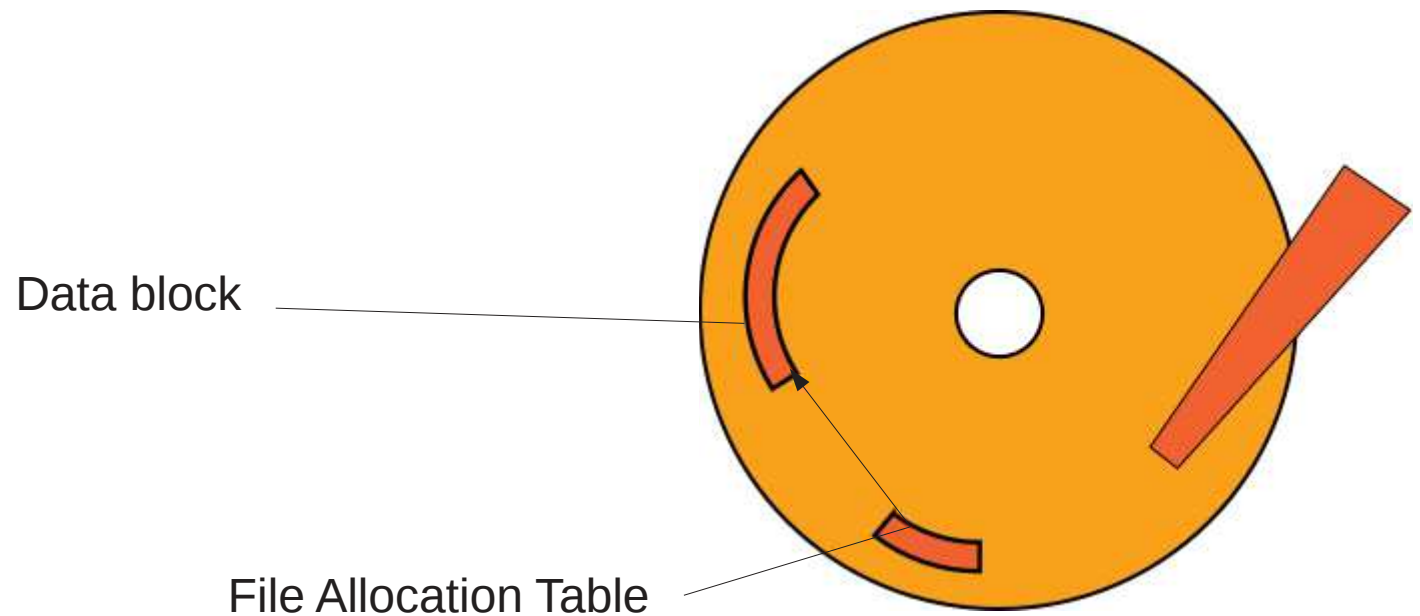


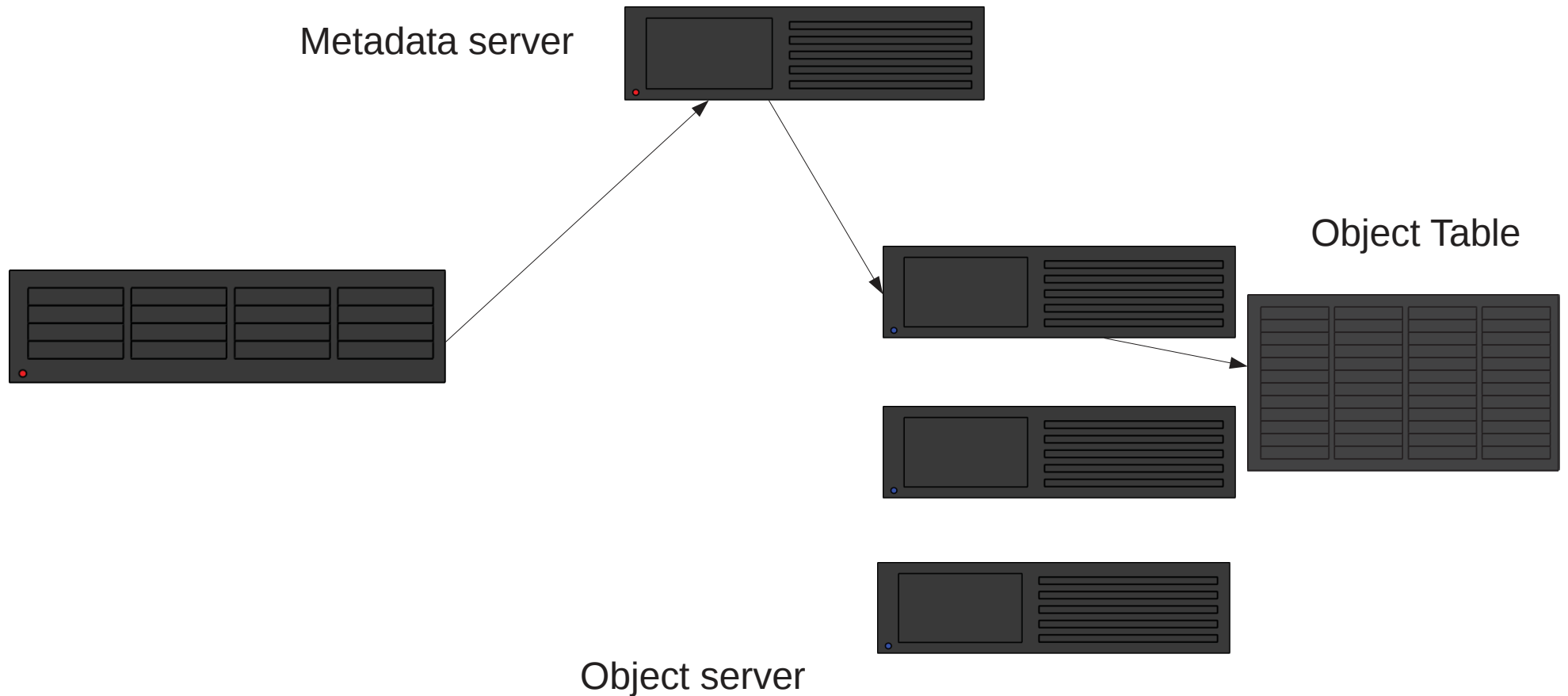
Filesystems

- Filesystems consist of two parts:
 - Metadata – where is my data
 - Content – the data itself



Lustre

- Same basic concept
- Built to scale



NFS

- For comparison:



- Metadata and object data in same place
– Reading excessively prevents access
- No ability to spread load
– No ability to server multiple clients efficiently

Reason for 'No datasets on /home' recommendation

Lustre

- 6xOSS
- 6x6xOST
- 1x MDS (+redundant)
 - Major bottleneck for distributed filesystem

