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Lustre On Demand
Evolution of Data Tiering on Storage System

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Agenda

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- Introduction
- LOD (Lustre On Demand) as Tiering solution
  - Overview
  - Use case
- Implementation and usage
- Current Status and Future work
- Conclusions

Evolution of data tiering on storage system

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- First Generation – primary filesystem to archive
  - E.g. HDD based filesystem to tape or even on cloud
  - HSM provides managing of data residence and transparent data access
- Second Generation – another tier in front of primary filesystem
  - Burst Buffer
  - Local filesystem or other filesystem on flash device
- Simplification, Automation and Transparency are important
  - Users complain about complexity, but administrator and users wants IO acceleration on flash devices
  - /tmp or /dev/shm are easy to use for users, but user need to manage data residence by themselves

Introduce LOD (Lustre On Demand), a tiering approach for Lustre, provides temporary filesystem per job and automated synchronization with primary filesystem job scheduler.

Various Lustre caching options

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- Hardware cache
  - Memory, SSD/NVMe, write back cache on storage array, cache on drives
  - Lustre relies on hardware capability transparently
- Ladvise (Lustre fadvise)
  - Giving hints to files and prefetch data on OSS memory or SSD with DSS
  - This is similar idea of fadvise(), but through Lustre client and Lustre server side caching
- PCC (Persistent Client Cache)
  - Leverages local SSD/NVMe on client and keep single namespace
  - Support write/read caches with HSM (and group lock) features for consistency
- Lustre Write Back Cache
  - Data and metadata into RAM on client as cache
  - Avoid of LDLM and network latency

LOD (Lustre On Demand)

