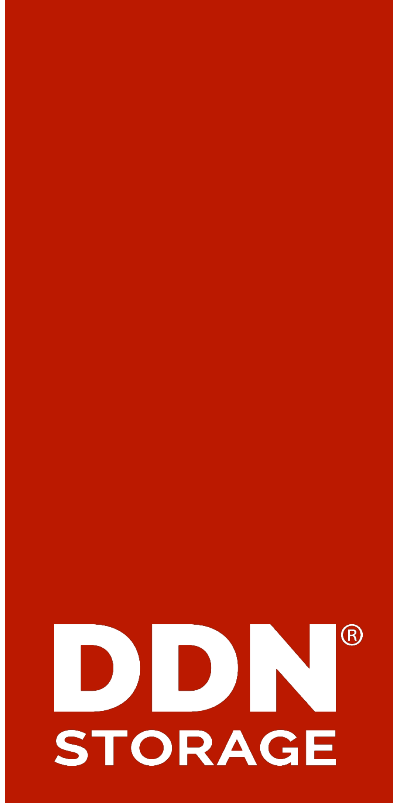
- Optimize small file I/O
  - Avoid OST RPC overhead

  "The Data On MDT (DOM) project aims to improve small file performance by allowing the data for small files to be placed only on the MDT, so that additional RPCs and I/O overhead can be eliminated, and performance correspondingly improved. "

  - Take advantage of flash-based MDT for small(er) files

  "Since the MDT storage is typically configured as high-IOPS RAID-1+0 and optimized for small IO, Data-on-MDT will also be able to leverage this faster storage."

  - Separates small-block workload from HDD-based sequential large(er)-block
- Works with DNE, PFL
- Feature parity (or better) with other PFS' similar feature
  - i.e. Spectrum Scale *large* inodes, which can hold ~3400 bytes of file data in a 4KB inode



DoM – Practical Usage

Functionality – dom_stripesize

Functionality – dom_stripesize – Defaults / Changing / Query

The LOD parameter **dom_stripesize** is used to control per MDS maximum size for a DoM component on a given MDT.

- Default dom_stripesize is 1MB
- Minimum dom_stripesize is 64KB
- Maximum dom_stripesize is 1GB

Changing dom_stripesize:

```
# lctl set_param lod.*MDT<index>*.dom_stripesize=<value in bytes>
# lctl conf_param lod.*MDT<index>*.dom_stripesize=<value in bytes>
```

Checking dom_stripesize:

```
# lctl get_param lod.*MDT<index>*.dom_stripesize
```

Functionality – dom_stripesize cont'd. – Change Example

Changing dom_stripesize

```
# clush –bgmds 'lctl set_param –n lod.*MDT000*.dom_stripesize=65536'

# clush –bgmds 'lctl get_param –n lod.*MDT000*.dom_stripesize'
---------------
mds[0-1] (2)
---------------
65536
65536
65536
65536

# clush –bgmds 'lctl set_param –n lod.*MDT000*.dom_stripesize=32768'
#     ← no complaints
# clush –bgmds 'lctl get_param –n lod.*MDT000*.dom_stripesize'
---------------
mds[0-1] (2)
---------------
1048576
1048576
1048576
1048576
```

Note: We didn't see an error when attempting to set dom_stripesize lower, i.e. 32KB – but this results in the value getting reset to the default of 1MB. See example above.

The next "lfs setstripe –L mdt ..." operation shows that the value is indeed now set to 1MB

Also, setting dom_stripesize to a non-64KB-aligned value will round down to the nearest 64KB boundary.

Functionality – dom_stripesize cont'd. – more Change Examples

128KB and 4MB are valid. > 1GB is not supported

```
# lctl set_param lod.*MDT000*.dom_stripesize=131072
# lctl get_param -n lod.*MDT000*.dom_stripesize
131072      (128KB)

# lctl set_param lod.*MDT000*.dom_stripesize=$((1048576*4))
# lctl get_param -n lod.*MDT000*.dom_stripesize
4194304      (4MB)
```

```
# lctl set_param lod.*MDT000*.dom_stripesize=$((1048576*1024))
# lctl get_param -n lod.*MDT000*.dom_stripesize
1073741824   (1024MB)              OK, 1GB works!


# lctl set_param lod.*MDT0000*.dom_stripesize=$((1048576*1025))
error: set_param: setting /proc/fs/lustre/lod/domfs-MDT0000-mdtlov/dom_stripesize=1074790400:
Numerical result out of range


# lctl get_param -n lod.*MDT0000*.dom_stripesize
1073741824   (1GB)                 1025MB is too Big, but 1GB value retained
```

Functionality – dom_stripesize cont'd. – turning it off

Disable for all MDTs, then verify

```
# clush -bgmds 'lctl set_param lod.*MDT000*.dom_stripesize=0'
# clush -bgmds 'lctl get_param -n lod.*MDT000*.dom_stripesize'
---------------
mds[0-1] (2)
---------------
0
0
0
0
```

Can we create a new DoM-backed file when dom_stripesize is zero?

```
# lfs setstripe -L mdt -E1M DNE.2c.file1
lfs setstripe: cannot create composite file 'DNE.2c.file1': Invalid argument
```

No!

Functionality – dom_stripesize cont'd. - procfs

There are procfs entries:

```
# clush -bgmds 'find /proc/fs/lustre/ -name stripesize'
---------------
mds0
---------------
/proc/fs/lustre/lod/domfs-MDT0000-mdtlov/stripesize
/proc/fs/lustre/lod/domfs-MDT0001-mdtlov/stripesize
/proc/fs/lustre/lod/domfs-MDT0002-mdtlov/stripesize
/proc/fs/lustre/lod/domfs-MDT0003-mdtlov/stripesize
/proc/fs/lustre/lov/domfs-clilov-ffff883f76242000/stripesize
---------------
mds1
---------------
/proc/fs/lustre/lod/domfs-MDT0004-mdtlov/stripesize
/proc/fs/lustre/lod/domfs-MDT0005-mdtlov/stripesize
/proc/fs/lustre/lod/domfs-MDT0006-mdtlov/stripesize

# clush -bgmds 'cat /proc/fs/lustre/lod/domfs-MDT000*-mdtlov/dom_stripesize'
---------------
mds[0-1] (2)
---------------
0
0
0
0
```

Read-Only – echoing a value into stripesize doesn't effect change

We heard from James Simmons on Tuesday, that /proc entries for lustre are going away, so ....

Components and Striping

DoM Overview – Component Layout

- PFL for Data on MDT
  - DoM layout is organized as a Progressive File Layout, which occupies the first entry describing the MDT stripe. The PFL semantics enable a DoM file to grow into OSTs.
  - In the example diagram below, Component 1 is a 1MB stripe, component 2 covers 1MB -> EOF, and is striped over all available OSTs .

```
# lfs setstripe –L mdt –E 1M –E –1 –S 4M fubar
```

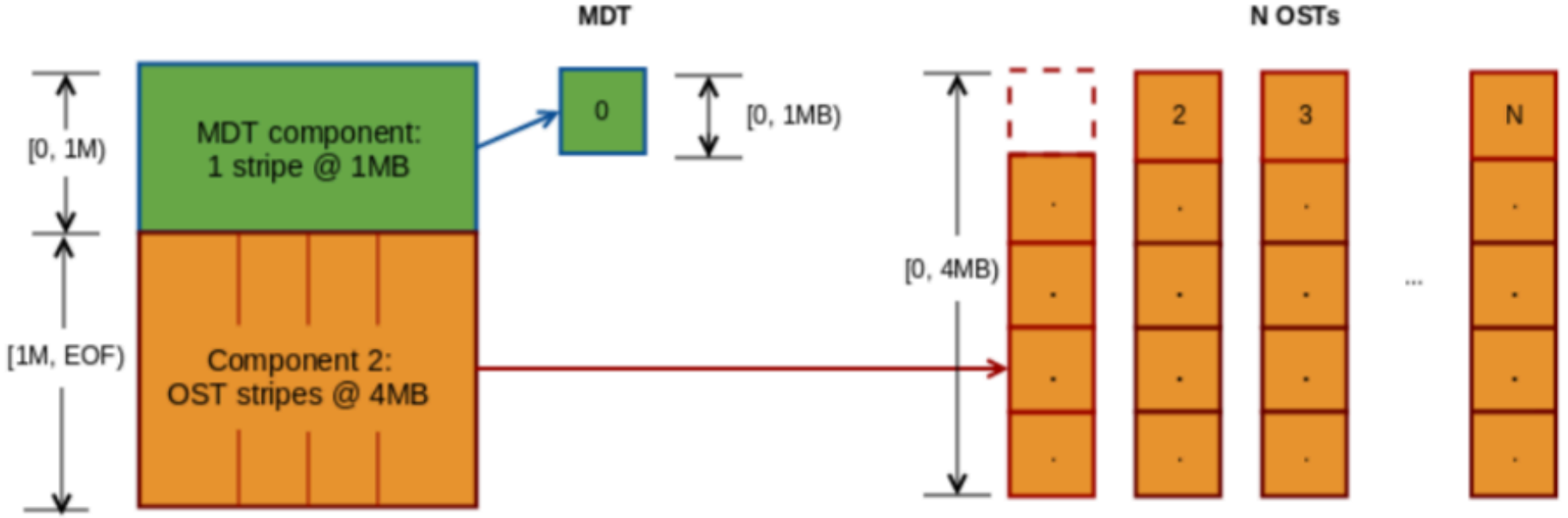


Image Source: Data-on-MDT (DoM) User Guide

Usage – lfs (setstripe) options used with DoM

LFS-SETSTRIPE(1) Lustre Utilities LFS-SETSTRIPE(1)

NAME

lfs setstripe - set striping pattern of a file or directory default

SYNOPSIS

lfs setstripe {--component-end|-E end1} [STRIPE_OPTIONS] [{--component-end|-E end2} [STRIPE_OPTIONS] ...] <filename>

Create a file with the specified composite layout.
Each component defines the stripe pattern of the file in the range of [start, end].
The first component implicitly starts at offset 0, and all later components start at the end of previous extent.
The -E option is used to specify the end offset of each component, and it also indicates the following STRIPE_OPTIONS are for this component. The end offset of -1 or EOF indicates the component extends to end of file.

<STRIPE_OPTIONS for DoM>

-L, --layout <layout type>

The type of stripe layout, can be RAID0, released or **mdt**. It is raid0 by default.
The mdt type allows place the first component of the file on the MDT where the inode is located.
This is used with composite file layouts and can be defined as first component only.
The stripe_size of MDT part is always equal to the component size.
There is also per-MDT parameter lod.dom_stripesize to limit maximum size of DoM stripe which can be changed with lctl set_param command, (e.g. lctl set_param lod.*.dom_stripesize=0)

Usage – lfs setstripe no-no's, and ... rules

lfs setstripe -E 1G -L mdt -E 1G -L mdt -E 1G -L mdt foo
error: 'mdt' layout can be only the first one

lfs setstripe -E 1G -L mdt -c 2 foo
Option 'stripe-count' can't be specified with Data-on-MDT component: 2

lfs setstripe -E 1G -L mdt -S 2M foo
Option 'stripe-size' can't be specified with Data-on-MDT component: 2147483648

Guidelines and Restrictions

- The layout of a DoM file is stored on disk as a *composite layout* and is a special case of a PFL file.
- For DoM files, the file layout is composed of the first special component which is placed on MDT and rest of components on OSTs.
- The first component has MDT layout which is a new layout type, and is placed on an MDT in MDT object data blocks.
- MDT component is always a single stripe, with size equal to the component size - no –S (stripe size) or –c (stripe count) arguments.
- The rest of the components are placed over OSTs as usual with RAID0 layout.
- The OST components are not instantiated until file growth beyond the limit of MDT layout.
- If a DoM layout is set on an existing directory, all subsequent files created will inherit this layout.