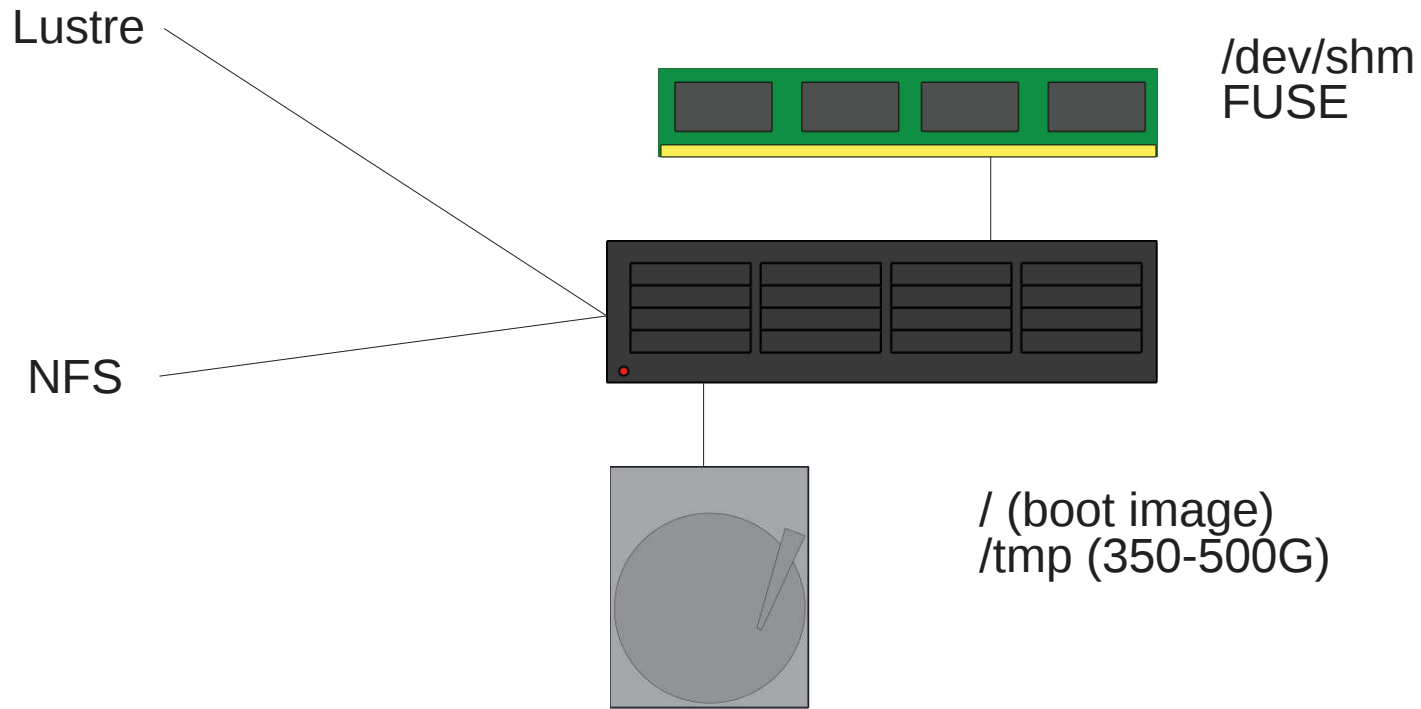
Lustre

- 100G in 1x file:
 - 1x access MDS
 - 1x access OST
 - Bottleneck is OST disk read speed (~500MB/s)
- 100G in 1000x files
 - 1000x access MDS
 - 1000x access OST
 - Bottleneck is MDS access rate (~300 iops/s)
 - Drastically affects other users!

Small File Workarounds

- Try to avoid using small (<1Mb) files individually
 - If you can't:
- If it's small (<32G), use shared memory
- If it's bigger (<350G), use /tmp

Local Storage



Local Storage

CAVEAT:

If you use local storage

