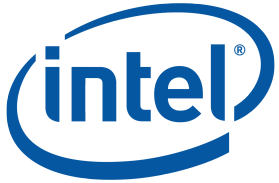

# Linux* Storage Stack performance

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# Legal Information



# Facts and Speculation about Solid State Drives (SSD)

1/5th the power consumption of a mechanical disk

200X (+) the performance

Same price?

Better performance, low power, competitive pricing make SSDs "disruptive technology"

By 2010, SSDs will:

- be 20% of the laptop market
- have "significant penetration" into the data center

SSDs will place much higher demands on storage stack than traditional disks.

- The Zeus IOPS - 52,000 IOPS
- Mtron – 78,000/16,000 IOPS

These numbers are going to increase rapidly over time as more players arrive in this huge potential market.

# Problem

As IOPS increases, CPU overhead, per I/O, becomes significant and a bottleneck.

Latency issues in the Linux* storage stack could make software a bottleneck.

Storage stacks are optimized for seek avoidance

- CPU time spent avoiding seeks is wasted.

SSDs are still fairly expensive and uncommon, making it hard for the Linux community to measure and optimize for them.

# “SSD” for everyone

- Simulate SSD with a RAM driver
  - The first step to reducing latency is finding out how bad it is. The only way to keep latency low is to allow everybody to measure the latency, and avoid changes to the kernel which would increase latency.
  - The ‘rd’ ram disc driver does not behave like a driver for real hardware, and is not a good simulator for our purposes.
- Put relevant measurement data together in a tool that's easy to use.

# Test Setup

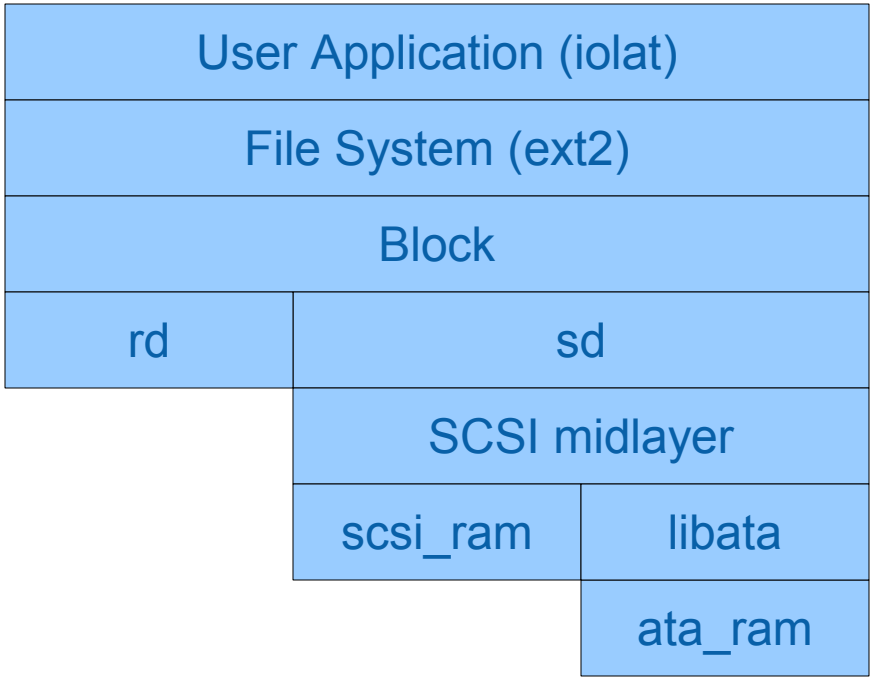
Fake Drivers

- The ‘scsi_ram’ and ‘ata_ram’ drivers are, respectively, scsi and ata drivers for the Linux kernel, which simulate really fast discs by storing data in memory.
- These drivers will allow us to measure latency all the way down into the ATA layer.

Real Measurements

- The ‘iolat’ tool generates random disk I/O  while simultaneously profiling the kernel.
- It reports the number of IOPS (I/O operations per second) that it achieves and where the kernel is spending its time.

# Linux storage stack



# Driver details

The scsi_ram driver is designed to behave like a driver for a real SCSI card. It accepts SCSI commands and, instead of sending them to a piece of hardware, it queues them to a thread. The thread, typically running on a different CPU, copies data to or from an array of pages, then reports success.