Usage – lfs find is DoM-aware! - Examples:

Find all files with DoM layout

```
# lfs find -L mdt . | wc -l
3200362
```

Find DoM files with a 1M stripe size

```
# lfs find DOM-7-MDT -L mdt -S 1M | head -8
DOM-7-MDT
DOM-7-MDT/mdtestdir
DOM-7-MDT/mdtestdir/#test-dir.1
DOM-7-MDT/mdtestdir/#test-dir.1/mdtest_tree.95.0
DOM-7-MDT/mdtestdir/#test-dir.1/mdtest_tree.95.0/file.mdtest.95.3412
DOM-7-MDT/mdtestdir/#test-dir.1/mdtest_tree.95.0/file.mdtest.95.2269
DOM-7-MDT/mdtestdir/#test-dir.1/mdtest_tree.95.0/file.mdtest.95.7863
DOM-7-MDT/mdtestdir/#test-dir.1/mdtest_tree.95.0/file.mdtest.95.1351
```

Find DoM directories with stripe size less than 180K

```
# lfs find -L mdt -S -180K -type d .
./128K
./64K
```

```
# lfs getstripe DOM-7-MDT/mdtestdir/#test-
dir.1/mdtest_tree.95.0/file.mdtest.95.3412

DOM-7-MDT/mdtestdir/#test-dir.1/mdtest_tree.
95.0/                   2
  lcm_layout_gen:    1
  lcm_mirror_count:  1
  lcm_entry_count:   1
    lcme_id:             1
    lcme_mirror_id:      0
    lcme_flags:          init
    lcme_extent.e_start: 0
    lcme_extent.e_end:   1048576
      lmm_stripe_count:  0
      lmm_stripe_size:   1048576
      lmm_pattern:       mdt
      lmm_layout_gen:    0
      lmm_stripe_offset: 0
```

Let’s see a few lfs setstripe usage examples

File example – data only on MDT – 1MB

```
# lfs setstripe -L mdt -E 1M DoM.1c.file1
```

1. 0-1MB on DoM MDT

```
DoM.1c.file1
  lcm_layout_gen:    1
  lcm_mirror_count:  1
  lcm_entry_count:   1
    lcme_id:             1
    lcme_mirror_id:      0
    lcme_flags:          init
    lcme_extent.e_start: 0
    lcme_extent.e_end:   1048576
      lmm_stripe_count:  0
      lmm_stripe_size:   1048576
      lmm_pattern:       mdt
      lmm_layout_gen:    0
      lmm_stripe_offset: 0
```


```
# dd if=/dev/zero of=DoM.1c.file1 bs=1M count=10
dd: error writing ‘DoM.1c.file1’: No data available
2+0 records in
1+0 records out
1048576 bytes (1.0 MB) copied, 0.00286129 s, 366 MB/s

# ls -lh DoM.1c.file1
-rw-r--r-- 1 root root 1.0M Apr 13 13:42 DoM.1c.file1
```

File example – data on 1MDT for 1MB, then restricted to 1 OST

```
# lfs setstripe  -L mdt -E 1M   -E -1 -S 1M      DoM.2c.file1
```

1. 0-1MB on DoM MDT
2. 1MB-EOF – restrict to 1 OST at 1MB stripe

```
DoM.2c.file1
  lcm_layout_gen:    2
  lcm_mirror_count:  1
  lcm_entry_count:   2
    lcme_id:             1
    lcme_mirror_id:      0
    lcme_flags:          init
    lcme_extent.e_start: 0
    lcme_extent.e_end:   1048576
      lmm_stripe_count:  0
      lmm_stripe_size:   1048576
      lmm_pattern:       mdt
      lmm_layout_gen:    0
      lmm_stripe_offset: 0
    ----------------------------
    lcme_id:             2
    lcme_mirror_id:      0
    lcme_flags:          0
    lcme_extent.e_start: 1048576
    lcme_extent.e_end:   EOF
      lmm_stripe_count:  1
      lmm_stripe_size:   1048576
      lmm_pattern:       raid0
      lmm_layout_gen:    0
      lmm_stripe_offset: -1
```

...write some data, get an object

```
DoM.2c.file1
  lcm_layout_gen:    3
  lcm_mirror_count:  1
  lcm_entry_count:   2
    lcme_id:             1
    lcme_mirror_id:      0
    lcme_flags:          init
    lcme_extent.e_start: 0
    lcme_extent.e_end:   1048576
      lmm_stripe_count:  0
      lmm_stripe_size:   1048576
      lmm_pattern:       mdt
      lmm_layout_gen:    0
      lmm_stripe_offset: 0
    ----------------------------
    lcme_id:             2
    lcme_mirror_id:      0
    lcme_flags:          init
    lcme_extent.e_start: 1048576
    lcme_extent.e_end:   EOF
      lmm_stripe_count:  1
      lmm_stripe_size:   1048576
      lmm_pattern:       raid0
      lmm_layout_gen:    0
      lmm_stripe_offset: 8
      lmm_objects:
      - 0: { l_ost_idx: 8, l_fid: [0x100080000:0x349639:0x0] }
```

File example – data on 1MDT for 1GB, then stripe across all OSTs

```
# lfs setstripe -L mdt -E 1G -E -1 -S 4M -c -1 DoM.2c.file2
```

1. 0-**1GB** on DoM MDT
2. 1GB-EOF – across all OSTs at 4MB stripesz

14 OSTs preset in this filesystem

```
DoM.2c.file2
  lcm_layout_gen:    2
  lcm_mirror_count:  1
  lcm_entry_count:   2
    lcme_id:             1
    lcme_mirror_id:      0
    lcme_flags:          init
    lcme_extent.e_start: 0
    lcme_extent.e_end:   1073741824
      lmm_stripe_count:  0
      lmm_stripe_size:   1073741824
      lmm_pattern:       mdt
      lmm_layout_gen:    0
      lmm_stripe_offset: 0
```

```
lcme_id:             2
lcme_mirror_id:      0
lcme_flags:          init
lcme_extent.e_start: 1073741824
lcme_extent.e_end:   EOF
  lmm_stripe_count:  14
  lmm_stripe_size:   4194304
  lmm_pattern:       raid0
  lmm_layout_gen:    0
  lmm_stripe_offset: 10
  lmm_objects:
  - 0: { l_ost_idx: 10, l_fid: [0x1000a0000:0x349338:0x0] }
  - 1: { l_ost_idx: 0, l_fid: [0x100000000:0x345c66:0x0] }
  - 2: { l_ost_idx: 7, l_fid: [0x100070000:0x349679:0x0] }
  - 3: { l_ost_idx: 3, l_fid: [0x100030000:0x3475e9:0x0] }
  - 4: { l_ost_idx: 9, l_fid: [0x100090000:0x346129:0x0] }
  - 5: { l_ost_idx: 2, l_fid: [0x100020000:0x3471a9:0x0] }
  - 6: { l_ost_idx: 13, l_fid: [0x1000d0000:0x346829:0x0] }
  - 7: { l_ost_idx: 5, l_fid: [0x100050000:0x364209:0x0] }
  - 8: { l_ost_idx: 11, l_fid: [0x1000b0000:0x348749:0x0] }
  - 9: { l_ost_idx: 6, l_fid: [0x100060000:0x345409:0x0] }
  - 10: { l_ost_idx: 12, l_fid: [0x1000c0000:0x349899:0x0] }
  - 11: { l_ost_idx: 1, l_fid: [0x100010000:0x34b789:0x0] }
  - 12: { l_ost_idx: 8, l_fid: [0x100080000:0x34963a:0x0] }
  - 13: { l_ost_idx: 4, l_fid: [0x100040000:0x34d338:0x0] }
```

DoM + PFL example – 4 components: DoM, 1/4/all OSTs

```
# lfs setstripe –E 1M –L mdt –E 64M –c1 –S 1M –E 8G –c4 –E –1 –c –1 –S 4M DNE.PFL.file1
```

```
DoM.PFL.file1
  lcm_layout_gen:    6
  lcm_mirror_count:  1
  lcm_entry_count:   4
    lcme_id:             1
    lcme_mirror_id:      0
    lcme_flags:          init
    lcme_extent.e_start: 0
    lcme_extent.e_end:   1048576
      lmm_stripe_count:  0
      lmm_stripe_size:   1048576
      lmm_pattern:       mdt
      lmm_layout_gen:    0
      lmm_stripe_offset: 0
    ---------------------------
    lcme_id:             2
    lcme_mirror_id:      0
    lcme_flags:          init
    lcme_extent.e_start: 1048576
    lcme_extent.e_end:   67108864
      lmm_stripe_count:  1
      lmm_stripe_size:   1048576
      lmm_pattern:       raid0
      lmm_layout_gen:    0
      lmm_stripe_offset: 10
      lmm_objects:
      - 0: { l_ost_idx: 10, l_fid: [0x1000a0000:0x349339:0x0] }
    ---------------------------
    lcme_id:             3
    lcme_mirror_id:      0
    lcme_flags:          init
    lcme_extent.e_start: 67108864
    lcme_extent.e_end:   8589934592
      lmm_stripe_count:  4
      lmm_stripe_size:   1048576
      lmm_pattern:       raid0
      lmm_layout_gen:    0
      lmm_stripe_offset: 0
      lmm_objects:
      - 0: { l_ost_idx: 0, l_fid: [0x100000000:0x345c67:0x0] }
      - 1: { l_ost_idx: 7, l_fid: [0x100070000:0x34967a:0x0] }
      - 2: { l_ost_idx: 3, l_fid: [0x100030000:0x3475ea:0x0] }
      - 3: { l_ost_idx: 9, l_fid: [0x100090000:0x34612a:0x0] }
```

1. 0-1MB on DoM MDT
2. 1-64MB on 1 stripe of 1MB stripesz
3. 64M-8GB on 4 OSTs at default stripesz
4. 8GB-EOF across all OSTs at 4MB stripesz

```
lcme_id:             4
   lcme_mirror_id:      0
   lcme_flags:          init
   lcme_extent.e_start: 8589934592
   lcme_extent.e_end:   EOF
     lmm_stripe_count:  14
     lmm_stripe_size:   4194304
     lmm_pattern:       raid0
     lmm_layout_gen:    0
     lmm_stripe_offset: 13
     lmm_objects:
     - 0: { l_ost_idx: 13, l_fid: [0x1000d0000:0x34682a:0x0] }
     - 1: { l_ost_idx: 5, l_fid: [0x100050000:0x36420a:0x0] }
     - 2: { l_ost_idx: 11, l_fid: [0x1000b0000:0x34874a:0x0] }
     - 3: { l_ost_idx: 6, l_fid: [0x100060000:0x34540a:0x0] }
     - 4: { l_ost_idx: 12, l_fid: [0x1000c0000:0x34989a:0x0] }
     - 5: { l_ost_idx: 1, l_fid: [0x100010000:0x34b78a:0x0] }
     - 6: { l_ost_idx: 8, l_fid: [0x100080000:0x34963b:0x0] }
     - 7: { l_ost_idx: 4, l_fid: [0x100040000:0x34d339:0x0] }
     - 8: { l_ost_idx: 2, l_fid: [0x100020000:0x3471aa:0x0] }
     - 9: { l_ost_idx: 10, l_fid: [0x1000a0000:0x34933a:0x0] }
     - 10: { l_ost_idx: 0, l_fid: [0x100000000:0x345c68:0x0] }
     - 11: { l_ost_idx: 7, l_fid: [0x100070000:0x34967b:0x0] }
     - 12: { l_ost_idx: 3, l_fid: [0x100030000:0x3475eb:0x0] }
     - 13: { l_ost_idx: 9, l_fid: [0x100090000:0x34612b:0x0] }
```