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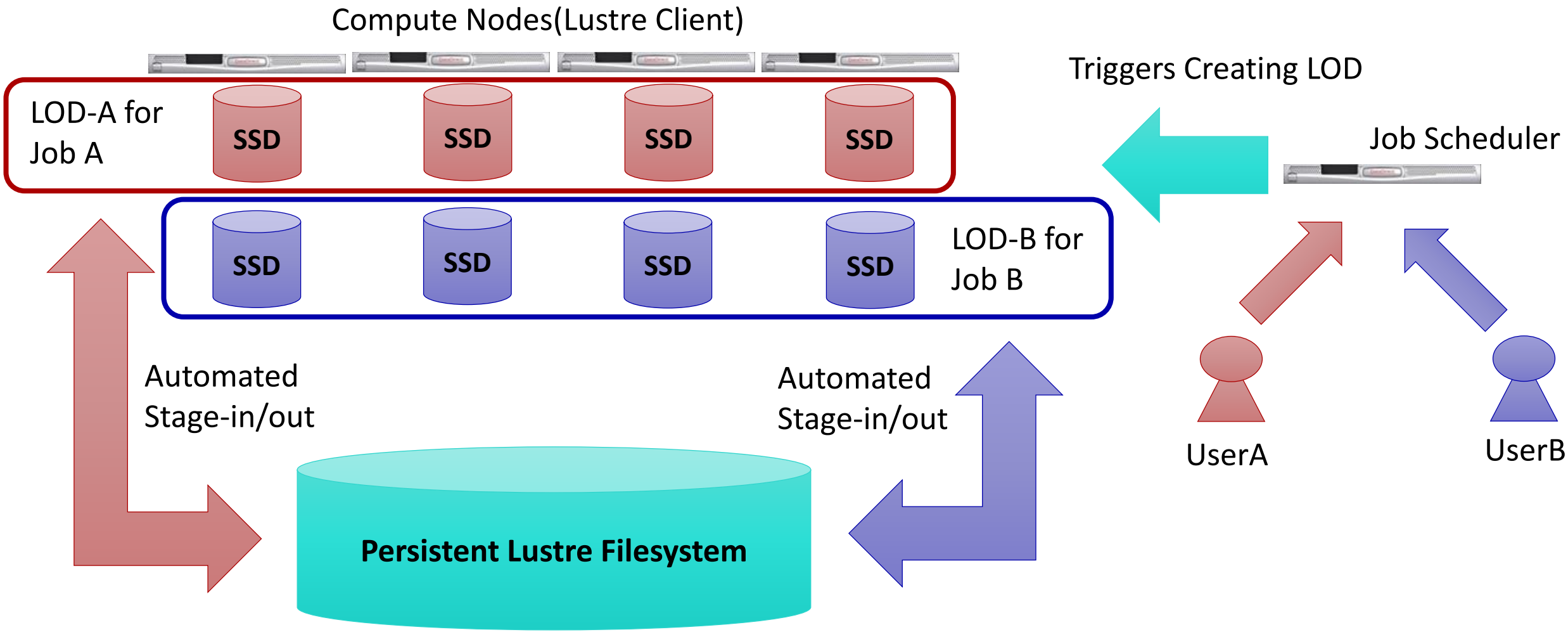
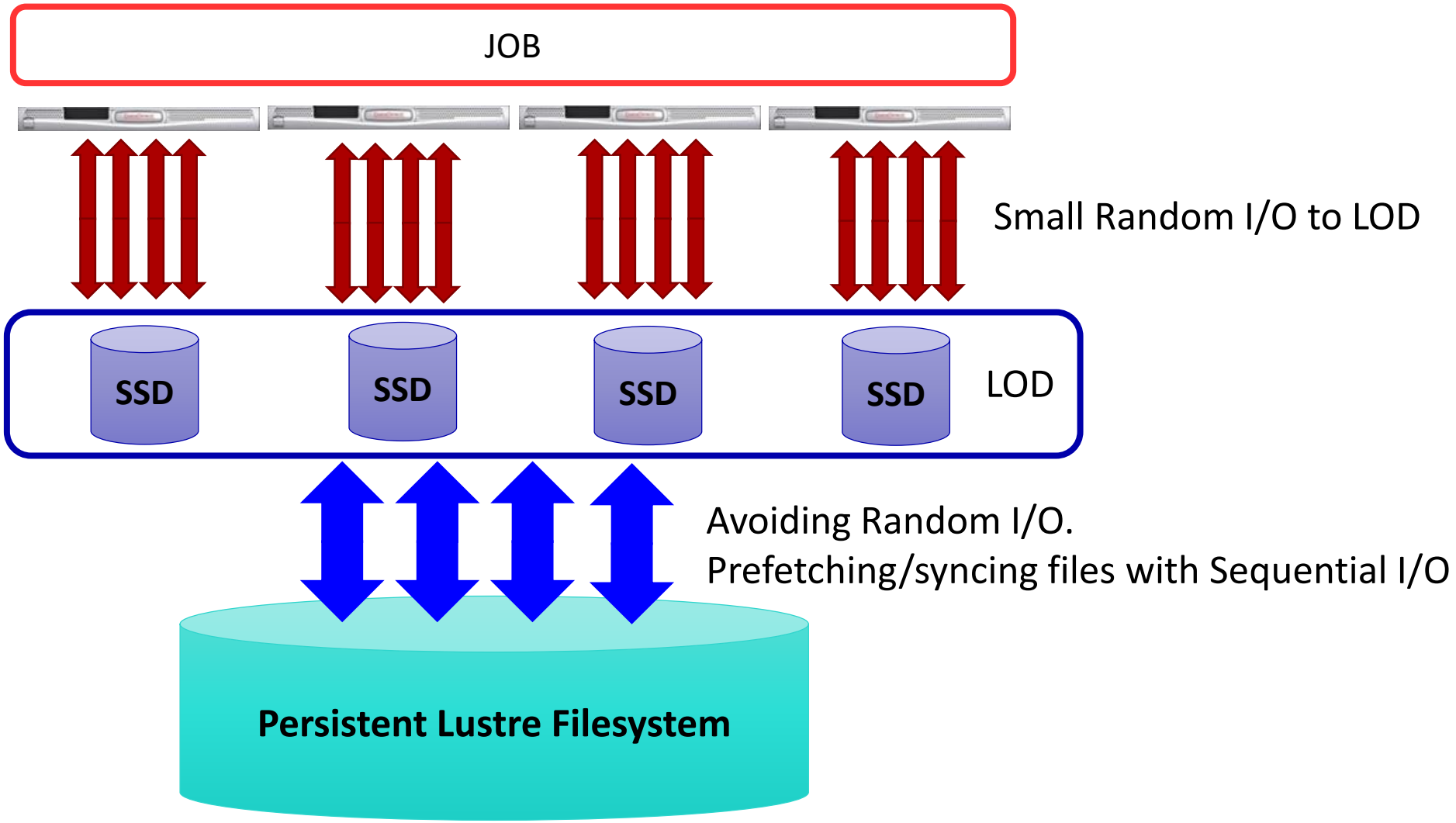
- Provide Dynamic Lustre filesystem on compute nodes using local SSD/NVMe
  - Temporary fast Lustre filesystem across the compute nodes
  - LOD creates Lustre on computes nodes dynamically
- Integration with job scheduler
  - User turn LOD on/off per job at job submission
  - Currently integrated into SLURM's Burst Buffer option, but other job scheduler also could work
- Transparent and automated stage-in/out
  - User can define file/directory list on stage-in/out to LOD at Job submission
  - LOD automatically sync/migrate data from persistent Lustre to created temporary Lustre filesystem
- Lots of flexibility and extendibility
  - Configurable MDT/OST configuration for advanced users