PLEASE CLEAN IT UP

I can't know what your job specifically has written, especially if there's more jobs of your own running there

- Thus there's no automatic way to remove local files
- This INCLUDES /dev/shm!

Local Storage

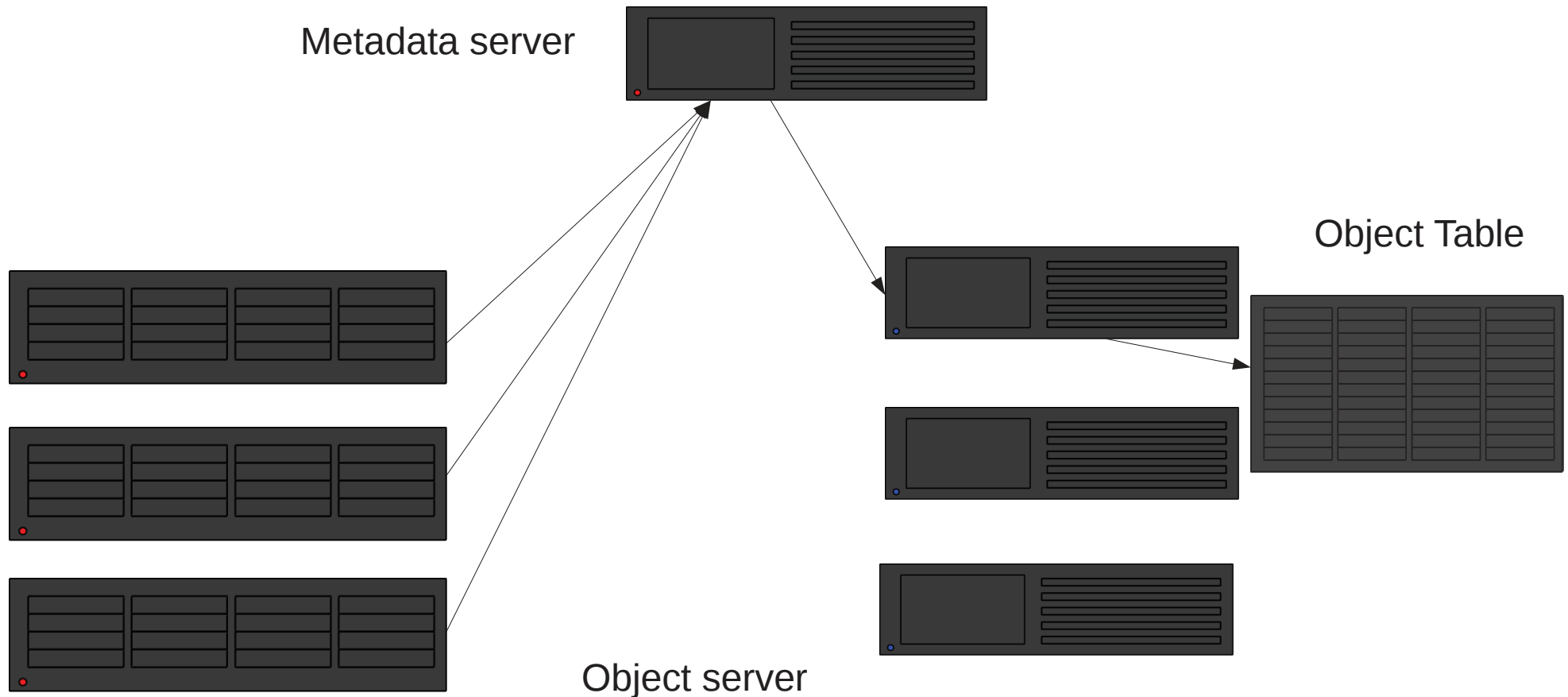
- /dev/shm means Shared Memory
 - Traditionally for transferring data between processes quickly
 - Can be abused for quick filesystem storage
 - 50% max ram size (32G/512G max capacity)
 - Counts against memory usage for job
 - Typical IO ~1Gb/s