The ata_ram driver is similar to the scsi_ram driver. The ATA command set is different from the SCSI command set, and the interface to libata is different from the interface to the SCSI midlayer, but the design of the driver is virtually unchanged.

Both drivers have options to help pinpoint performance issues. For example, the actual data copies can be disabled, removing that factor from the performance profile.

# Iolat details

Generate Traffic and measure IOPS
- Random reads and writes
- Single large test file
- Size of read/write configurable
- Compare to “reference” data

Profile Kernel
- Uses /proc/profile

Classify functions profiled
- Hand classified, stored in a text file

Generates Reports
- IOPS measurement
- Classification report

# More Tester details

Types of tests:

- Read
- Write
- Mixed reads and write

Can do Direct I/O, and Cached I/O

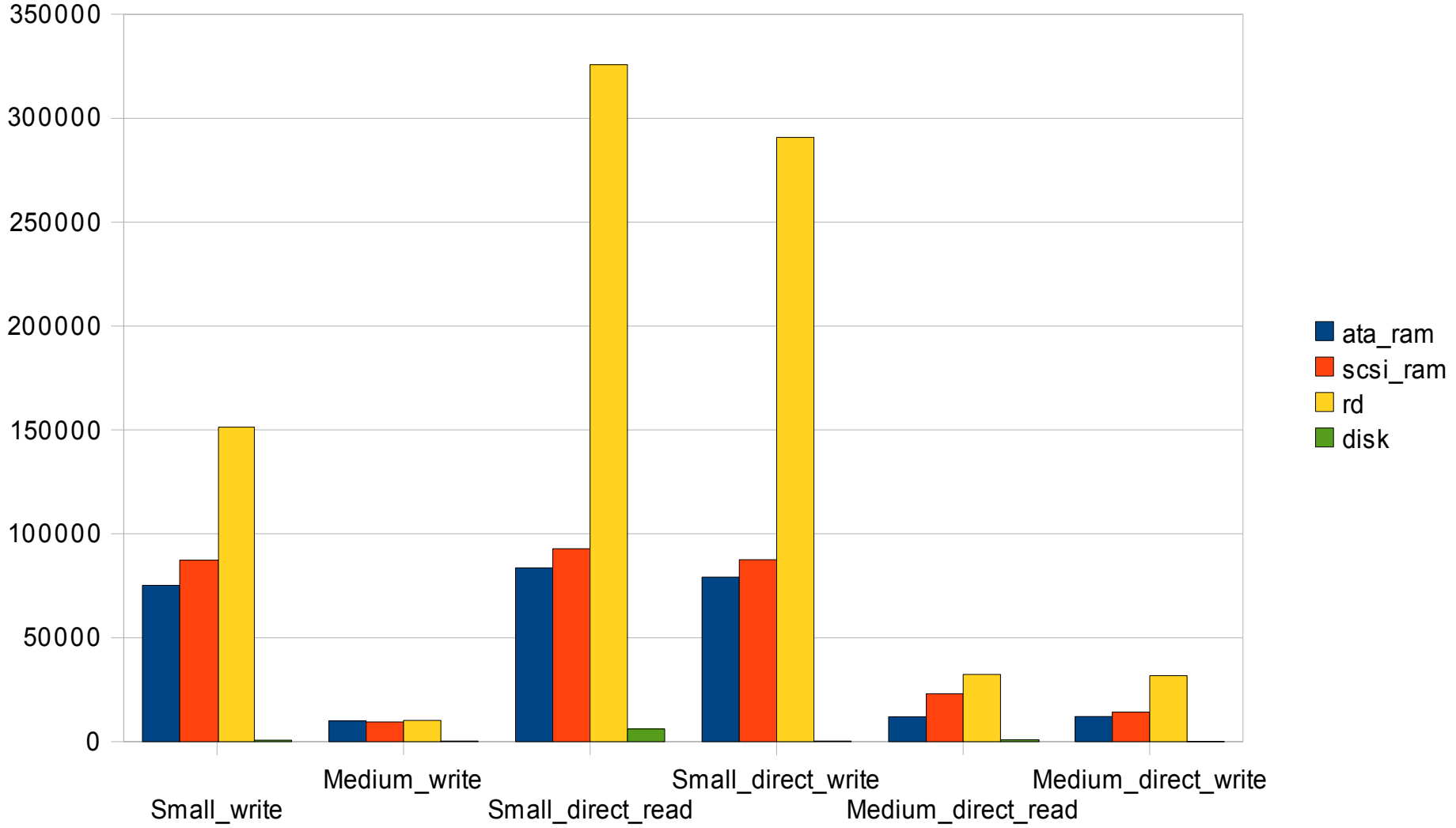
- Cached I/O tests will fdatasync() every 10 iterations.
- Direct I/O tests wait for previous I/O to complete before submitting next I/O. No batching or merging can occur in the driver.