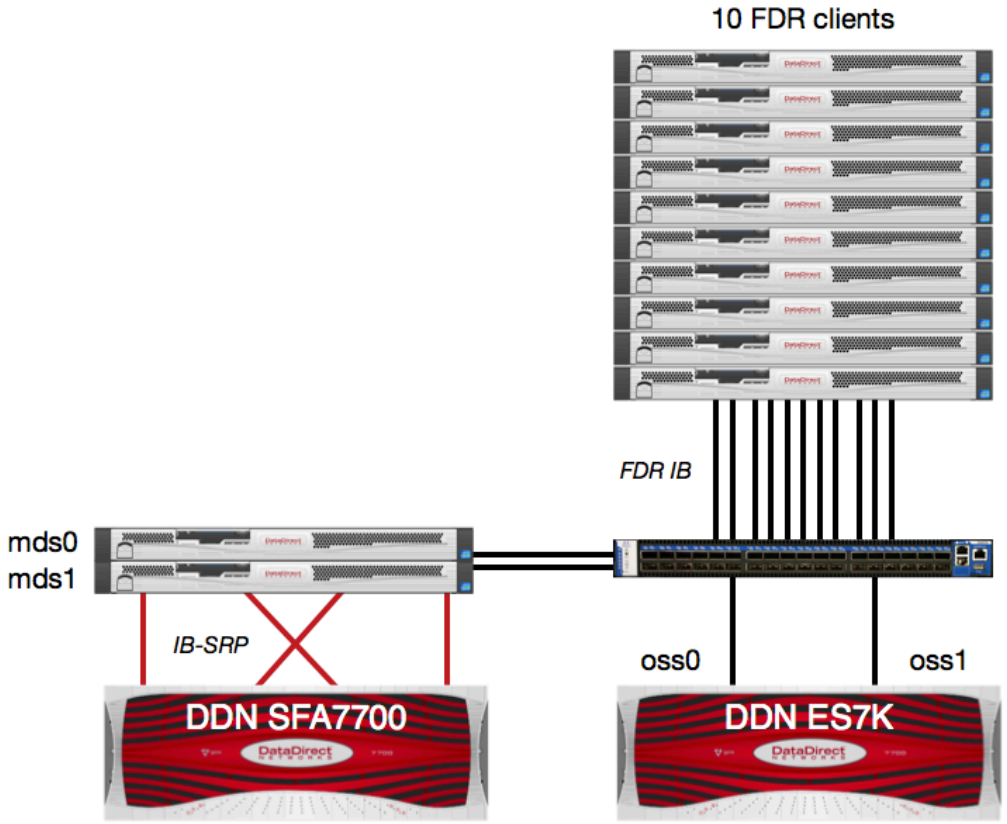
Testing – Environment, Configuration

- Collection of hardware that we tested on – description and diagrams
- Software versions and filesystem information

Test Environment - Hardware

Hardware Configuration

- Metadata
  - SFA7700-IB
  - 2 Dell R640, 2 CX-3 ea.
  - 8 RAID6 4+2 SSD MDT LUNs
  - 1 RAID1 SSD MGT LUN
- Data
  - ES7K
  - 2 VM OSS
  - 14 RAID6 8+2 NLSAS OST LUNs
- Clients
  - 10 Dell R620, 1 FDR LNET ea.
- FDR Infiniband fabric



Test Environment – Software Stack

- MDS R640 servers
  - EXAScaler ***HPC*** CentOS 4.0.0-r2.lustre_upstream
  - lustre-2.11.50_51_g8d37637-1.el7.x86_64
  - kernel 3.10.0-693.21.1.el7.x86_64.lustre

- ES7K vOSS
  - EXAScaler ***SFA*** CentOS 4.0.0-r2.lustre_upstream
  - lustre-2.11.50_51_g8d37637-1.el7.x86_64
  - kernel 3.10.0-693.21.1.el7.x86_64.lustre

- Clients
  - lustre-client-2.11.50_51_g8d37637-1.el7.centos.x86_64
  - kernel 3.10.0-693.el7.x86_64

- Common
  - CentOS Linux release 7.4.1708 (Core)

- SFA platforms
  - SFAOS 3.1.3.0 41240

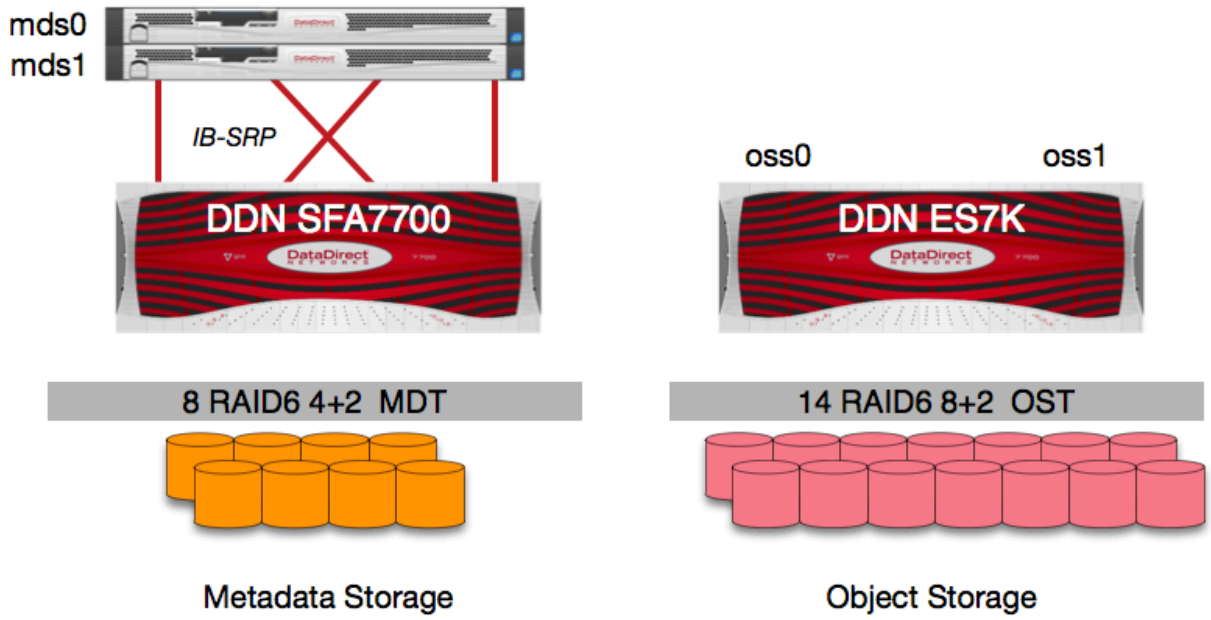
- Tuning
  - osc.*.max_pages_per_rpc=16M
  - osc.*.max_rpcs_in_flight=32

Test Case I mdtest

- **1a:** SSD non-DoM MDT + HDD OST – mdtest w/file size scaling, (no DoM)
- **1b:** SSD DoM MDT – mdtest w/file size scaling, no OST I/O

Test Case 1 mdtest – storage allocation

- Metadata – MDT
  - 8 RAID6 4+2 SSD MDT LUNs
- Data – OST
  - 14 RAID6 8+2 NLSAS OST LUNs



Test case 1a: mdtest – non-DoM MDT, HDD OST

Test case 1a: mdtest - non-DoM MDT + SAS OST – details

Set up directories. Create 1 per MDT using *lfs mkdir –I <index>*

```
for i in 0 1 2 3 4 5 6 7; do lfs mkdir –i ${i} MDT${i}; done
```

This leaves us with

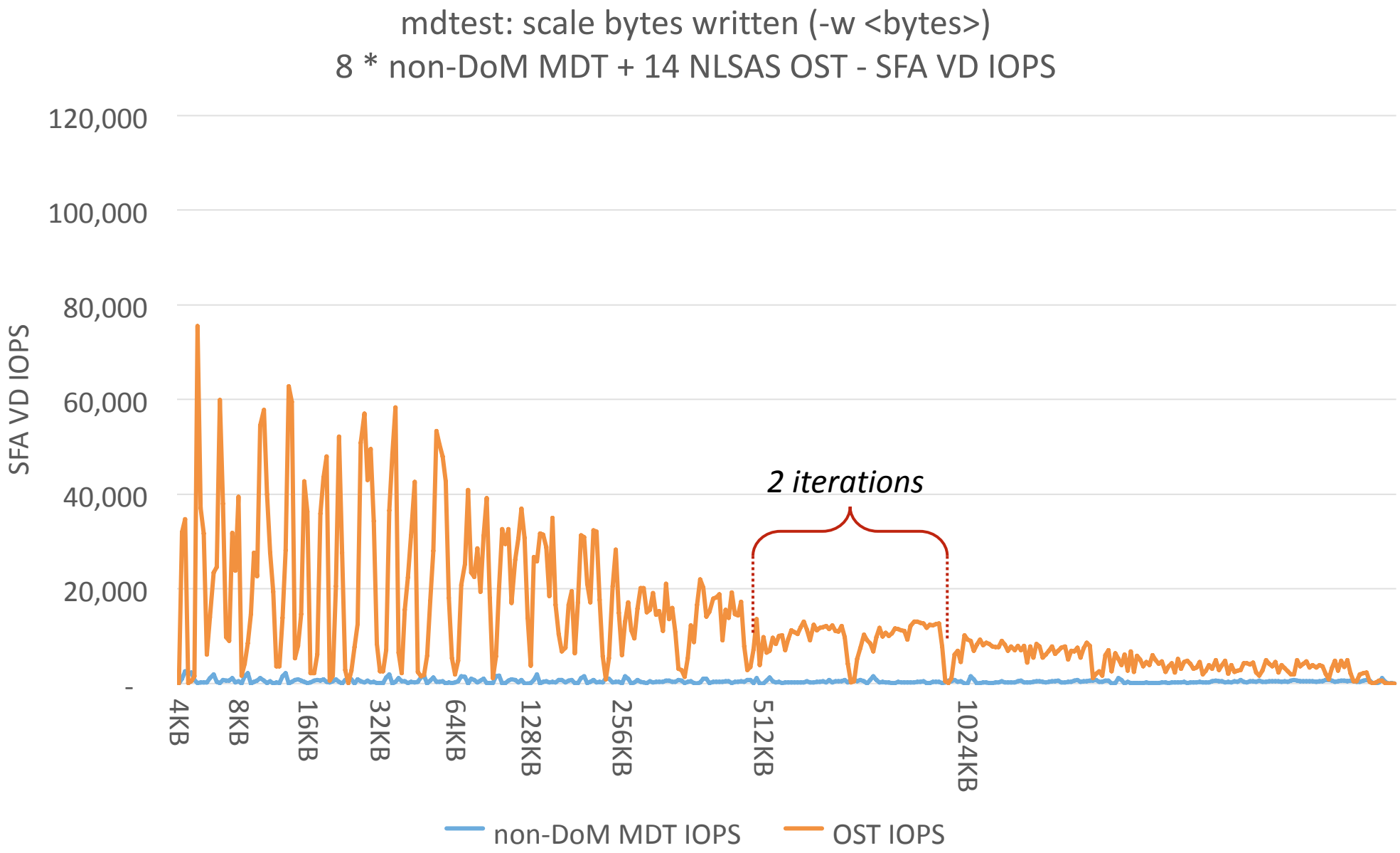
```
# for i in 0 1 2 3 4 5 6 7
> do index=`lfs getdirstripe --mdt-index MDT${i}`
> echo "directory MDT${i} has master index ${index}"
> done

directory MDT0 has master index 0
directory MDT1 has master index 1
directory MDT2 has master index 2
directory MDT3 has master index 3
directory MDT4 has master index 4
directory MDT5 has master index 5
directory MDT6 has master index 6
directory MDT7 has master index 7
```