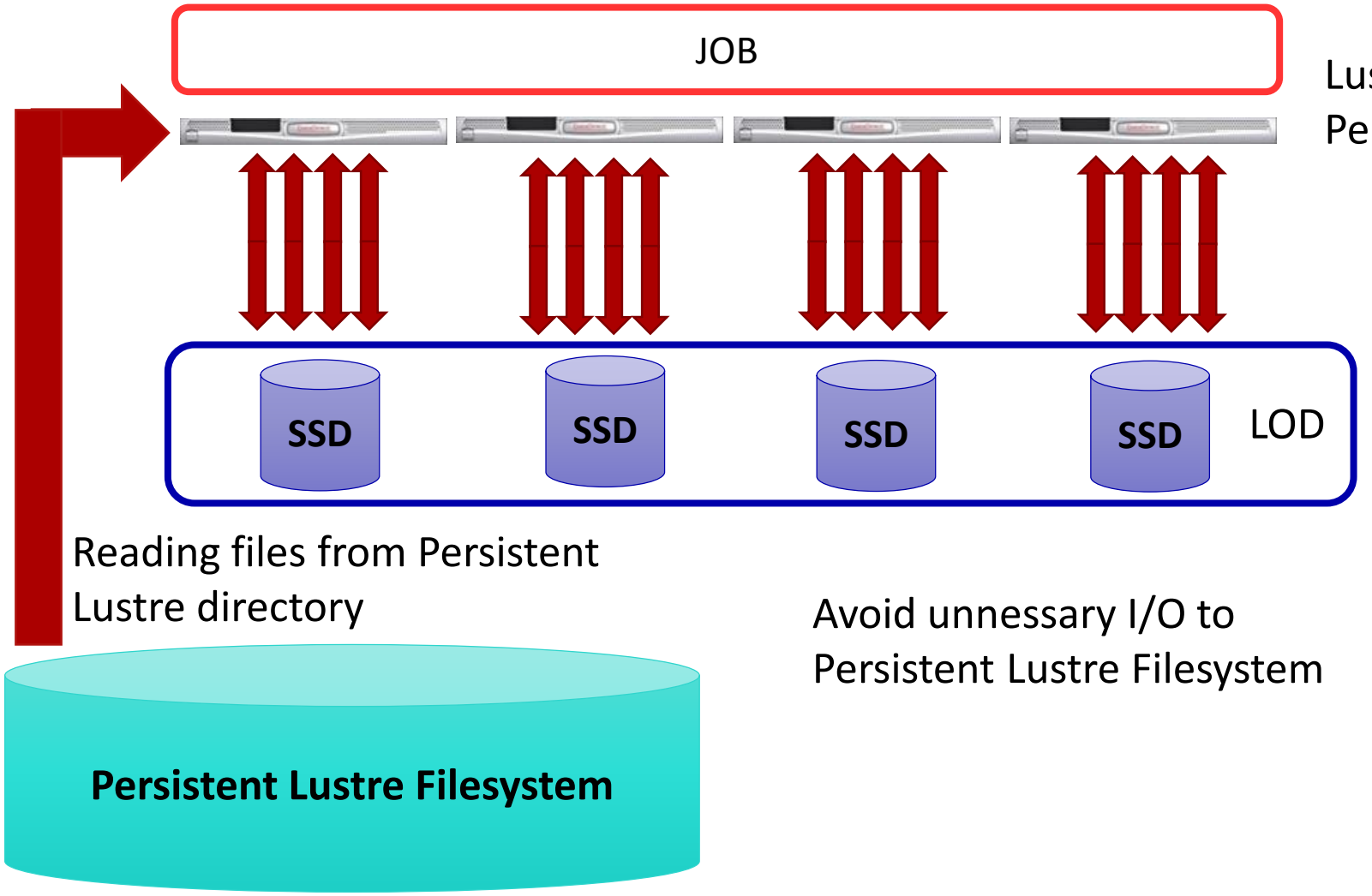
LOD architecture and design



Use cases(1) : Accelerated random I/O operations



Use cases(2) : Reduce loads on PFS



Lustre clients mount both LOD and Persistent Lustre

Temporary Clustered filesystem for Job