Local Storage

- /tmp locally present on compute node
 - Small size disk – high RPM + high iops
- Nodes installed onto this disk (~20G)
 - Rest available for tmp
- But – you still have to copy data to and from this location
 - If consists of small files – still problems!
 - tar + untar is your friend

Large File Workarounds

- One file – one location – one disk
 - Bottleneck



Lustre striping

Using lfs setstripe

Set stripe size and count

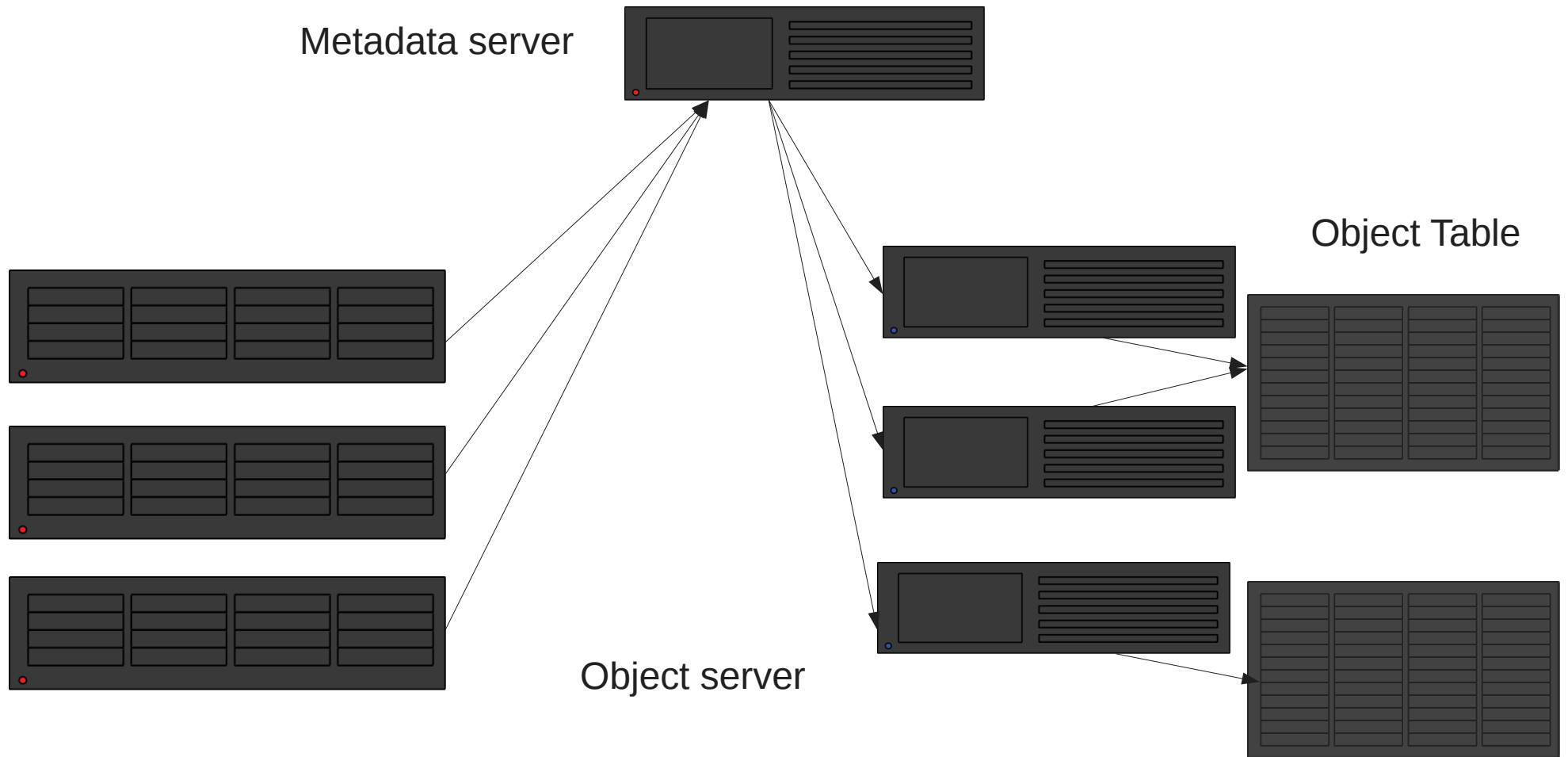
Spreads file over multiple OSTs

MUST BE pool = normalposts

```
dawes001@L0134766: ~
File Edit View Search Terminal Help
-bash-4.2$ lfs setstripe -p normalosts -c -1 -S  $((1024*1024))$  striped_file
-bash-4.2$ dd if=/dev/urandom of=striped_file count=100 bs=1M
100+0 records in
100+0 records out
104857600 bytes (105 MB) copied, 9.99168 s, 10.5 MB/s
-bash-4.2$ lfs getstripe striped_file
striped_file
lmm_stripe_count: 36
lmm_stripe_size: 1048576
lmm_pattern: 1
lmm_layout_gen: 0
lmm_stripe_offset: 12
lmm_pool: normalosts
  obdidx      objid      objid      group
    12      50086365  0x2fc41dd      0
    32      48926968  0x2ea90f8      0
    34      51866669  0x3176c2d      0
    19      48653588  0x2e66514      0
     6      47527451  0x2d5361b      0
    26      49695813  0x2f64c45      0
    35      48306347  0x2e118ab      0
    15      47376379  0x2d2e7fb      0
     2      47776151  0x2d90197      0
    11      47625562  0x2d6b55a      0
    14      46751053  0x2c95d4d      0
     4      52353914  0x31edb7a      0
     8      51172500  0x30cd494      0
    29      39334253  0x258316d      0
     9      50231833  0x2fe7a19      0
    30      50669726  0x305289e      0
     7      46047589  0x2bea165      0
    18      46581747  0x2c6c7f3      0
    21      49561994  0x2f4418a      0
     0      48112706  0x2de2442      0
    31      49924850  0x2f9caf2      0
    33      38360434  0x2495572      0
    13      51352170  0x30f926a      0
    20      49089063  0x2ed0a27      0
    28      41945275  0x28008bb      0
