Managing Lustre on AWS

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Amazon FSx for Lustre

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Agenda

- Amazon FSx for Lustre Introduction
- Connecting to S3 with Lustre and HSM
- Example Deep Learning workflow
- What's next?

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Introducing:

Amazon FSx
for Lustre

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Why Lustre?

- At AWS we work backwards from the customer
- Our customers needed hundreds of GB/s throughput and sub-ms latencies
- They wanted Lustre by name

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Presentation

- Fully managed Lustre filesystem
- Lustre clients are customer-managed
- Can be attached to an S3 bucket
- Encrypted at rest.

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Characteristics

From 3.6 TiB to more than 1,000 TiB
Bandwidth: 200 MB/s per TiB

Running in virtual machines, on AWS EC2

1 MDT - 3 % of total filesystem size
Many OSTs - 1.1 TiB each, NVMe based

Lustre 2.10

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Easy to start

Create with a simple CLI command (Web GUI and API available)

```
aws fsx create-file-system
 --file-system-type LUSTRE --storage-capacity 3600
 --subnet-ids ... --security-group-ids ...
{
    "FileSystem": {
        "FileSystemType": "LUSTRE",
        "StorageCapacity": 3600,
        "Lifecycle": "CREATING",
        "DNSName": "fs-0bd0cc7e8.fsx.us-east-1.amazonaws.com",
        ...
    }
}
```


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Easy to access

1. Start an EC2 instance, with the proper networking configuration
2. Install the Lustre client (documentation available for major distros)
3. Mount the filesystem using standard command:

```
$ mount –t lustre fs-0bd0cc7e8.fsx.us-east-1.amazonaws.com@tcp /fsx
$ lfs df -h
UUID                       bytes        Used   Available Use% Mounted on
fsx-MDT0000_UUID         102.8G        2.6M       102.8G   0% /fsx[MDT:0]
fsx-OST0000_UUID           1.1T        4.5M         1.1T   0% /fsx[OST:0]
fsx-OST0001_UUID           1.1T        4.5M         1.1T   0% /fsx[OST:1]
fsx-OST0002_UUID           1.1T        4.5M         1.1T   0% /fsx[OST:2]

filesystem_summary:        3.3T       13.5M         3.3T   0% /fsx
```


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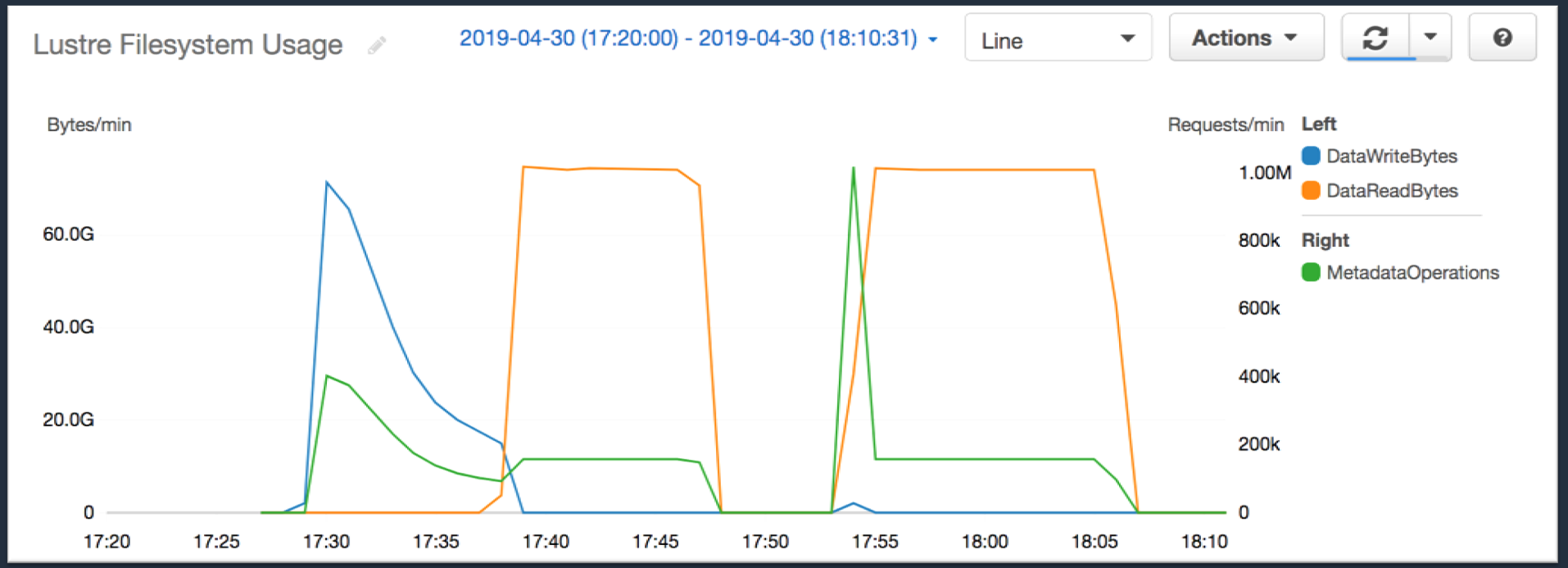
Monitoring with Amazon CloudWatch