Reading files from Persistent Lustre directory

Avoid unnessary I/O to Persistent Lustre Filesystem

Use cases(3) : Isolated namespace per JOB or clients

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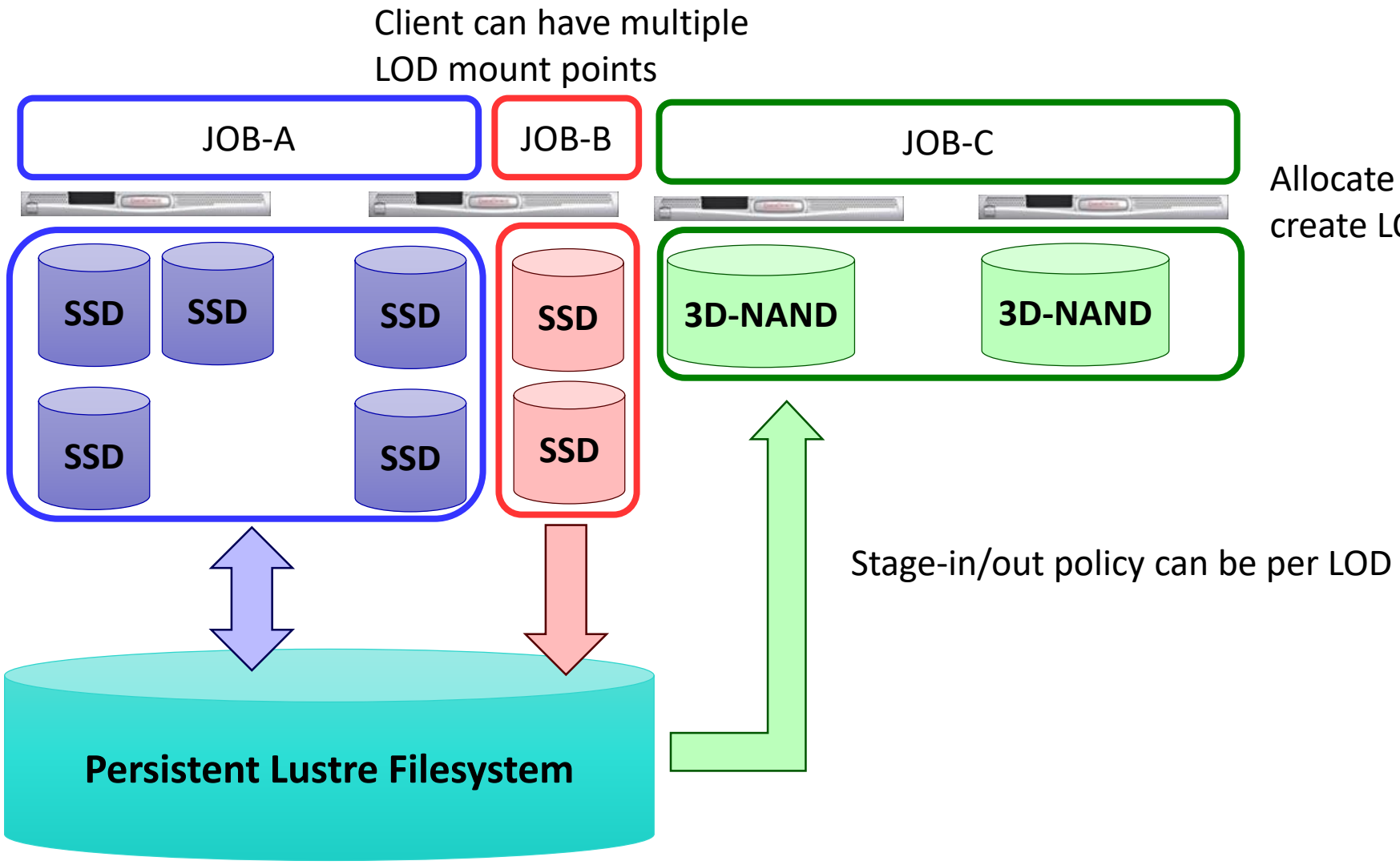