    23      47492004  0x2d4aba4      0
    16      45745846  0x2ba06b6      0
    27      42089200  0x2823af0      0
    22      45202256  0x2b1bb50      0
    25      49002279  0x2ebb727      0
    17      43806772  0x29c7034      0
     3      49495471  0x2f33daf      0
    10      48776495  0x2e8452f      0
    24      47735116  0x2d8614c      0
     5      49202209  0x2eec421      0
     1      46308998  0x2c29e86      0
-bash-4.2$
```

Large File Workarounds

- No longer bottlenecked on multiple section reads



Other Filesystems

- /archive on nfs01 – data on ISILON
 - WUR only
- FUSE:
 - sshfs – mounts to remote file servers

Scontrol

```
dawes001@L0134766: ~  
File Edit View Search Terminal Help  
-bash-4.2$ scontrol show job 3452241  
JobId=3452241 JobName=test_slurm_low  
  UserId=dawes001(17103507) GroupId=domain users(16777729) MCS_label=N/A  
  Priority=10000 Nice=0 Account=99999999 QOS=normal  
  JobState=PENDING Reason=PartitionTimeLimit Dependency=(null)  
  Requeue=1 Restarts=0 BatchFlag=1 Reboot=0 ExitCode=0:0  
  RunTime=00:00:00 TimeLimit=20:00:00 TimeMin=N/A  
  SubmitTime=2017-11-03T15:36:52 EligibleTime=2017-11-03T15:36:52  
  StartTime=Unknown EndTime=Unknown Deadline=N/A  
  PreemptTime=None SuspendTime=None SecsPreSuspend=0  
  Partition=GUESTS_Low AllocNode:Sid=nfs01:25440  
  ReqNodeList=(null) ExcNodeList=(null)  
  NodeList=(null)  
  NumNodes=1 NumCPUs=2 NumTasks=2 CPUs/Task=1 ReqB:S:C:T=0:0:*:*  
  TRES=cpu=2,mem=8000,node=1  
  Socks/Node=* NtasksPerN:B:S:C=0:0:*:* CoreSpec=*  
  MinCPUsNode=1 MinMemoryCPU=4000M MinTmpDiskNode=0  
  Features=(null) Gres=(null) Reservation=(null)  
  OverSubscribe=OK Contiguous=0 Licenses=(null) Network=(null)  
  Command=/home/WUR/dawes001/slurm_testing/test_slurm_low.sh  
  WorkDir=/home/WUR/dawes001/slurm_testing  
  StdErr=/home/WUR/dawes001/slurm_testing/error_output_3452241.txt  
  StdIn=/dev/null  
  StdOut=/home/WUR/dawes001/slurm_testing/output_3452241.txt  
  Power=  
-bash-4.2$
```