8 directories, each linked to one of our 8 MDTs

mdtest run parameters for 10 clients, 16PPN

```
mpirun --machinefile 10.txt \
--map-by ppr:16:node \


  mdtest -v \
  -i 2 \
  -n 10000 \
  -w ${FILESZ} \
  -u -F -C -T -r \
  -d /domfs/MDT0/mdtestdir@
  /domfs/MDT1/mdtestdir@
  /domfs/MDT2/mdtestdir@
  /domfs/MDT3/mdtestdir@
  /domfs/MDT4/mdtestdir@
  /domfs/MDT5/mdtestdir@
  /domfs/MDT6/mdtestdir@
  /domfs/MDT7/mdtestdir
```

Test case 1a: mdtest - non-DoM MDT + SAS OST – **IOPS**



Test case 1b: mdtest – DoM MDT only

Test case 1b: mdtest - DoM MDT – details

Setup directories

```
# for i in 0 1 2 3 4 5 6 7
> do
> lfs mkdir -i ${i} DOM-${i}-MDT
> lfs setstripe -L mdt --component-end 1M DOM-${i}-MDT
> done
```

lfs mkdir with MDT index

lfs setstripe for MDT-only DoM component, 1MB max

Leaves us with …

```
# lfs getstripe DOM-?-MDT
DOM-0-MDT
.
.
DOM-7-MDT
    lcme_extent.e_end:   1048576
    lcme_extent.e_start: 0
    lcme_flags:          0
    lcme_id:             N/A
    lcme_mirror_id:      N/A
  lcm_entry_count:   1
  lcm_layout_gen:    0
  lcm_mirror_count:  1
      stripe_count:  0
      stripe_size:   1048576
      pattern:       mdt
      stripe_offset: -1
```

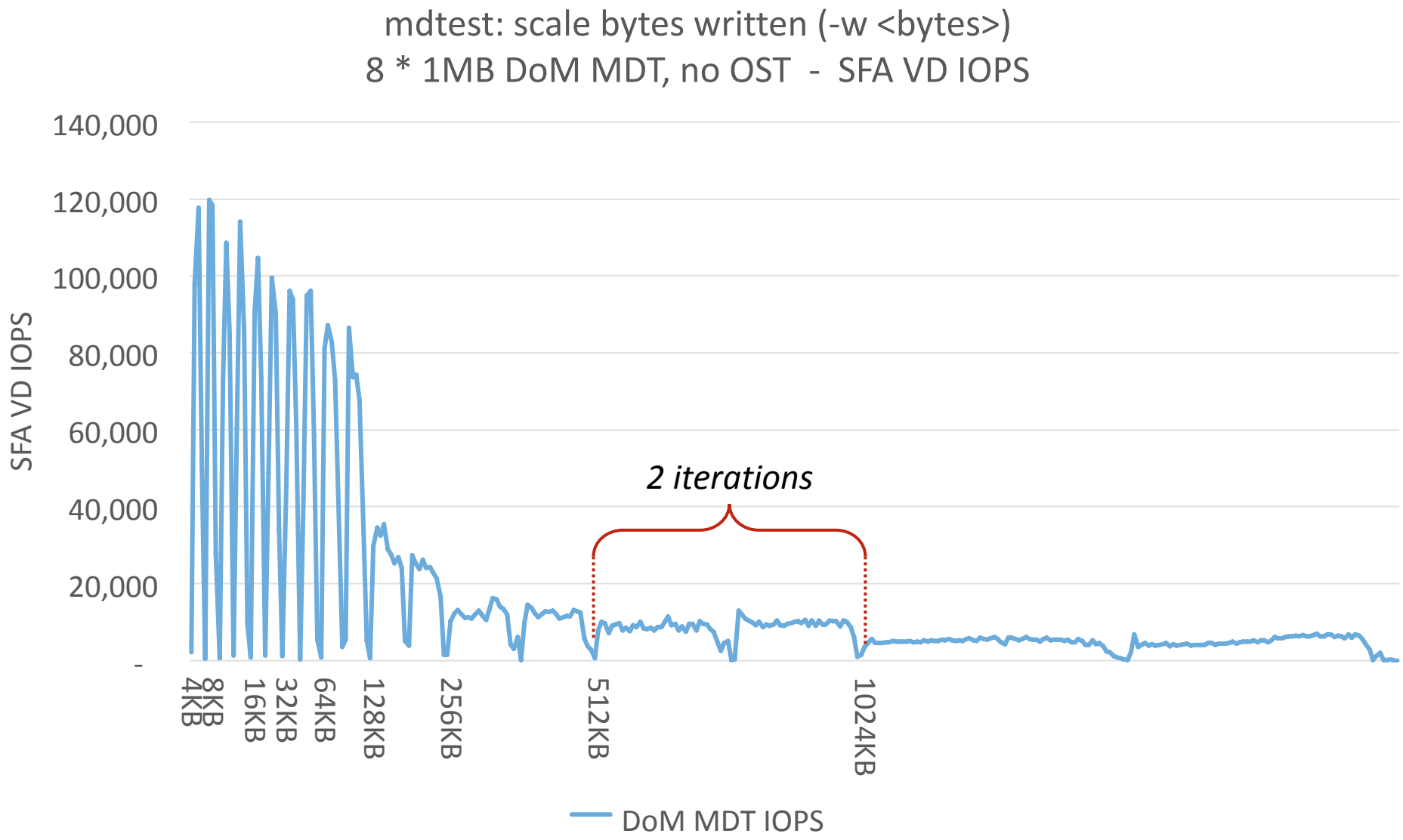
mdtest run parameters for 10 clients, 16PPN

```
mpirun --machinefile 10.txt \
--map-by ppr:16:node \

  mdtest -i 2 -v \
  -n 10000 \
  -w ${FILESZ} \
  -u -F -C -T -r \
  -d /domfs/DOM-0-MDT/mdtestdir@
  /domfs/DOM-1-MDT/mdtestdir@
  /domfs/DOM-2-MDT/mdtestdir@
  /domfs/DOM-3-MDT/mdtestdir@
  /domfs/DOM-4-MDT/mdtestdir@
  /domfs/DOM-5-MDT/mdtestdir@
  /domfs/DOM-6-MDT/mdtestdir@
  /domfs/DOM-7-MDT/mdtestdir
```

Test case 1b: mdtest - MDT + SAS OST – run excerpt

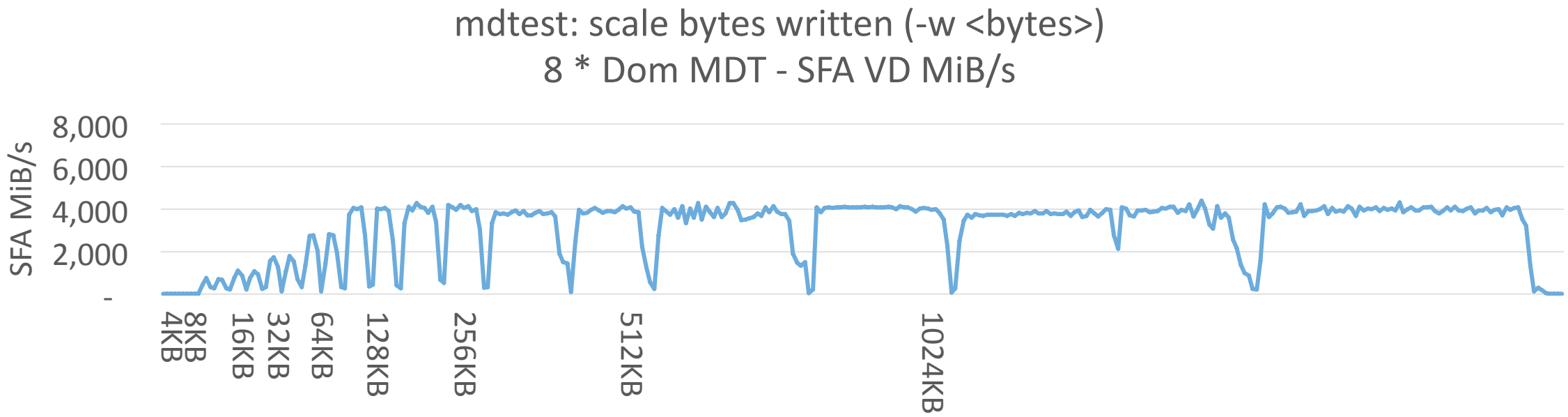
```
File size is 8192
-- started at 04/16/2018 22:19:27 --

mdtest-1.9.3 was launched with 160 total task(s)
on 10 node(s)
Command line used: mdtest -v -i 2 -n 10000 -w 8192
-u -F -C -T -r -d /domfs/DOM-0-MDT/mdtestdir@
/domfs/DOM-1-MDT/mdtestdir@/domfs/DOM-2-MDT/mdtestdir@
/domfs/DOM-3-MDT/mdtestdir@/domfs/DOM-4-MDT/mdtestdir@
/domfs/DOM-5-MDT/mdtestdir@/domfs/DOM-6-MDT/mdtestdir@
/domfs/DOM-7-MDT/mdtestdir
V-1: Entering parse_dirpath...
V-1: Entering valid_tests...
barriers               : True
collective_creates     : False
create_only            : True
dirpath(s):
        /domfs/DOM-0-MDT/mdtestdir
        /domfs/DOM-1-MDT/mdtestdir
        /domfs/DOM-2-MDT/mdtestdir
        /domfs/DOM-3-MDT/mdtestdir
        /domfs/DOM-4-MDT/mdtestdir
        /domfs/DOM-5-MDT/mdtestdir
        /domfs/DOM-6-MDT/mdtestdir
        /domfs/DOM-7-MDT/mdtestdir
dirs_only              : False
read_bytes             : 0
read_only              : False
first                  : 1
files_only             : True
iterations             : 2
items_per_dir          : 0
last                   : 0
leaf_only              : False
items                  : 10000
nstride                : 0
pre_delay              : 0
remove_only            : False
random_seed            : 0
stride                 : 1
shared_file            : False
time_unique_dir_overhead: False
stat_only              : True
unique_dir_per_task    : True
write_bytes            : 8192
sync_file              : False
depth                  : 0
V-1: Entering display_freespace...
V-1: Entering show_file_system_size...
Path: /domfs/DOM-0-MDT
FS: 396.5 TiB   Used FS: 0.0%   Inodes: 400.2 Mi   Used Inodes:
0.1%

160 tasks, 1600000 files

   Operation               Duration              Rate
   ---------               --------              ----
V-1: main: * iteration 1 *
V-1: Entering create_remove_directory_tree, currDepth = 0...
V-1: Entering create_remove_directory_tree, currDepth = 1...
.
.
.
```