Allocate SSD devices and create LOD per JOB

Stage-in/out policy can be per LOD

LOD Implementation

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- LOD is a framework that runs on top of job scheduler
  - Job scheduler have storage extension/plugin to manage storage resources on compute nodes
  - Prolog/epliog also works, but storage extensions/plugin can allow tighter integration and flexibility
- Selected SLURM for demonstration of LOD
  - Open source and one of the major job scheduler for HPC
  - “Burst Buffer” plugin is available
  - LOD framework can be integrated on BB plugin
- No more patched kernel for Lustre server
  - Thanks for patchless server support

SLURM : Introduction

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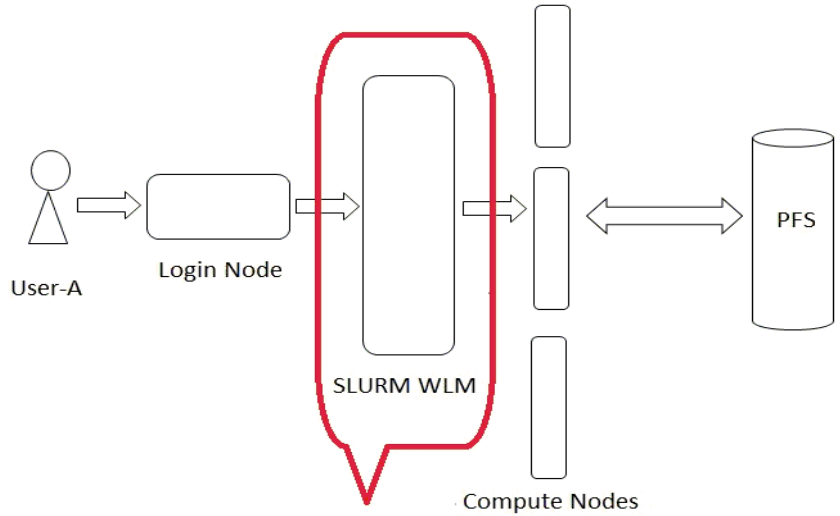
- What is SLURM ? (Simple Linux Utility for Resource Management)
  - Allocates resource (compute nodes) for user to execute the job
    - Exclusive and/or non-exclusive access
    - For some duration of time
  - Provides facility to start, execute and monitor jobs on allocated nodes
  - Manages queue of pending jobs in case of contention for resource



- How to use it ?
  - Provides sets of command to start, execute and monitor jobs
    e.g. sbatch, salloc, sinfo, etc.
  - Mainly jobs are run in
    - Batch mode (e.g. sbatch test.sh)
    - Interactive mode (e.g. salloc command)

test.sh

```
#!/bin/bash
#SBATCH -p debug
#SBATCH -N 1
#SBATCH -t 00:05:00
srun a.out
```

SLURM : Burst Buffer (BB) Infrastructure

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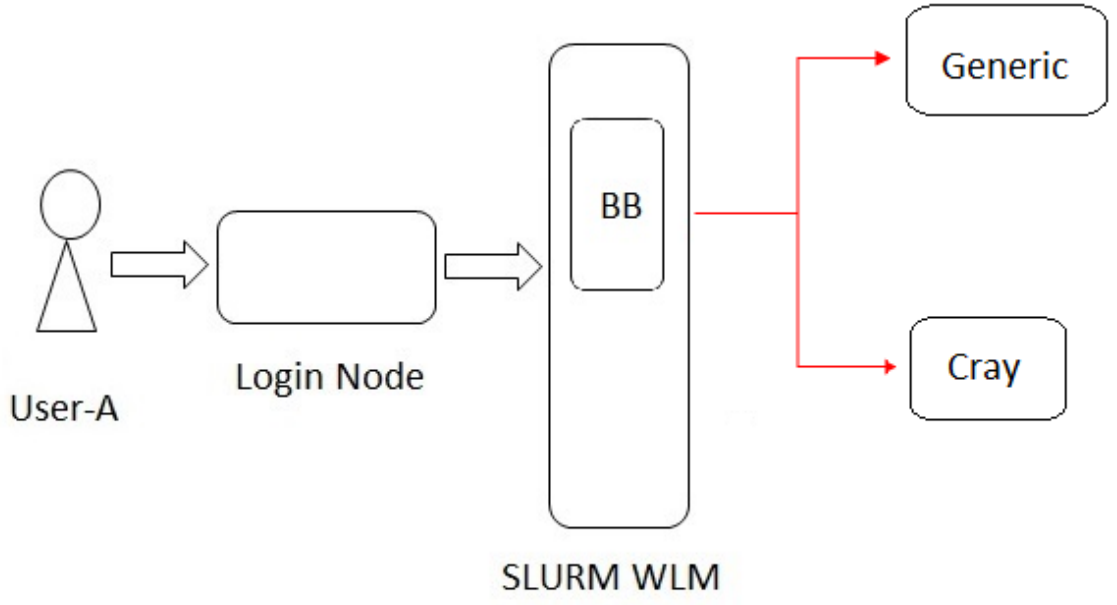
- SLURM Burst Buffer is a pluggable architecture which facilitates usage of high-speed storage resource