scontrol details

- Priority
 - Scheduling priority given to job based on information in sprio
- JobState=PENDING
Reason=PartitionTimeLimit
 - Descriptive reason why job isn't starting

scontrol details

- Not all reasons are easy to see at first:
 - ReqNodeNotAvail
 - UnavailableNodes:node[XXX]
- Means that the selected node isn't available for some period during the run
 - Could be downtime
 - Could be reserved

scontrol details

- SubmitTime/EligibleTime/StartTime/EndTime
 - (Start – Eligible) Rough queue length based on what Slurm expects jobs to take
 - Reason why job lengths are important
- NumNodes=1 NumCPUs=2 NumTasks=2
CPUs/Task=1

TRES (Trackable Resources)

- Check for what resources you've specified

scontrol update?

- Basically no – you can't change the requirements of a job after it's running
 - Except for TimeLimit – you may always **reduce** this
- But you can reduce the MinCPUNode/MinMemNode fields whilst job is pending

sbatch Options

- Sbatch has many options
- Here's some you might not know about:

sbatch Options

- Unusual options you might not know...

`--tmp`

Temporary Space

- You're going to use /tmp for something
- You need X Mb of space

`--tmp=X`

- Will not execute job on node with less than X available space
- Reduces heartache from other lazy users

sbatch Options

- Unusual options you might not know...

--dependency

sbatch Dependencies

- `after:job_id[:jobid...]`
 - This job can begin execution after the specified jobs have **begun** execution.
- `afterany:job_id[:jobid...]`
 - This job can begin execution after the specified jobs have **ended**.
- `afternotok:job_id[:jobid...]`
 - This job can begin execution after the specified jobs have **terminated in some failed state** (non-zero exit code, node failure, timed out, etc).
- `afterok:job_id[:jobid...]`
 - This job can begin execution after the specified jobs have **successfully executed** (ran to completion with an exit code of zero).

sbatch Dependencies

- This allows you to submit multiple jobs in a chain
 - Not all the same size too, e.g.
 - small linear job to download/unpack (e.g. on normalmem)
 - Large assembly job (e.g. on fat)
 - Small packing job (e.g. on normalmem)

sbatch Dependencies

- `expand:job_id`
 - Resources allocated to this job should be used to expand the specified job. The job to expand must share the same QOS (Quality of Service) and partition. Gang scheduling of resources in the partition is also not supported.
- `singleton`
 - This job can begin execution after any previously launched jobs sharing the same job name and user have terminated.

sbatch Dependencies

- Singleton can be used to limit job rate
 - Name all in one ‘pool’ of jobs the same job-name
 - Only one will be executed at a time
- Don’t get excited about expand!
 - Can only add additional nodes to jobs
 - scontrol update jobid NumNodes=ALL

sbatch Options

- Unusual options you might not know...

`--begin`

Deadlines

- Submit a job now, but don't allow it to run until a certain time
- Useful if you want to submit a bunch of jobs to run at night/quieter times/unsupervised

sbatch Options

- Unusual options you might not know...

`--deadline`

Deadlines

- You can opt to have a job fail if it will never get to finish before a certain time
- Can also be a good safety switch for massive job submission

sbatch Options

- Unusual options you might not know...

`--export`

Environment Settings

- You are submitting jobs from a script and want to pass in some environment variable:

```
sbatch --export="MYVAR=3"
```

- You want to explicitly prevent your environment from tainting this job:

```
sbatch --export=NONE
```

sbatch Options

- Unusual options you might not know...