Several metrics available like space usage, bandwidth, iops, …



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Connect to S3 with Lustre/HSM

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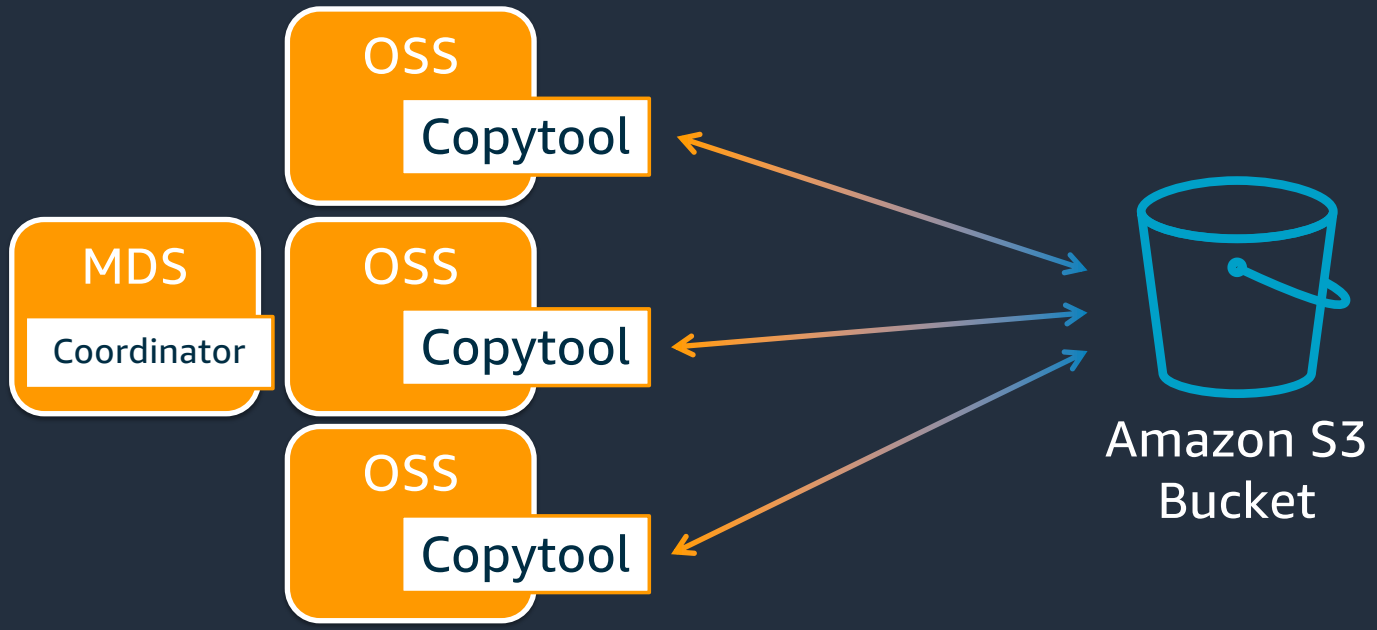
Highly performant Amazon S3 access

Amazon FSx For Lustre can be connected to S3 as an HSM backend



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Spin-up / spin-down Workflow