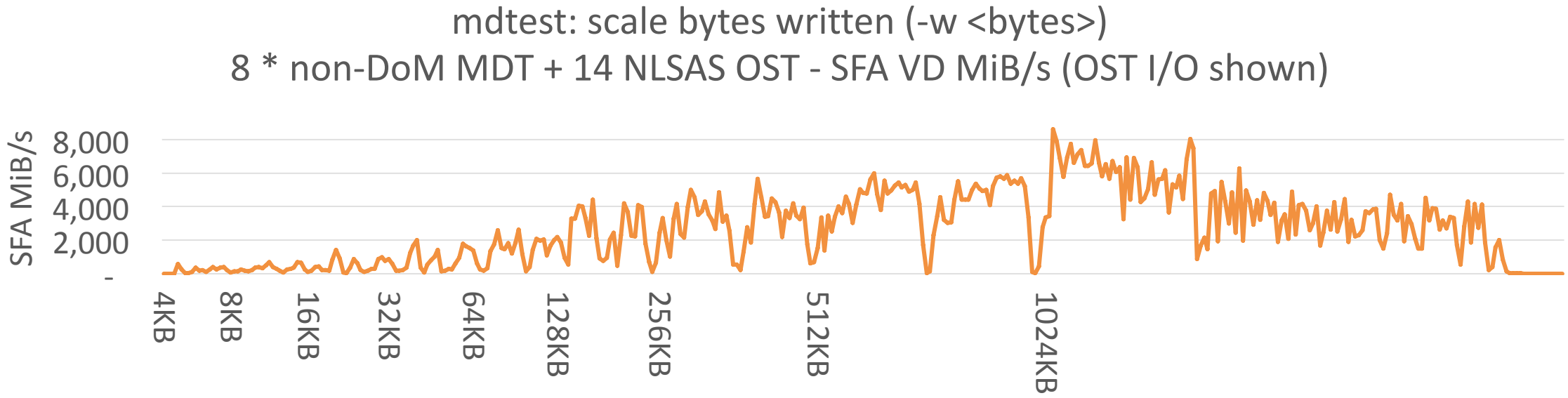
Test case 1b: mdtest - DoM-only MDT – **IOPS**



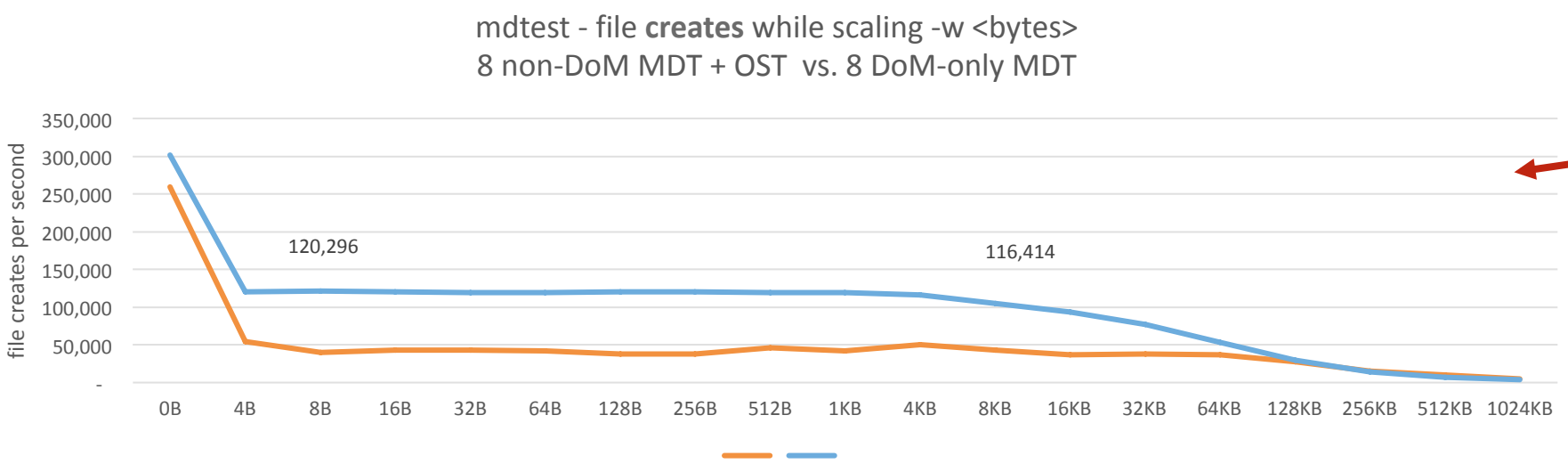
Test cases 1a and 1b: Side-by-Side

Test case 1a and 1b: mdtest - DoM MDT vs. non-DoM MDT+OST - **B/W**





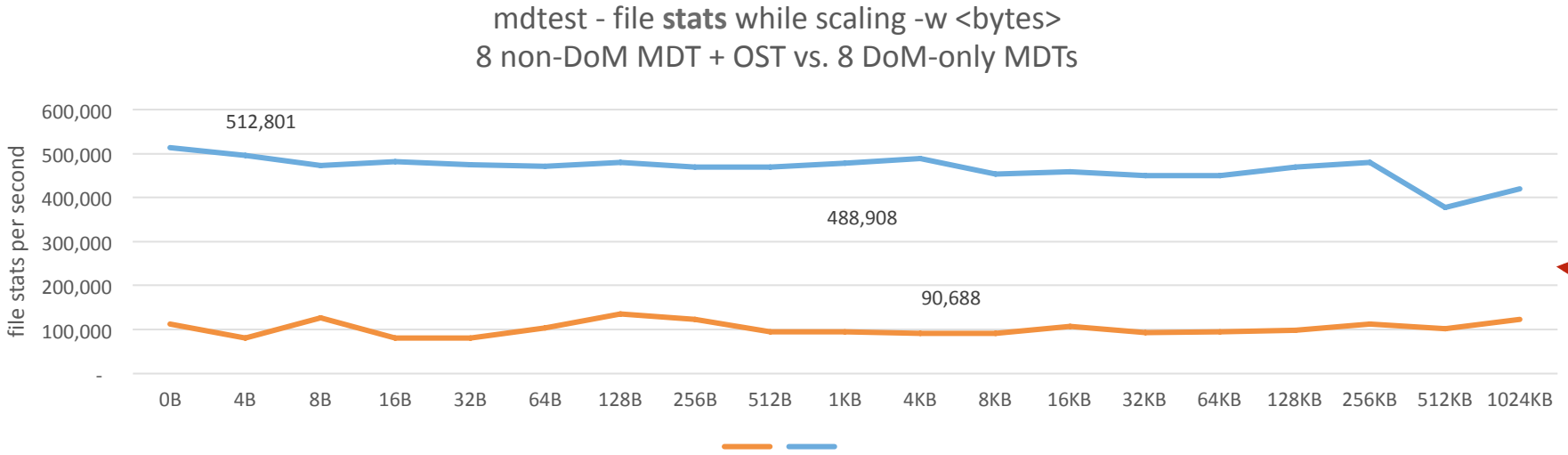
Test cases 1a and 1b – file create and stat operations



file create operations

Max Summary for DoM run

```
SUMMARY: (of 2 iterations)
   Operation                     Max
   ---------                     ---
   File creation     :     120784.307
   File stat         :     504216.064
   File read         :          0.000
   File removal      :     271487.848
   Tree creation     :         72.891
   Tree removal      :         39.345
```



file stat operations

Test Case 2 – IOR

- 4KB, 8KB, 32KB random read/write against:
  - **2a:** *8 RAID6 8+2 SAS OST, no DoM
  - **2b:** 8 DoM MDT

*we used 8 of 14 available OSTs
- this test started as an fio exercise, see LU-10777

Test case 2a - Setup

Test case 2a – IOR on OST - small block random, 1GB files

- **Instantiation and striping of 160 directories over 8 OSTs**
- **stripe count=1, component end=1G, stripe size=1MB, rotate through 2 sets of 10**

```
for i in `seq 0 9`; do lfs mkdir -i 0 ${i}; lfs setstripe -E 1G -c1 -S1G -o0 ${i}; done
for i in `seq 10 19`; do lfs mkdir -i 1 ${i}; lfs setstripe -E 1G -c1 -S1G -o1 ${i};done
for i in `seq 20 29`; do lfs mkdir -i 2 ${i}; lfs setstripe -E 1G -c1 -S1G -o2 ${i};done
for i in `seq 30 39`; do lfs mkdir -i 3 ${i}; lfs setstripe -E 1G -c1 -S1G -o3 ${i};done

for i in `seq 40 49`; do lfs mkdir -i 4 ${i}; lfs setstripe -E 1G -c1 -S1G -o7 ${i};done
for i in `seq 50 59`; do lfs mkdir -i 5 ${i}; lfs setstripe -E 1G -c1 -S1G -o8 ${i};done
for i in `seq 60 69`; do lfs mkdir -i 6 ${i}; lfs setstripe -E 1G -c1 -S1G -o9 ${i};done
for i in `seq 70 79`; do lfs mkdir -i 7 ${i}; lfs setstripe -E 1G -c1 -S1G -o10 ${i};done

for i in `seq 80 89`; do lfs mkdir -i 0 ${i}; lfs setstripe -E 1G -c1 -S1G -o0 ${i};done
for i in `seq 90 99`; do lfs mkdir -i 1 ${i}; lfs setstripe -E 1G -c1 -S1G -o1 ${i};done
for i in `seq 100 109`; do lfs mkdir -i 2 ${i}; lfs setstripe -E 1G -c1 -S1G -o2 ${i};done
for i in `seq 110 119`; do lfs mkdir -i 3 ${i}; lfs setstripe -E 1G -c1 -S1G -o3 ${i};done

for i in `seq 120 129`; do lfs mkdir -i 4 ${i}; lfs setstripe -E 1G -c1 -S1G -o7 ${i};done
for i in `seq 130 139`; do lfs mkdir -i 5 ${i}; lfs setstripe -E 1G -c1 -S1G -o8 ${i};done
for i in `seq 140 149`; do lfs mkdir -i 6 ${i}; lfs setstripe -E 1G -c1 -S1G -o9 ${i};done
for i in `seq 150 159`; do lfs mkdir -i 7 ${i}; lfs setstripe -E 1G -c1 -S1G -o10 ${i};done
```

- **IOR runs are 10 client, 16 PPN, unique directory**
- **4KB random read example below**
- **all caches dropped between runs**

```
# mpirun --machinefile dom-10 --map-by ppr:16:node IOR -z -e -r -k -E -F -u -t4k -b1g -o /domfs/ior
```