- Burst Buffer infrastructure has following workflow:
  - Allocates burst buffer resource
  - Staging in required file(s) into it
  - Schedule compute node(s) for the job execution using these resources
  - Stage out file(s) if needed after completion of job

- Currently there are two plugins available:
  - Generic: Not implemented
  - Cray



BB plugin integration details

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Important steps to add new plugin into BB infrastructure are:

- Unique name assigned to plugin and same will be used in slurm.conf
  - E.g. for generic plugin it is like:
    const char plugin_type[] = "burst_buffer/generic";
  - And mention into configuration as:
    BurstBufferType=burst_buffer/generic
- Workflow API to be implemented

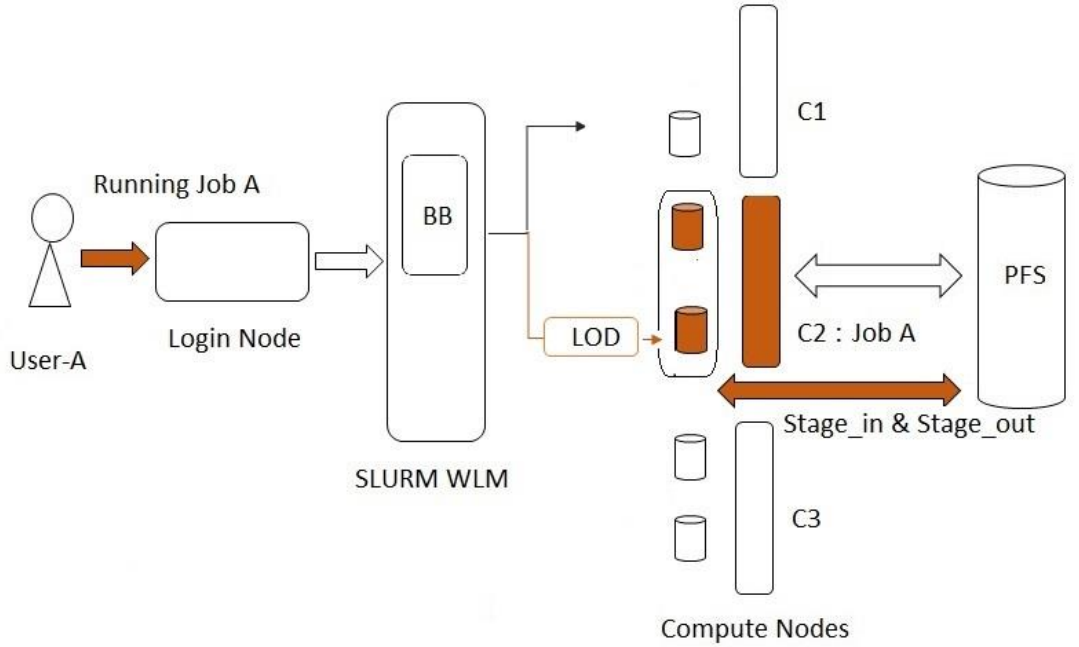
```
bb_p_get_system_size
bb_p_load_state
bb_p_get_status
bb_p_state_pack
bb_p_reconfig
bb_p_job_validate
bb_p_job_validate2
bb_p_job_set_tres_cnt
bb_p_job_get_est_start
bb_p_job_try_stage_in
bb_p_job_test_stage_in
bb_p_job_begin
bb_p_job_revoke_alloc
bb_p_job_start_stage_out
bb_p_job_test_post_run
bb_p_job_test_stage_out
bb_p_job_cancel
bb_p_xlate_bb_2_tres_str
```