Typical workflow is to start, restore, compute and archive back

1. Start
2. Read
3. Compute
4. Archive

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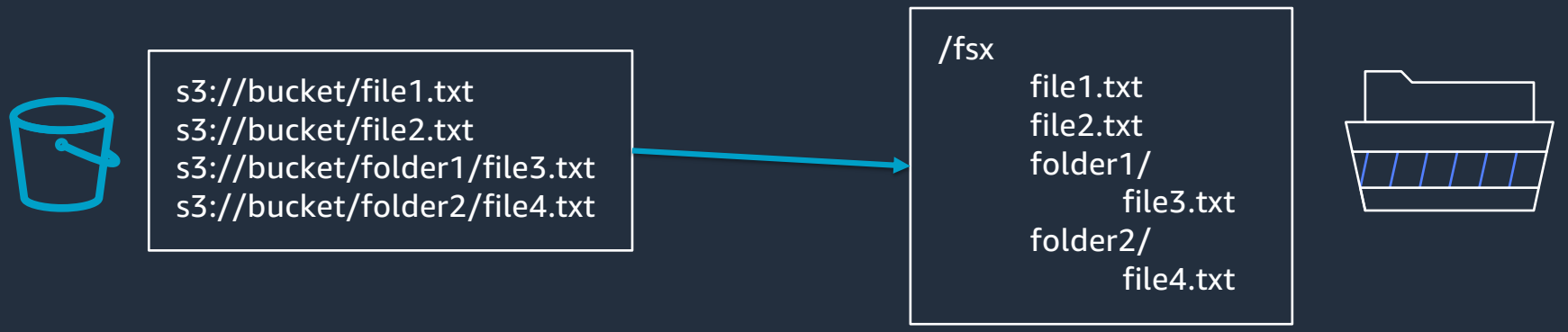
Importing millions of files

- There is no limit to the number of objects that can be stored in S3 buckets
- Customers will frequently have millions or even billions of objects
- Challenge is to create a full namespace using an object list from S3
- We create empty, *released* files in the Lustre filesystem for each of them
- Lustre client performance sustains S3 speed
    - Be careful with very large directories (LU-8047)



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Restoring and archiving large buckets

Files are accessed using standard mechanisms:

- Opening a released file
- Using standard Lustre `lfs hsm_restore` commands

Convenient to restore all files, prior to start working

Periodically, or at the end, archive all their files back to S3.

Using standard Lustre `lfs` commands, you can enqueue thousands of requests into the coordinator queue.

Workload is distributed across all filesystem servers to maximize bandwidth

Operating Lustre/HSM at S3 scale

- We have done a lot of stress testing of HSM and are helping to maintain it
- Large-scale imports, restores and full system archives have exercised Lustre/HSM a lot
  - Example: memory leak fix (LU-11892)
  - Example: identified opportunity to optimize import/export performance by avoiding linear scans
- Copytools not reading incoming work (KUC) can deadlock the coordinator
  - We have had to make sure that our copytool does not deadlock the coordinator
  - Further opportunities for coordinator-side enhancements
- Coordinator activity reporting:
  - Status is available per file (using lfs hsm_action or lfs hsm_state)
  - Opportunity to have a overall status report for the global archiving or restore progress

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Example Use Case: Amazon FSx for Lustre and Deep Learning

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Example Use Case: Amazon FSx for Lustre and Deep Learning

- Integrating Lustre with AWS batch computing services and GPU hosts for deep learning training jobs
- Deep learning training using ImageNet2012 dataset and Tensorflow
  - Annotated image database
- Deploy an infrastructure with a workflow using several AWS Services
  - Schedule compute tasks with AWS Batch
  - Efficient I/O with Amazon FSx for Lustre and Amazon S3
- Based on AWS Compute Blog post