`--open-mode`

Append/Truncate

```
#SBATCH --open-mode=append
```

- Will append to existing output/error files rather than overwriting them
- Great for extending jobs / repeating jobs

sbatch Options

- Unusual options you might not know...

`--gres`

Generic Resources

- Not so generic
- Mainly used for additional hardware plugins – Graphical Processing Units (GPUs) and Many Integrated Cores (MICs, e.g. Knights Landing)
 - This is how you (could) specify GPU's if/when requested:

```
#SBATCH --gres=gpu:1
```

sbatch Options

- Unusual options you might not know...

`--signal`

Signalling

- Slurm will send out signals to processes at a controlled time period before termination
 - `--signal=INT@120`
 - Sends out a SIGINT (Interrupt) 120 seconds before job period expires
- Also can be done from scancel:
 - `scancel --signal USR1`
 - Useful for sending signals in to get jobs to do things

sbatch Options

- Unusual options you might not know...

`--constraint`

Features

- Nodes are not uniform:
 - Normal nodes:
 - Intel CPUs
 - 4000M/CPU
 - Fat nodes:
 - AMD CPUs
 - 16000M/CPU
- May well be others besides in the future

scontrol Features

scontrol show nodes

```
dawes001@L0134766: ~  
File Edit View Search Terminal Help  
NodeName=node054 Arch=x86_64 CoresPerSocket=8  
  CPUAlloc=16 CPUErr=0 CPUTot=16 CPULoad=3.40  
  AvailableFeatures=normalmem,4gpercpu,intel  
  ActiveFeatures=normalmem,4gpercpu,intel  
  Gres=(null)  
  NodeAddr=node054 NodeHostName=node054 Version=16.05  
  OS=Linux RealMemory=64337 AllocMem=64000 FreeMem=3655 Sockets=2 Boards=1  
  State=ALLOCATED ThreadsPerCore=1 TmpDisk=384587 Weight=1 Owner=N/A MCS_label  
=N/A  
  BootTime=2017-09-06T09:31:17 SlurmdStartTime=2017-09-06T09:33:37  
  CapWatts=n/a  
  CurrentWatts=0 LowestJoules=0 ConsumedJoules=0  
  ExtSensorsJoules=n/s ExtSensorsWatts=0 ExtSensorsTemp=n/s  
-bash-4.2$
```

scontrol Features

/cm/shared/apps/accounting/list_all_features

```
dawes001@L0148837: ~  
-----  
Last login: Tue Oct 16 10:08:44 2018 from 137.224.111.205  
-----  
Welcome to nfs01.hpcagrogeomics.wur.nl.  
  
For usage information,  
  please see the wiki at https://wiki.hpcagrogeomics.wur.nl  
-----  
-bash-4.2$ /cm/shared/apps/accounting/list_all_features  
16gpercpu - fat[001-002]  
4gpercpu - node[001-042,049-054]  
8gpercpu - gpu001,node[001-008,019-026]  
amd - fat[001-002]  
intel - gpu001,node[001-042,049-054]  
largemem - fat[001-002]  
moremem - gpu001,node[001-008,019-026]  
normalmem - node[009-018,027-042,049-054]  
nvidia - gpu001  
-bash-4.2$
```

Features

- Can be combined:
 - "opteron&video"
 - AND
 - "fast|faster"
 - OR
 - [rack1|rack2|rack3|rack4]
 - EVERY part of this job must be in one rack

Environment Variables

- Jobs set large numbers of environment variables when run:
- Useful examples:
 - Data from submission:
 - SLURM_JOB_NAME
 - SLURM_NTASKS
 - SLURM_TASKS_PER_NODE
 - SLURM_STEP_NUM_TASKS
 - SLURM_JOB_CPUS_PER_NODE
 - SLURM_JOB_PARTITION
 - SLURM_JOB_ACCOUNT
 - SLURM_JOB_NUM_NODES
 - SLURM_STEP_TASKS_PER_NODE
 - SLURM_NPROCS

Environment Variables

- Data about current job:
 - SLURM_JOB_NAME
 - SLURM_NTASKS
 - SLURM_TASKS_PER_NODE
 - SLURM_STEP_NUM_TASKS
 - SLURM_JOB_CPUS_PER_NODE
 - SLURM_JOB_PARTITION
 - SLURM_JOB_ACCOUNT
 - SLURM_JOB_NUM_NODES
 - SLURM_STEP_TASKS_PER_NODE
 - SLURM_NPROCS

Reservations

- Some point in the future you need resources immediately
 - e.g. a course
 - A seminar
 - Time critical computation
- You can submit a job in advance, but you have to specify the result of that
 - How to proceed?