File Edit View Terminal Tabs Help

```
IOPSMeasure version 0.3 (C) 2008 Intel Corporation
Test Name           Direct    bytes     IOPS      +/-  Avg. req time
Small_direct_read   Yes       4096      90044     %-3         0.10899
Small_direct_write  Yes       4096      85578     %-2         0.11536
Medium_direct_read  Yes       131072    22893     %0          0.45172
Medium_direct_write Yes       131072    13302     %0          0.96110
```

```
  3352 scsi_ram_read                    scsi_ram_driver       28.3545
  3127 scsi_ram_write                   scsi                  14.9986
  2451 scsi_request_fn                  block                 11.5580
   838 scsi_dispatch_cmd                scheduler              9.4730
   748 blk_end_io                       mm                     8.3916
   581 blk_done_softirq                 fs                     8.3420
   458 __make_request                   data_copy              2.1940
   458 __blockdev_direct_IO             primatives             1.3418
   370 bio_alloc_bioset                 elevator               0.6260
   354 *unknown*            *           Unclassified          14.7205
   350 __end_that_request_first
   277 get_request
   206 __find_get_block
   198 __bio_add_page
   159 generic_make_request
   150 __might_sleep
```

# IOPS


350000
300000
250000
200000
150000
100000
50000
0
ata_ram
scsi_ram
rd
disk
Small_write
Medium_write
Small_direct_read
Small_direct_write
Medium_direct_read
Medium_direct_write

# Each layer subtracts performance

scsi_ram much slower than rd

ata_ram 10% slower than scsi_ram

- Medium direct reads 50% slower??

Neither scsi nor ata layers can handle SSD IOPS

File Edit View Terminal Tabs Help

```
IOPSMeasure version 0.3 (C) 2008 Intel Corporation
Test Name           Direct    bytes     IOPS      +/-  Avg. req time
Small_direct_read   Yes       4096      89944     %-3        0.10843
Small_direct_write  Yes       4096      85774     %-2        0.11414
Medium_direct_read  Yes       131072    22704     %-1        0.40915
Medium_direct_write Yes       131072    13010     %-2        0.69613
```

```
  9241 scsi_ram_read                    scsi_ram_driver       27.7452
  8809 scsi_ram_write                   scsi                  14.9654
  7068 scsi_request_fn                  block                 11.1748
  2357 scsi_dispatch_cmd                scheduler             10.0787
  2080 blk_end_io                       mm                     8.5664
  1500 blk_done_softirq                 fs                     8.2771
  1372 __blockdev_direct_IO             data_copy              2.1303
  1359 __make_request                   primatives             1.2933
  1020 __end_that_request_first         elevator               0.5323
   998 bio_alloc_bioset                 Unclassified          15.2365
   909 *unknown*            *
   829 get_request
   604 __bio_add_page
   531 __find_get_block
   440 __might_sleep
   429 generic_make_request
```