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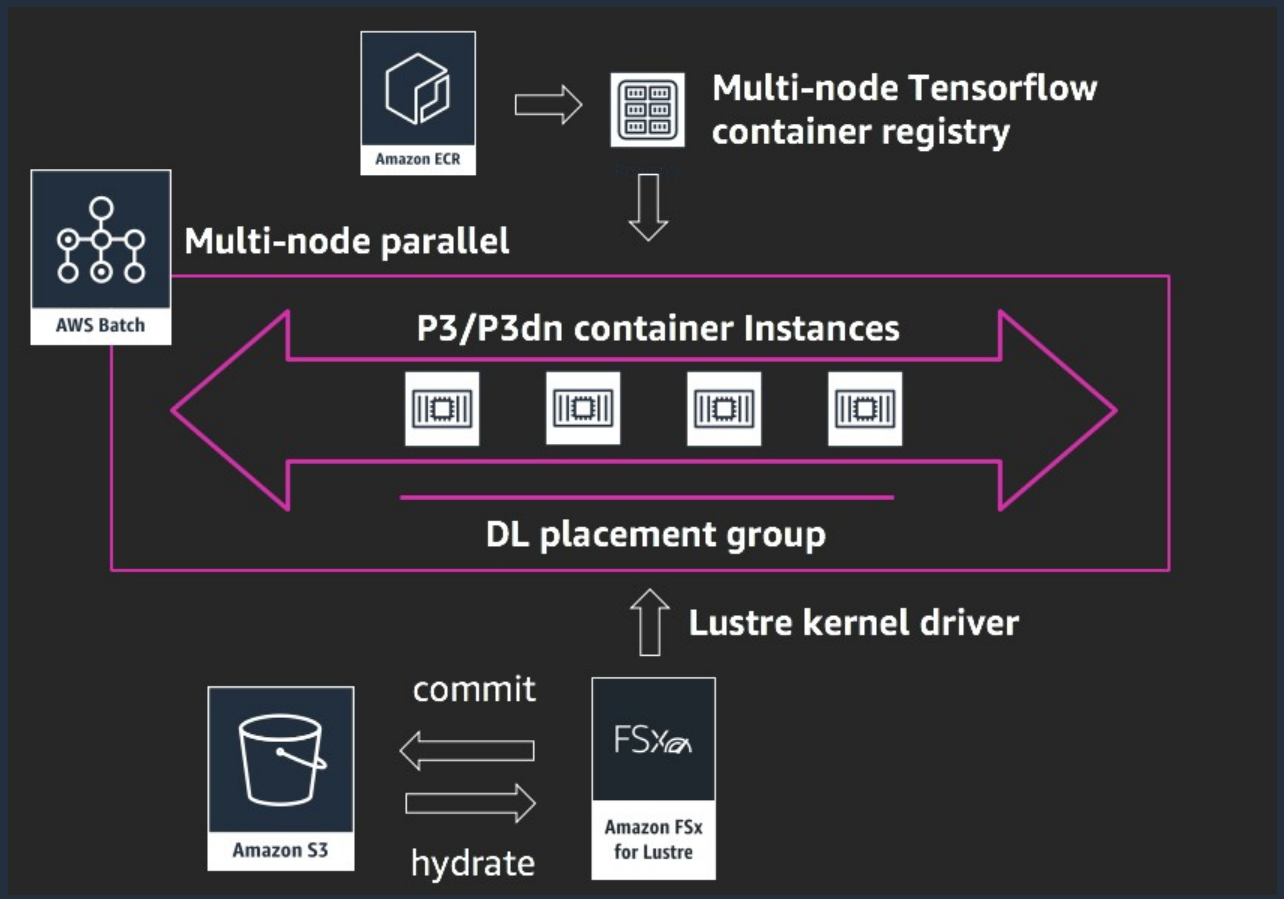
Architecture



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Prepare images

1. Prepare an EC2 instance image using Ubuntu 16.04, with Nvidia drivers, Lustre client and Docker.
    - Save it as an Amazon Machine Image (AMI) for later use
2. Prepare a TensorFlow container with TensorFlow, Horodov, Cuda libraries and OpenMPI
    - Push it to ECR registry

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Workflow

1. Start a 3.6-TB filesystem, attached to S3 bucket with ImageNet dataset

   ```
   $ aws fsx create-filesystem … --ImportPath s3://mybucket/imagenet
   ```

2. Start a AWS Batch environment
    1. Compute environment
    2. Compute resources
        - Instance type: p3 family (Tesla V100)
        - vCPUs: 0 to 4096
    3. Proper network access to the Lustre filesystem
3. Create the job definition that uses these definitions and the docker container
4. And run!