Test case 2a – IOR on OST - small block random + 1M sequential

Representative example of an OST Directory Domponent

Before File creation...

```
# lfs getstripe 0
0
  lcm_layout_gen:    0
  lcm_mirror_count:  1
  lcm_entry_count:   1
    lcme_id:             N/A
    lcme_mirror_id:      N/A
    lcme_flags:          0
    lcme_extent.e_start: 0
    lcme_extent.e_end:   1073741824
      stripe_count:  1
      stripe_size:   1073741824
      pattern:       raid0
      stripe_offset: 0
```

directory

1 fie

with lmm_object

...and Directory + File Component After Write

```
# lfs getstripe 0
0
  lcm_layout_gen:    0
  lcm_mirror_count:  1
  lcm_entry_count:   1
    lcme_id:             N/A
    lcme_mirror_id:      N/A
    lcme_flags:          0
    lcme_extent.e_start: 0
    lcme_extent.e_end:   1073741824
      stripe_count:  1
      stripe_size:   1073741824
       pattern:       raid0
       stripe_offset: 0
```

```
0/ior.00000000
  lcm_layout_gen:    1
  lcm_mirror_count:  1
  lcm_entry_count:   1
    lcme_id:             1
    lcme_mirror_id:      0
    lcme_flags:          init
    lcme_extent.e_start: 0
    lcme_extent.e_end:   1073741824
      lmm_stripe_count:  1
      lmm_stripe_size:   1073741824
      lmm_pattern:       raid0
      lmm_layout_gen:    0
      lmm_stripe_offset: 0
      lmm_objects:
      - 0: { l_ost_idx: 0, l_fid: [0x100000000:0x15c:0x0] }
```

Test case 2b – IOR on DoM - small block random, 1GB files

- **IOR runs are 10 client, 16 PPN, unique directory**
- **Instantiation of 160 directories over 8 MDTs – 20 per**
- **stripe count implied, component end=1G, stripe size implied, rotate through 2 sets 8 MDTs**

```
for i in `seq 0 9`; do lfs mkdir -i 0 ${i}; done
for i in `seq 10 19`; do lfs mkdir -i 1 ${i}; done
for i in `seq 20 29`; do lfs mkdir -i 2 ${i}; done
for i in `seq 30 39`; do lfs mkdir -i 3 ${i}; done
for i in `seq 40 49`; do lfs mkdir -i 4 ${i}; done
for i in `seq 50 59`; do lfs mkdir -i 5 ${i}; done
for i in `seq 60 69`; do lfs mkdir -i 6 ${i}; done
for i in `seq 70 79`; do lfs mkdir -i 7 ${i}; done

for i in `seq 80 89`; do lfs mkdir -i 0 ${i}; done
for i in `seq 90 99`; do lfs mkdir -i 1 ${i}; done
for i in `seq 100 109`; do lfs mkdir -i 2 ${i}; done
for i in `seq 110 119`; do lfs mkdir -i 3 ${i}; done
for i in `seq 120 129`; do lfs mkdir -i 4 ${i}; done
for i in `seq 130 139`; do lfs mkdir -i 5 ${i}; done
for i in `seq 140 149`; do lfs mkdir -i 6 ${i}; done
for i in `seq 150 159`; do lfs mkdir -i 7 ${i}; done

for i in `seq 0 159`; do lfs setstripe -E 1G -L mdt ${i}; done
```

```
# mpirun --machinefile dom-10 --map-by ppr:16:node IOR -z -e (-w | -r) -k -E -F -u -t4k -b1g -o /domfs/ior
```

Test case 2b – IOR on DoM - small block random + 1M sequential

Representative example of a DoM Directory Domponent

Before File Creation...

```
# lfs getstripe 0
0
  lcm_layout_gen:    0
  lcm_mirror_count:  1
  lcm_entry_count:   1
    lcme_id:             N/A
    lcme_mirror_id:      N/A
    lcme_flags:          0
    lcme_extent.e_start: 0
    lcme_extent.e_end:   1073741824
      stripe_count:  0       stripe_size:   1073741824
      pattern:       mdt       stripe_offset: -1
```

directory

1 file

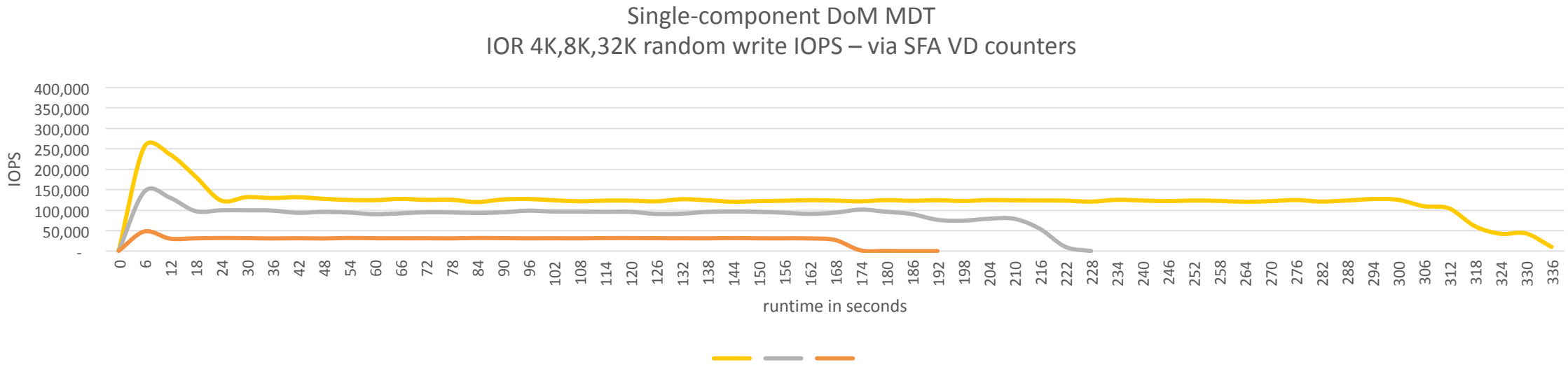
...and Directory + File Component After Write

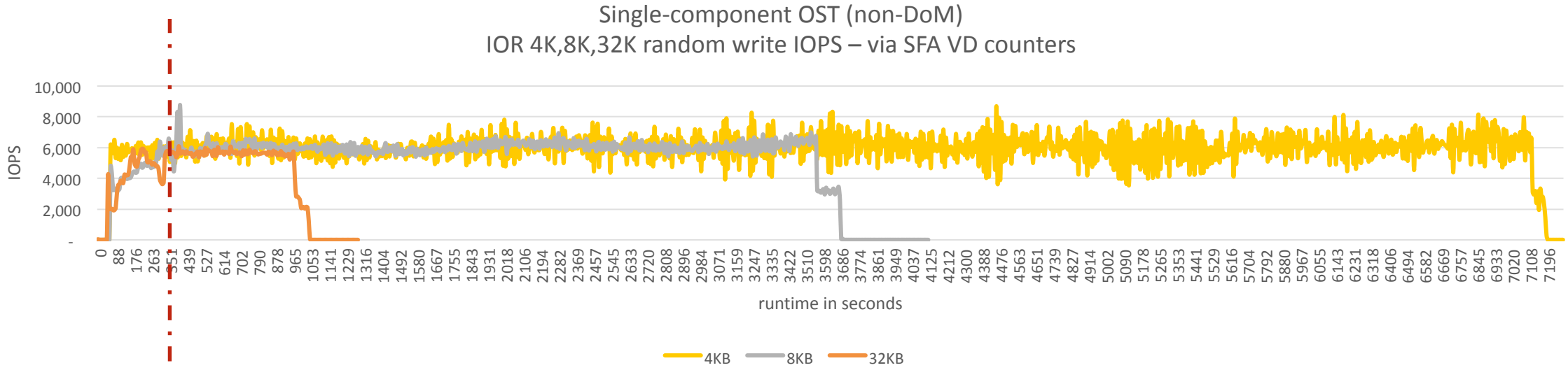
```
# lfs getstripe 0
0
  lcm_layout_gen:    0
  lcm_mirror_count:  1
  lcm_entry_count:   1
    lcme_id:             N/A
    lcme_mirror_id:      N/A
    lcme_flags:          0
    lcme_extent.e_start: 0
    lcme_extent.e_end:   1073741824
      stripe_count:  0       stripe_size:   1073741824
      pattern:       mdt       stripe_offset: -1

0/ior.00000000
  lcm_layout_gen:    1
  lcm_mirror_count:  1
  lcm_entry_count:   1
    lcme_id:             1
    lcme_mirror_id:      0
    lcme_flags:          init
    lcme_extent.e_start: 0
    lcme_extent.e_end:   1073741824
      lmm_stripe_count:  0
      lmm_stripe_size:   1073741824
      lmm_pattern:       mdt
      lmm_layout_gen:    0
      lmm_stripe_offset: 0
```