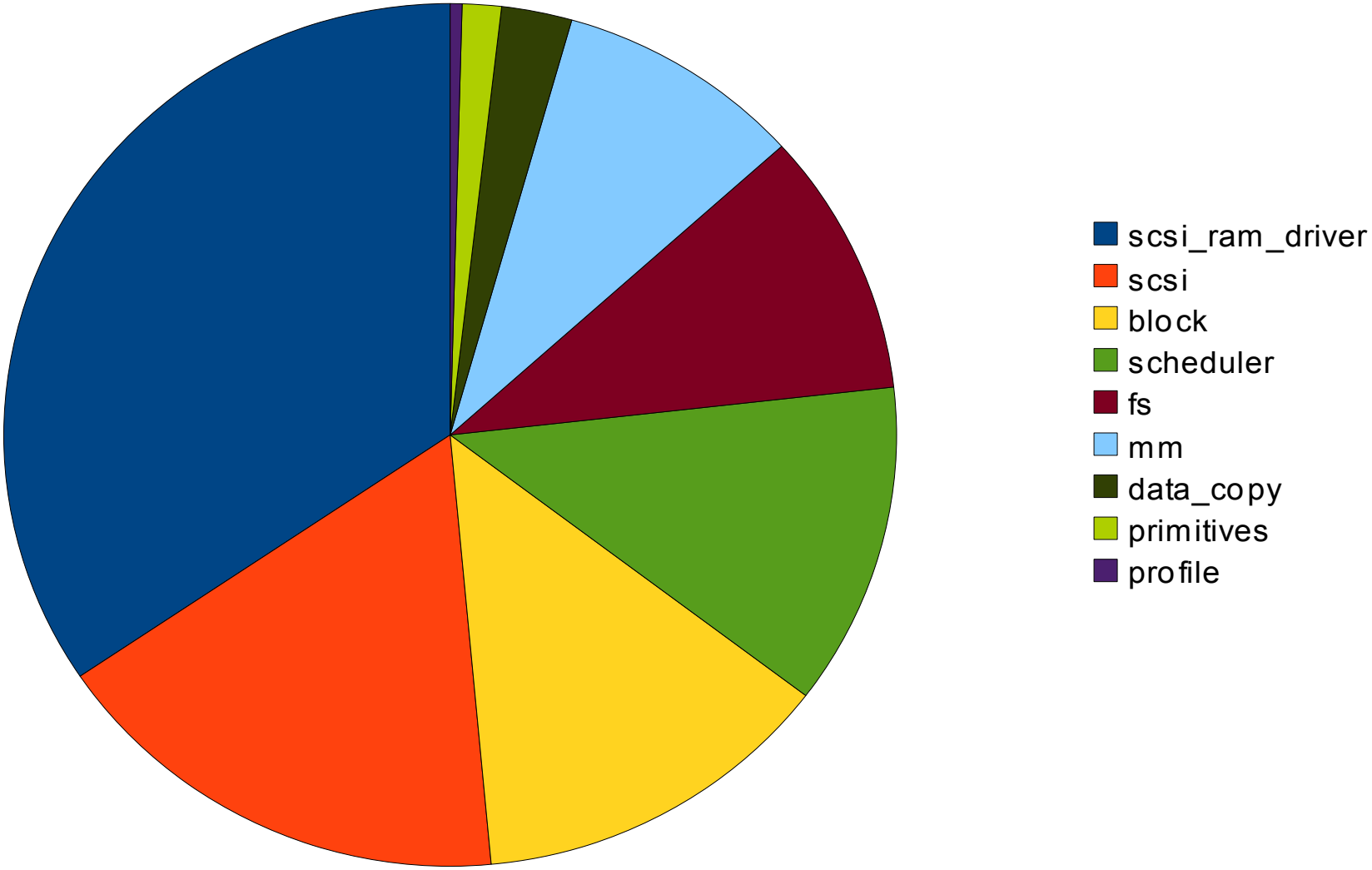
File Edit View Terminal Tabs Help

```
IOPSMeasure version 0.4 (C) 2008 Intel Corporation
Test Name           Direct    bytes     IOPS      +/-  Avg. req time
Small_direct_read   Yes       4096      82022     %-11       0.12420
Small_direct_write  Yes       4096      77907     %-11       0.13057
Medium_direct_read  Yes       131072    12321     %-46       0.53577
Medium_direct_write Yes       131072    12436     %-6        0.53186



  1440 scsi_request_fn                  scsi                  22.5076
  1170 ata_ram_read                     ata_ram_driver        21.0077
  1050 ata_ram_write                    scheduler             12.5522
   892 scsi_dispatch_cmd                block                 11.9045
   432 blk_end_io                       fs                     7.4762
   281 blk_done_softirq                 mm                     6.9612
   178 __blockdev_direct_IO             data_copy              1.5829
   160 kmem_cache_free                  primitives             1.1760
   157 get_request                      interrupt_handling     0.4297
   152 kmem_cache_alloc                 elevator               0.3483
   130 __end_that_request_first         libata                 0.2869
   110 follow_page                      idle                   0.1294
   109 bio_alloc_bioset                 Unclassified          13.6374
    93 blk_recalc_rq_segments
```

# scsi_ram Direct IO Profile



# Focus performance work on SCSI layer rather than Block Layer

scsi_ram is much slower than rd on small direct reads and small direct writes test

Profile data indicates a much greater % of time spent in block layer, and that the scsi layer adds significant overhead over just the block layer.