scontrol Reservations

```
dawes001@L0134766: ~
File Edit View Search Terminal Help
-bash-4.2$ scontrol show reservations
ReservationName=Major Downtime Nov 2017 StartTime=2017-11-23T08:00:00 EndTime=2017-11-23T20:00:00 Duration=12:00:00
  Nodes=fat[001-002],node[001-042,049-054] NodeCnt=50 CoreCnt=896 Features=(null) PartitionName=(null) Flags=MAINT,IGNORE_JOBS,SPEC_NODES
  TRES=cpu=896
  Users=root Accounts=(null) Licenses=(null) State=INACTIVE BurstBuffer=(null) Watts=n/a

ReservationName=GPTEST StartTime=2017-08-30T15:27:19 EndTime=2017-11-01T00:00:00 Duration=62-09:32:41
  Nodes=gpu001 NodeCnt=1 CoreCnt=16 Features=nvidia PartitionName=(null) Flags=IGNORE_JOBS
  TRES=cpu=16
  Users=katzi001,vande018,verho068,moral005,warri004,knape001,dawes001,lith010 Accounts=(null) Licenses=(null) State=INACTIVE BurstBuffer=(null) Watts=n/a

ReservationName=CANU_roden015 StartTime=2017-09-28T13:17:31 EndTime=2017-10-27T00:00:00 Duration=28-10:42:29
  Nodes=node[004-006,008,016] NodeCnt=5 CoreCnt=80 Features=(null) PartitionName=(null) Flags=IGNORE_JOBS,SPEC_NODES
  TRES=cpu=80
  Users=roden015 Accounts=(null) Licenses=(null) State=INACTIVE BurstBuffer=(null) Watts=n/a

ReservationName=HG_FREE StartTime=2017-10-10T10:48:36 EndTime=2018-01-01T00:00:00 Duration=82-14:11:24
  Nodes=node001 NodeCnt=1 CoreCnt=16 Features=normalmem PartitionName=(null) Flags=OVERLAP
  TRES=cpu=16
  Users=dings01,huisma01,vereij01,peeter01,ytourn01,willem01,bronsv01,zwiers01,bink01,visser01,blonk01,vila01,weteri01,ehlers01,faure01,rome01,fablet01
  Accounts=(null) Licenses=(null) State=ACTIVE BurstBuffer=(null) Watts=n/a

ReservationName=HG_5 StartTime=2017-11-20T08:00:00 EndTime=2017-11-22T23:59:59 Duration=2-15:59:59
  Nodes=node002 NodeCnt=1 CoreCnt=16 Features=normalmem PartitionName=(null) Flags=
  TRES=cpu=16
  Users=dings01,huisma01,vereij01,peeter01,ytourn01,willem01,bronsv01,zwiers01,bink01,visser01,blonk01,vila01,weteri01,ehlers01,faure01,rome01,fablet01
  Accounts=(null) Licenses=(null) State=INACTIVE BurstBuffer=(null) Watts=n/a

ReservationName=HG_6 StartTime=2017-12-11T08:00:00 EndTime=2017-12-13T23:59:59 Duration=2-15:59:59
  Nodes=node002 NodeCnt=1 CoreCnt=16 Features=normalmem PartitionName=(null) Flags=
  TRES=cpu=16
  Users=dings01,huisma01,vereij01,peeter01,ytourn01,willem01,bronsv01,zwiers01,bink01,visser01,blonk01,vila01,weteri01,ehlers01,faure01,rome01,fablet01
  Accounts=(null) Licenses=(null) State=INACTIVE BurstBuffer=(null) Watts=n/a

ReservationName=HPC_ADVANCED_COURSE StartTime=2017-11-09T08:00:00 EndTime=2017-11-09T13:00:00 Duration=05:00:00
  Nodes=node[002-004] NodeCnt=3 CoreCnt=48 Features=normalmem PartitionName=GUESTS_Low Flags=
  TRES=cpu=48
  Users=-root Accounts=(null) Licenses=(null) State=INACTIVE BurstBuffer=(null) Watts=n/a

-bash-4.2$
```

Reservations

- Need to be added by admin
- Can only be assigned to users, not groups
 - Can be hacked to follow groups – contingent on admin awareness
- Can only allocate entire nodes
 - Can allocate CPU's, but no memory – basically useless
- General policy – max 3 nodes

Future Work – May 2019

- Containers on HPC
 - Specific workflow needed?
- Quality of Service rather than partitions
 - Allows for balance between capacity and availability
- GPU Teaching course
 - Teaching from NVidia on GPU coding