- Current LOD implementation using generic plugin

Job execution workflow

- LOD Framework and SLURM integration

  - LOD Framework perform underlying management functions e.g. creation of Lustre on demand based on user input
  - Used SLURM generic BB plugin skeleton and integrated LOD framework into it for ease of use
  - How this works
    - User will submit the job, e.g. Job A
    - It will allocate compute node, e.g. C2
    - The files which required for job will be stage_in first
    - Once files stage_in then it will start execution of job
    - After completion of job, only required file(s) to be stage_out (sync) to main PFS



How to use LOD : Example

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Running it in batch mode using slurm command “sbatch <script_file>”

$ sbatch example_job.sh

[example job.sh]

```
#!/bin/bash
#LOD setup_lod type=scratch capacity=10GB
#LOD stage_in source=/mnt/pfs/large_file destination=$LOD_MNT/ type=file
#LOD stage_out source=$LOD_MNT/output destination=/mnt/pfs/sample_task/ type=file
srun sample_task.sh
```

[example job.sh]

#LOD : setup_lod

- Information :

  This will setup the LOD instance as per job requirement through SLURM

- Parameters

  - type = scratch or persistent
  - capacity = <number>[MB|GB|TB|PB]
  - lod_config = <path to config file> This is optional parameter.

[example job.sh]

```
#!/bin/bash
#LOD setup lod type=scratch capacity=10GB
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srun sample_task.sh
```

[example job.sh]

#LOD : stage_in

- Information :

  This will fetch file(s)/directory(ies) needed for the job before it starts through SLURM

- Parameters :
  - source : path of source file/directory
  - destination : path of destination file/directory
  - type : file or directory

[example job.sh]

```
#!/bin/bash
#LOD setup_lod type=scratch capacity=10GB
#LOD stage_in source=/mnt/pfs/large_file destination=$LOD_MNT/ type=file
#LOD stage_out source=$LOD_MNT/output destination=/mnt/pfs/sample_task/ type=file
srun sample_task.sh
```

[example job.sh]

#LOD : stage_out

- Information :

  This will sync file(s)/directory(ies) needed for the job after completion of job

- Parameters :
  - source : path of source file/directory
  - destination : path of destination file/directory
  - type : file or directory

[example job.sh]

```
#!/bin/bash
#LOD setup_lod type=scratch capacity=10GB
#LOD stage_in source=/mnt/pfs/large_file destination=$LOD_MNT/ type=file
#LOD stage_out source=$LOD_MNT/output destination=/mnt/pfs/sample_task/ type=file
srun sample_task.sh
```

[example job.sh]

srun sample_task.sh

- Information:
  - Ready to execute the job as the required instance is ready with input files needed.
  - After completion of the job all the files except files mention under stage_out will be removed

[example job.sh]

```
#!/bin/bash
#LOD setup_lod type=scratch capacity=10GB
#LOD stage_in source=/mnt/pfs/large_file destination=$LOD_MNT/ type=file
#LOD stage_out source=$LOD_MNT/output destination=/mnt/pfs/sample_task/ type=file
srun sample_task.sh
```

[example job.sh]

Current Status and future Plan

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- Current status:
  - LOD frame work : Basic infrastructure ready with limited testing
  - Integration with SLURM: Used generic BB plugin for integration
- stage_in/stage_out :

  Automate data movement in Lustre server side use case where files are transparently move into and from flash storage tier, using FLR as per job requirement. e.g.

  #LOD stage_in source=hdd:/mnt/pfs/large_file destination=flash: type=flr_file

  #LOD stage_out source=flash:large_file destination=hdd type=flr_file

- To improve on LOD creation part by providing profile based creation

  e.g. data intensive, metadata intensive, balanced, default

- Options to tune LOD as per job requirement for small files, I/O size, I/O patters

Conclusions

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- Introduced Lustre On Demand as a new Tiering option on Lustre
  This not only allows new use cases on Lustre and but also accelerate
  I/O Performance

- Lustre On Demand is a framework and integrated as an extension of the
  Burst Buffer plugin on the SLURM job scheduler as a prototype implementation

- Will continue to extend LOD framework and look at integration with another job scheduler

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Thank you!

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