# Next Steps

Investigate reducing SCSI layer overhead by:

- Digging down in the profiles to find hot spots
- Optimizing host lock acquisition

Take Performance analysis down to ATA layer with ata_ram

- libata uses the SCSI layer, then translates to ATA commands
- Many SSDs will interface as SATA devices

Investigate using different elevators

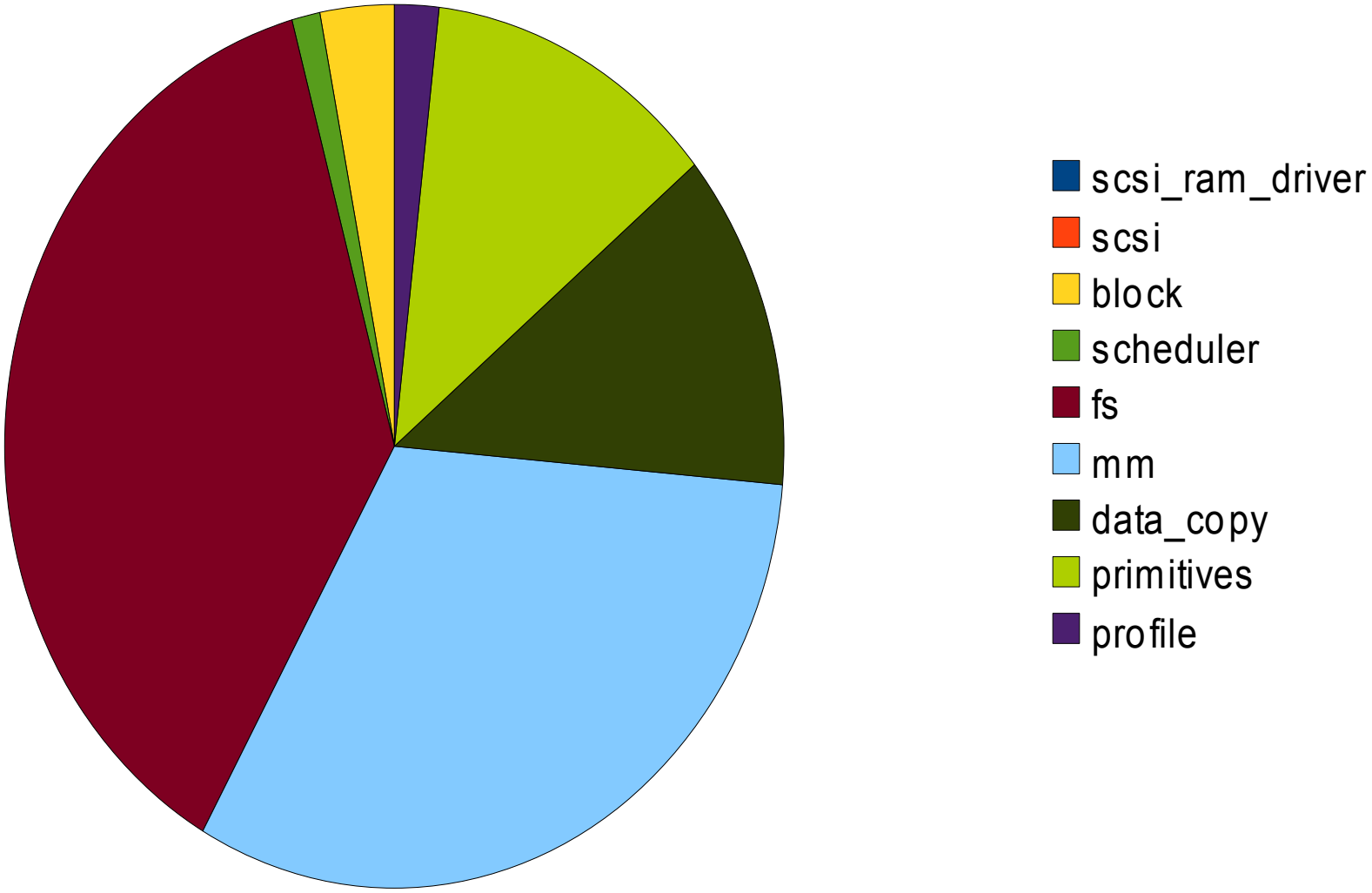
- Existing elevators are optimised for avoiding seeks. This is wasted work when seeks are cheap.