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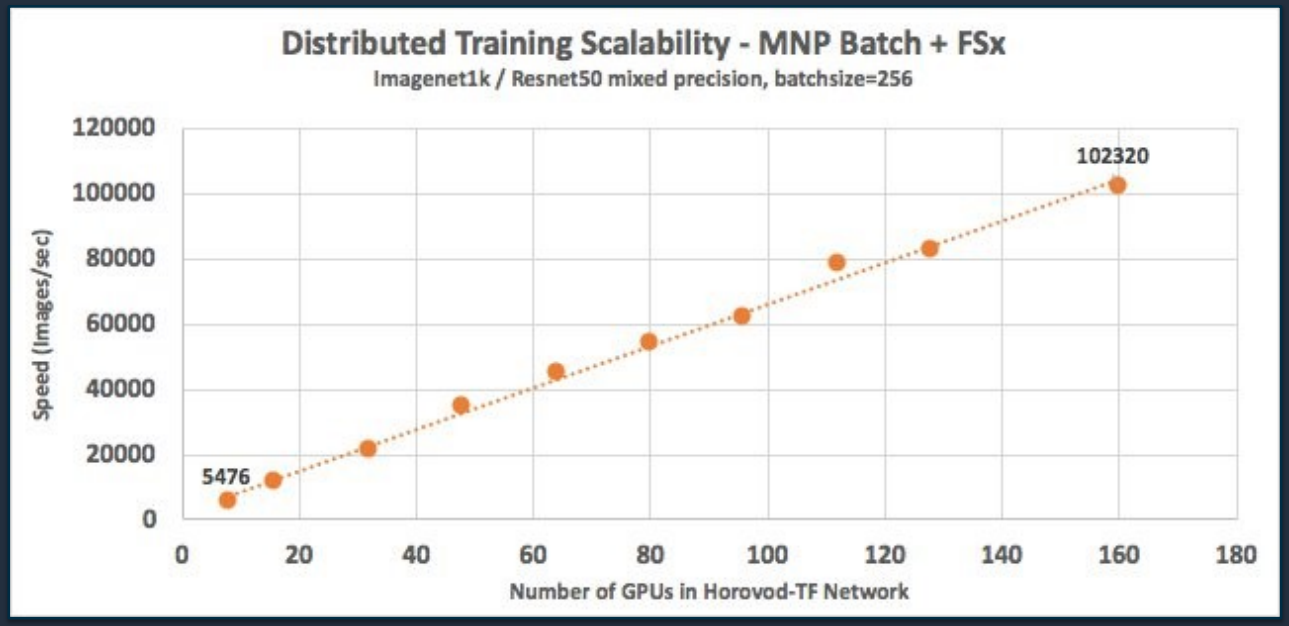
Results

- Using: 20 x p3.16xlarge instances (8 Tesla V100, 64 cores, 128 GB RAM)
- 100,000 images/sec, 90-100% GPU utilization



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What’s Next?

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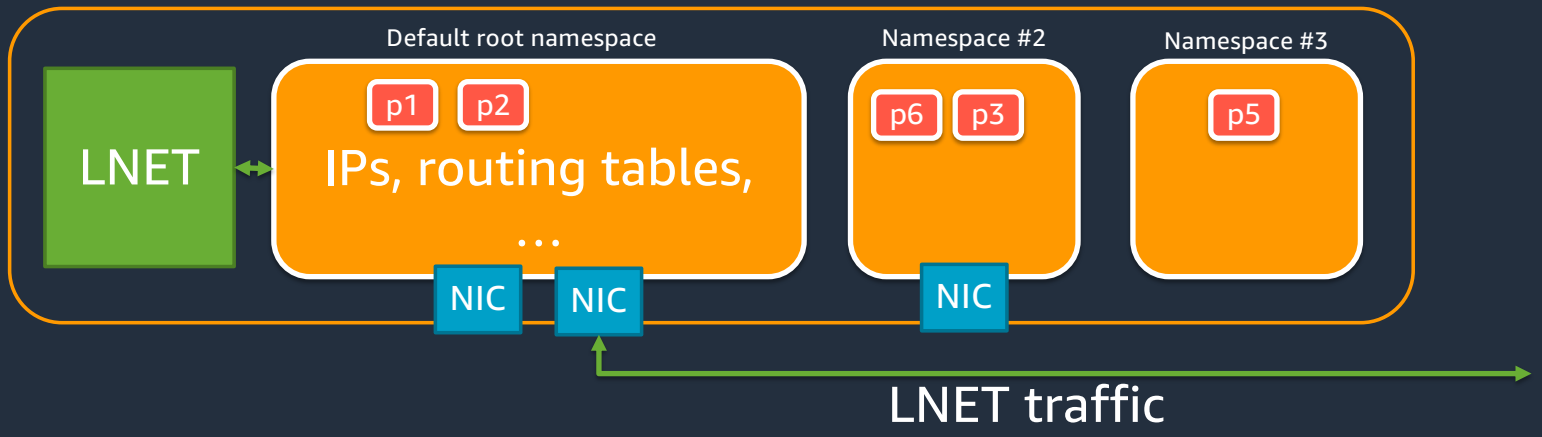
Network namespace enhancement (1/2)