Note that there is no lmm object present for a MDT DoM file stripe entry

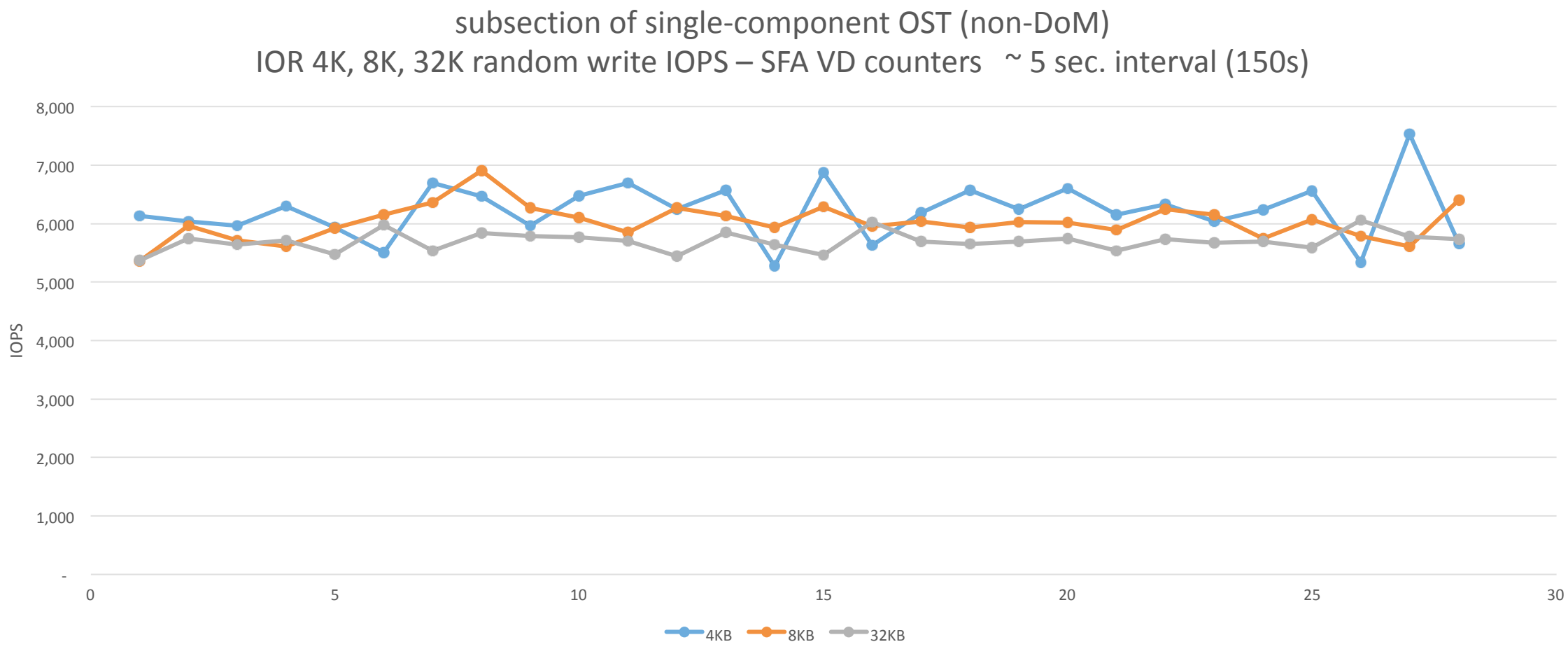
Test cases 2a and 2b: Side-by-Side

Test case 2 – IOR Write IOPS – DoM MDT vs. OST

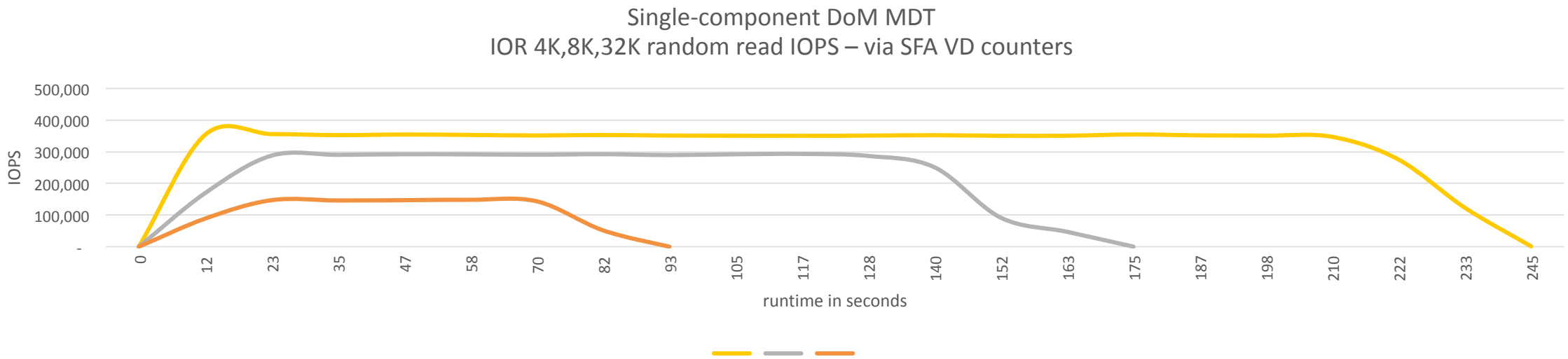


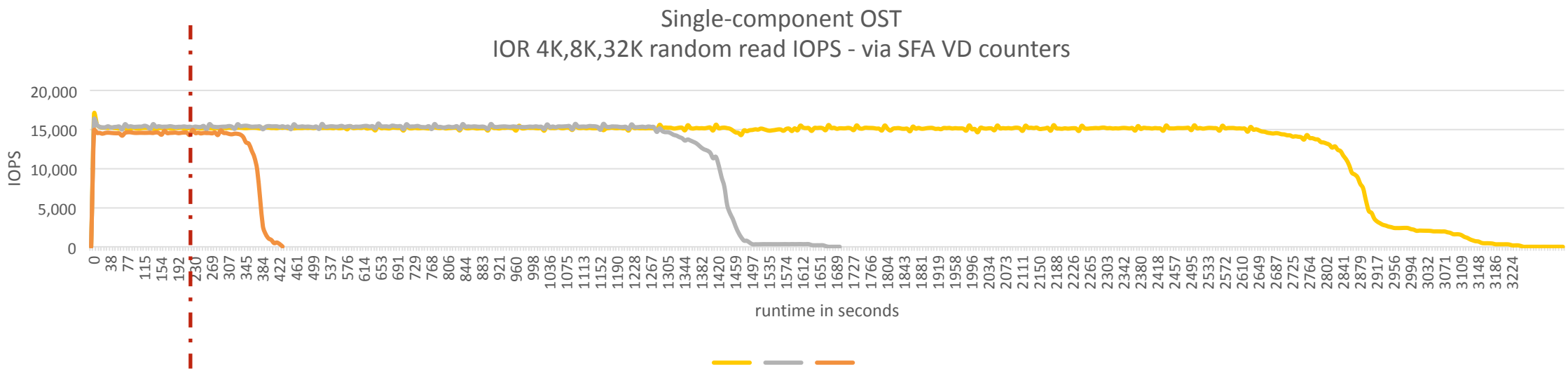


Test case 2 – OST IOR Write IOPS – subsection zoom-in peek



Test case 2 – IOR Read IOPS – DoM MDT vs. OST





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Test Case 3

- Workload Isolation Benefits. Compare:
  - **a:** Sequential read from HDD OSTs – standalone baseline workload (Background workload)
  - **b:** Start background sequential read from OSTs ... introduce 2nd workload (IOR write) - same OSTs
  - **c:** Start Background sequential read from OSTs ... introduce 2nd workload (IOR write) - DoM

Test case 3: Workload Isolation – details

3 Workloads - Description

a. Background workload (IOR sequential read) target directories in root of lustre filesystem with default striping. Pre-create files.

b. Foreground disruptive OST workload (IOR sequential write) target directories
240 directories with ***lfs setstripe -E 1G -o*** *${i}* over **14 OSTs** (4 clients 8 PPN)

c. Foreground DoM workload (IOR sequential write) target directories
Similar to test case 2, but 240 directories, with ***lfs setstripe -E 1G -L mdt*** *${i}* over **8 MDTs** (6 clients 40PPN)

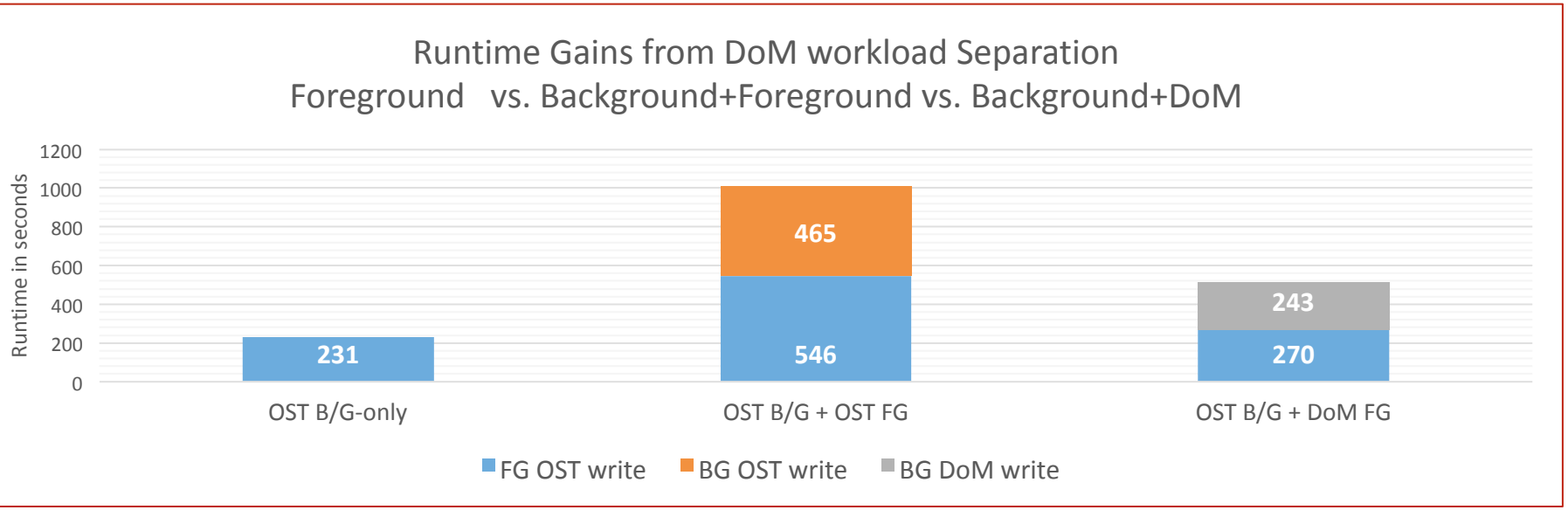
IOR Run Description:

Background/Control OST-only 1MB sequential read
$ mpirun --machinefile dom-4 --map-by ppr:8:node IOR -e -r -k -E -F -t 1m -b64g -vv -o /domfs/ior

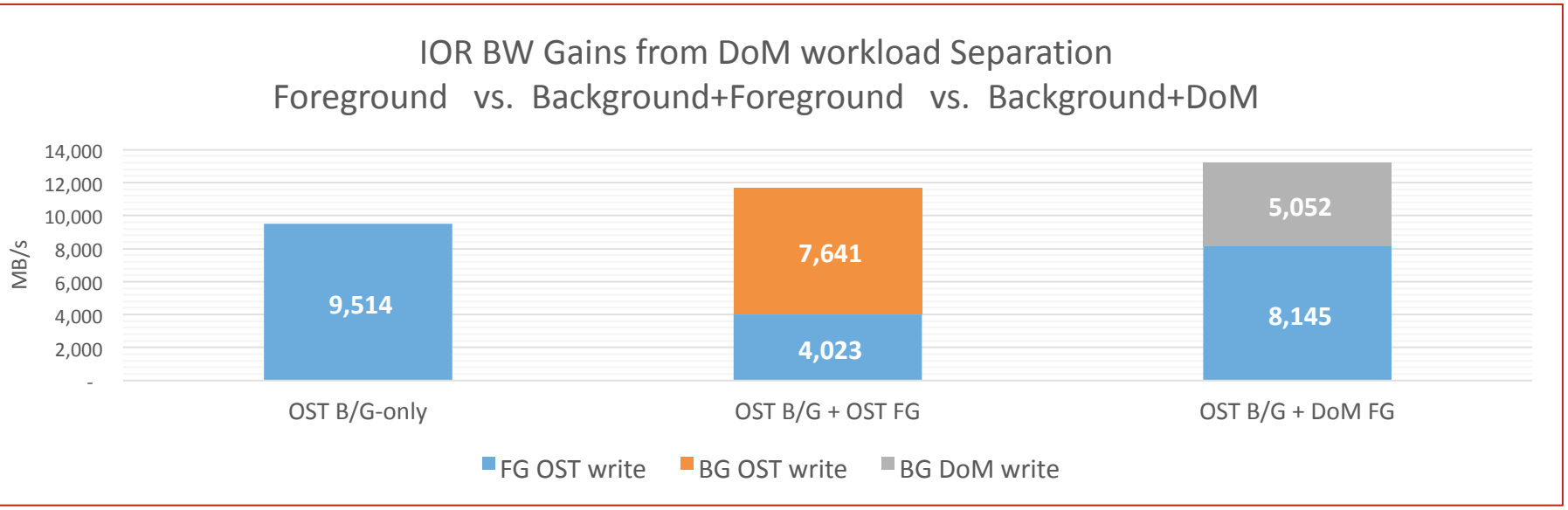
Foreground/OST-only 1MB sequential write
$ clients=6;rs=40;ppn=40;np=$[$ppn*$clients];mpirun --oversubscribe --machinefile dom-havoc \
--map-by node --np $np IOR -i10 -d10 -e -w -E -F -u -t1m -b1g -vv -o /domfs/**havoc-O**/ior