Move libata away from SCSI

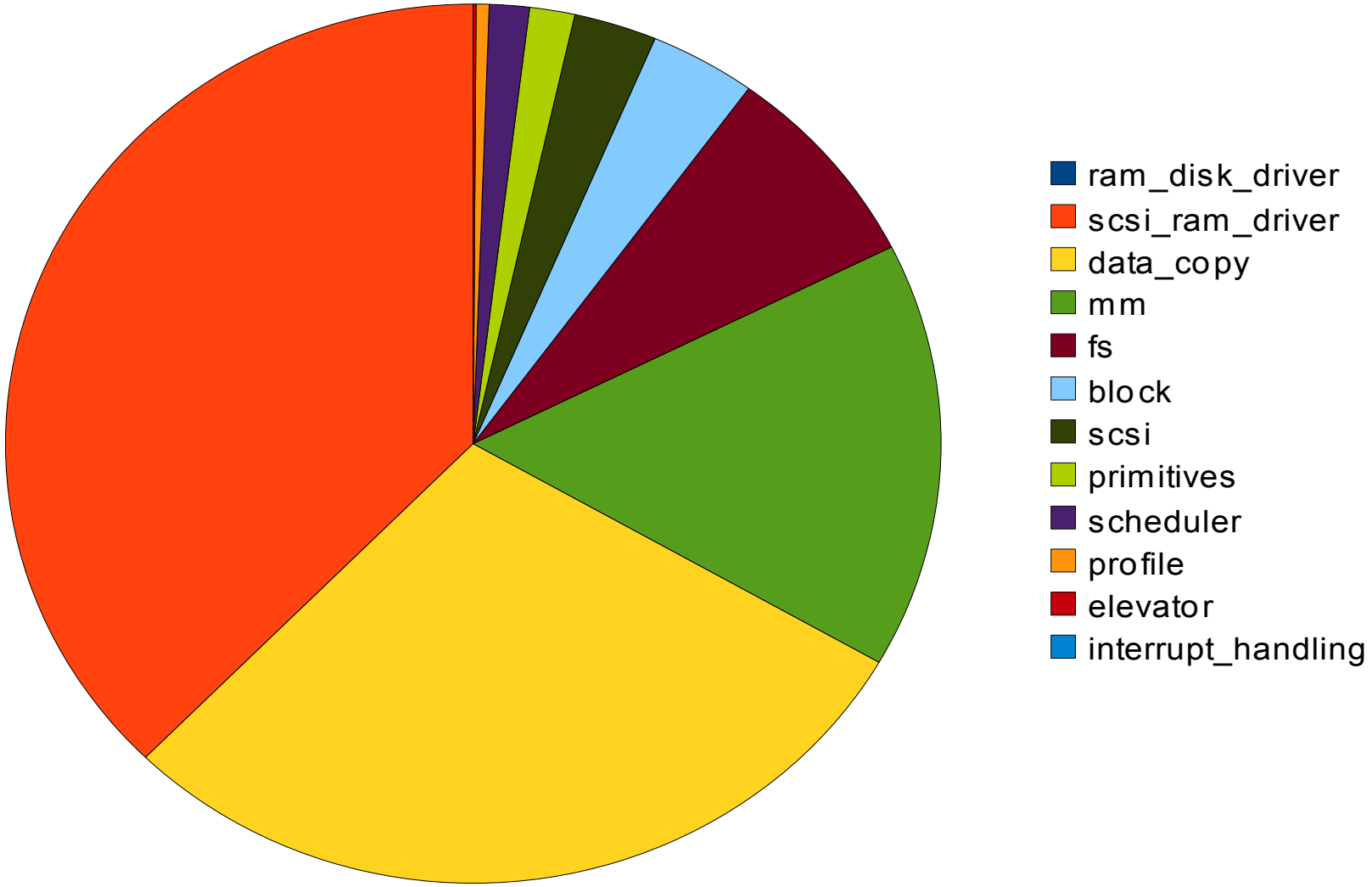
- If it were to interface directly to the block layer, we could avoid the SCSI-to-ATA translation layer.
  - Need to be careful with drivers that support SAS and SATA drives

# Backup

# Ram Disk (rd) Direct IO Profile



# scsi_ram - Cached I/O Profile



# rd - Cached I/O Profile