- Containers are very popular, especially in the Cloud
- Based on *cgroups* and *user namespaces*
- *Network user namespaces* own specific network interfaces, IP addresses, routing and firewalling tables, …
- LNET only supports the default network namespace



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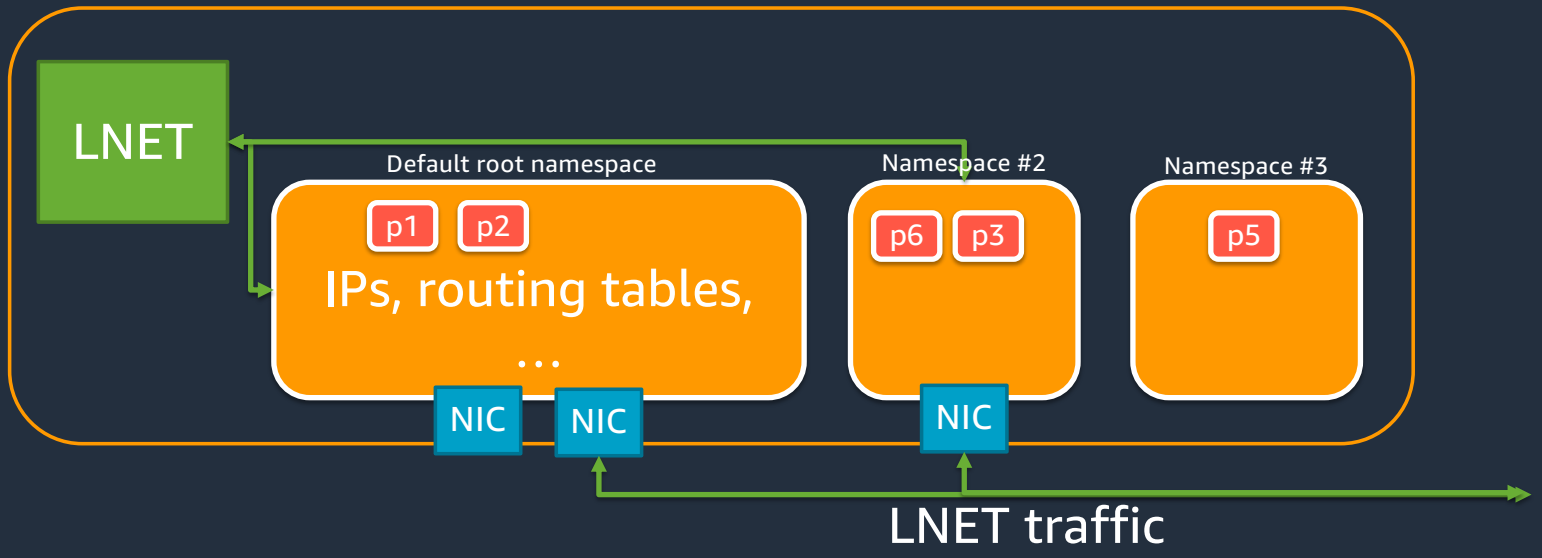
Network namespace enhancement (2/2)

- We are enabling the use of any network namespace and not only the root namespace.
  - LU-12236 – Support more than the default root network namespace



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Working with the community

- We are sharing our Lustre modifications
  - LU-11892 – Memory leak in MDT Coordinator
  - LU-12227 – Lustre init script does not check if ZFS devices are already mounted
  - LU-12236 – Support more than the default root network namespace
- We plan to do more!

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Thank you!

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