Foreground/DoM-only 1MB sequential write
$ clients=6;rs=40;ppn=40;np=$[$ppn*$clients];mpirun --oversubscribe --machinefile dom-havoc \
--map-by node --np $np IOR -i4 –d10 -e -w -E -F -u -t1m -b1g -vv -o /domfs/**havoc-D**/ior

Test case 3 – Workload Isolation Benefits



Workload Residence	Runtime
OST Only	211s
OST B/G + OST F/G	1011s
OST B/G + DoM F/G	513s



Workload Residence	MB/s
OST Only	9,514
OST B/G + OST F/G	11,664
OST B/G + DoM F/G	13,197

DDN STORAGE

Looking Ahead

- Migration of files from MDT to OST by request or automatically
- Performance enhancements
- Read-ahead for small files, return data in open()
- Client - first write size detect will change layout

- Performance testing with DNE2 striped directories
- Large-scale performance investigation with a diverse workload
- Benefits of diverting DoM RPCs to MDS on an all-flash lustre filesystems
- Small file size ranges – further studies with real codes

References – Documentation and Planned Enhancements

- Data on MDT
- Data on MDT High Level Design
- DoM User Guide
- DoM Performance Optimization
- Data on MDT Phase II
- Lock-ahead - Request extent locks from userspace
- Better DOM+DNE integration

Acknowledgements

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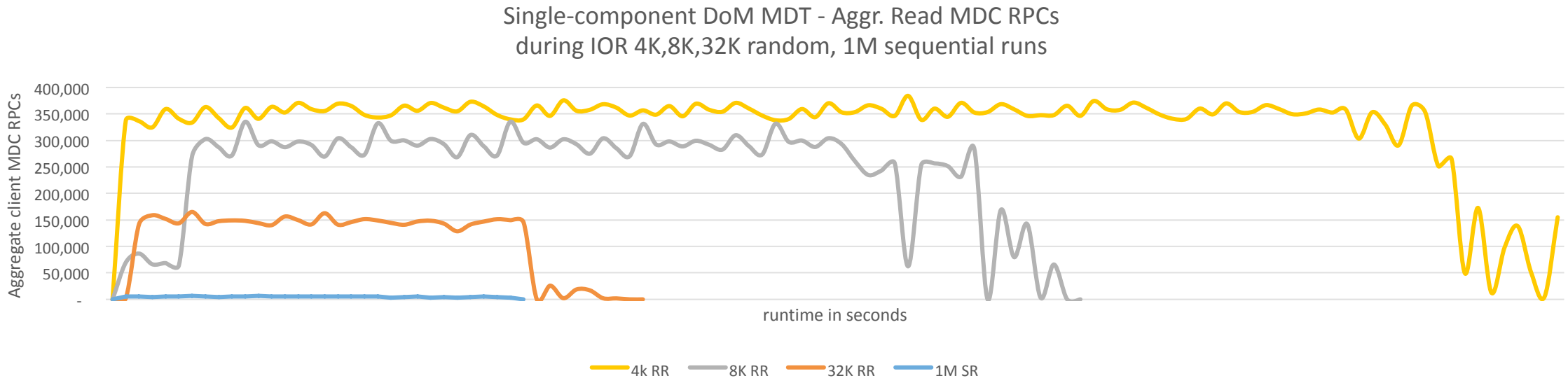
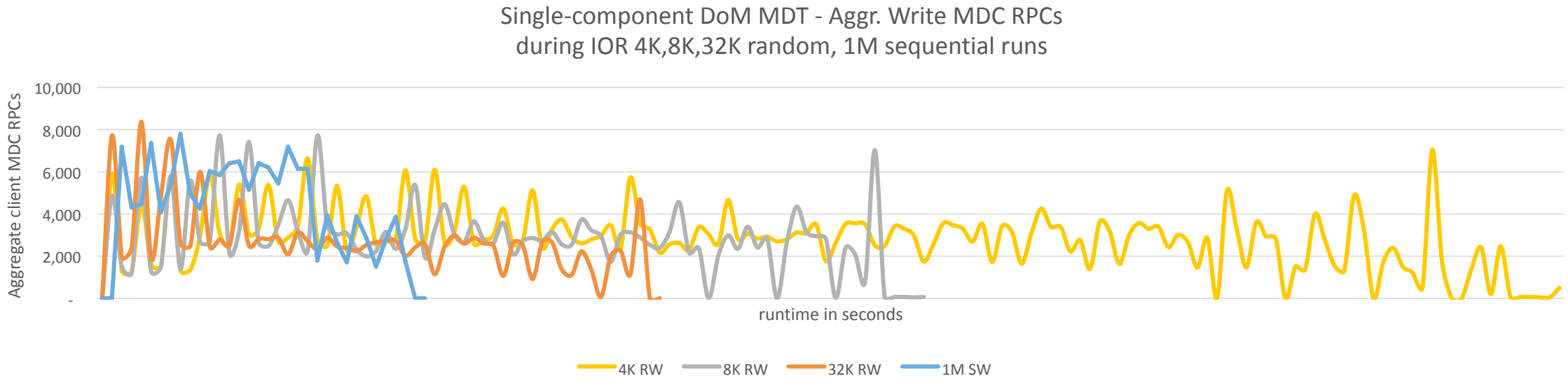
Appendix

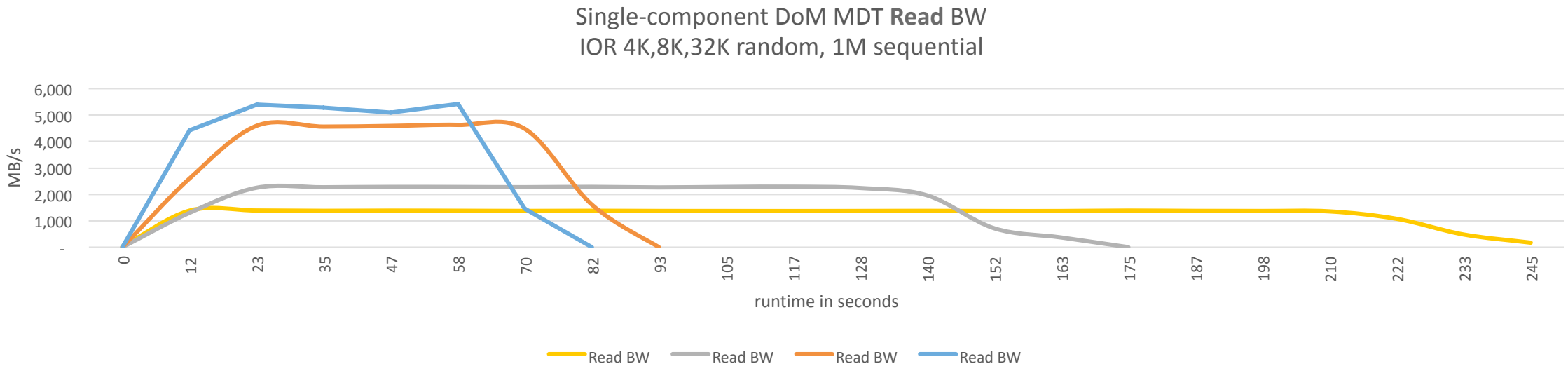
- RPC Graph
- IOR Write throughput
- LBUG during lfs migrate

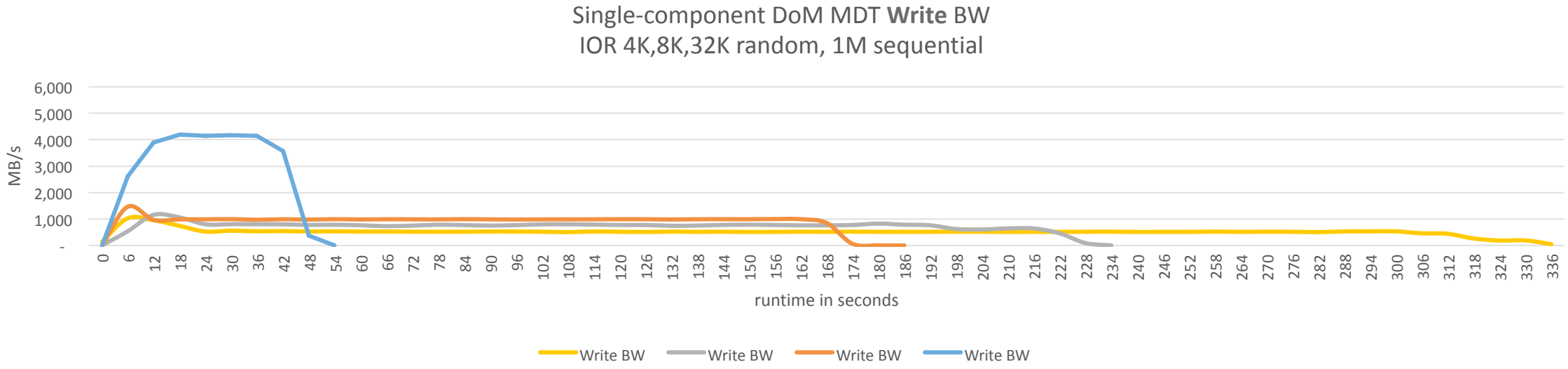
Test case 2a – IOR on DoM – Read / Write MDC RPCs at client





Test case 2 – IOR Write Throughput – DoM MDT vs. OST





LBUG seen while using lfs migrate on a DoM file

```
lfs getstripe test-1M.3
test-1M.3
  lcm_layout_gen:    1
  lcm_mirror_count:  1
  lcm_entry_count:   1
    lcme_id:             1
    lcme_mirror_id:      0
    lcme_flags:          init
    lcme_extent.e_start: 0
    lcme_extent.e_end:   1048576
      lmm_stripe_count:  0
      lmm_stripe_size:   1048576
      lmm_pattern:       mdt
      lmm_layout_gen:    0
      lmm_stripe_offset: 0

# lfs migrate -L mdt -E 4M test-1M.3

Message from syslogd@ at Apr 15 21:38:31 ...
 kernel:LustreError: 4366:0:(mdc_dev.c:1346:mdc_req_attr_set()) LBUG

Message from syslogd@s at Apr 15 21:38:31 ...
 kernel:Kernel panic - not syncing: LBUG
packet_write_wait: Connection to 10.x.x.x port 22: Broken pipe
```

```
# ls -l
total 1049460
-rw-r--r-- 1 root root 1073741824 Apr 22 09:31 10.testfile

# lfs getstripe 10.testfile
10.testfile
  lcm_layout_gen:    1
  lcm_mirror_count:  1
  lcm_entry_count:   1
    lcme_id:             1
    lcme_mirror_id:      0
    lcme_flags:          init
    lcme_extent.e_start: 0
    lcme_extent.e_end:   1073741824
      lmm_stripe_count:  0
      lmm_stripe_size:   1073741824
      lmm_pattern:       mdt
      lmm_layout_gen:    0
      lmm_stripe_offset: 0

# lfs migrate -E 64M -c 1 -E 256M -c 4 -E -1 -c -1 10.testfile

Message from syslogd@ at Apr 16 09:32:02 ...
 kernel:LustreError: 2634:0:(mdc_dev.c:1346:mdc_req_attr_set()) LBUG
```

LU-10910 - LBUG with "lfs migrate -c 1 <domfile>"