Quick Start: Using Apache Spark for Large-Scale Data Processing

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ALCF Developer Session

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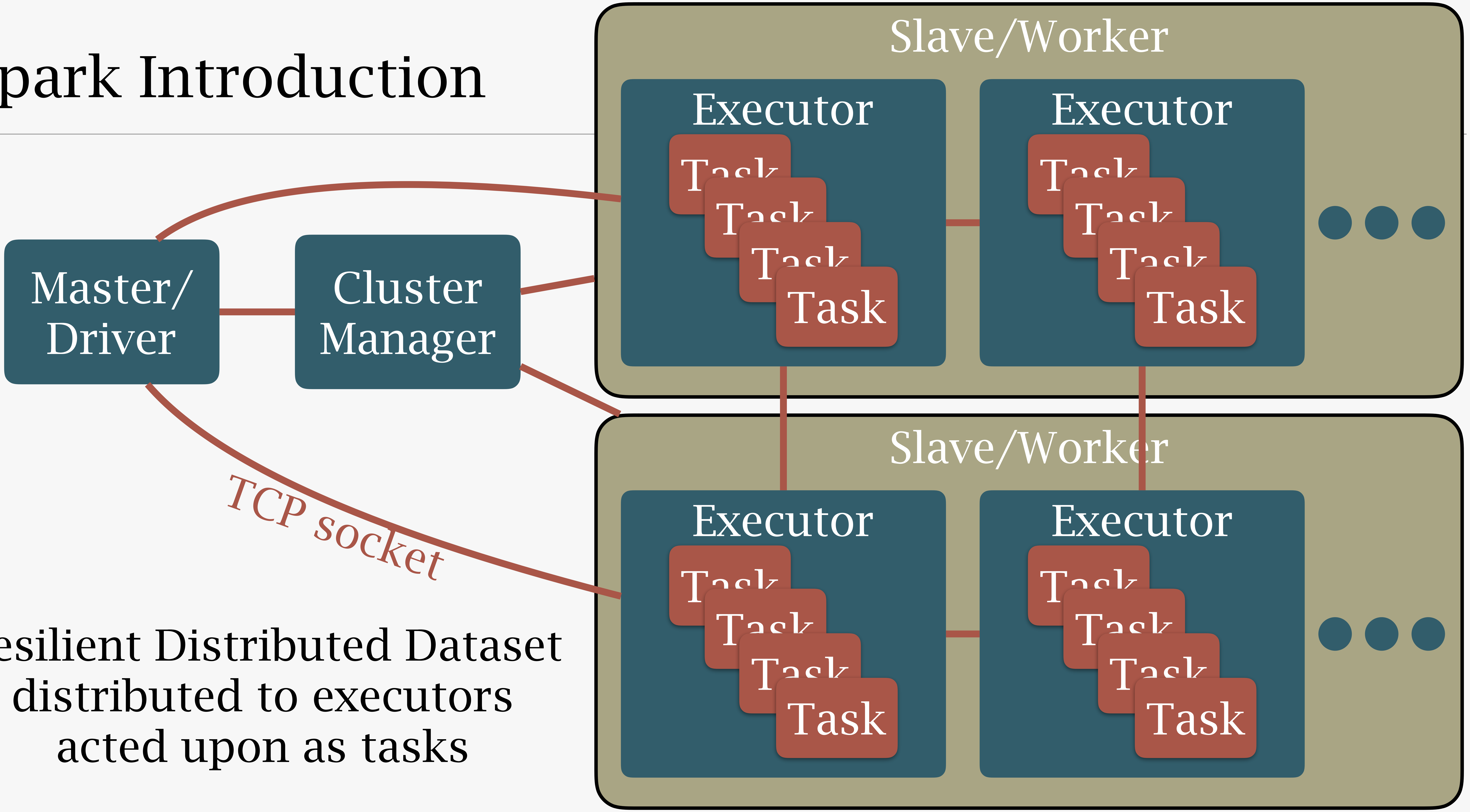
Spark Introduction



Resilient Distributed Dataset distributed to executors acted upon as tasks

PySpark code demo on GitHub

https://github.com/SparkHPC/spark-examples/blob/master/Julia_set_reverse_iteration_Spark.ipynb

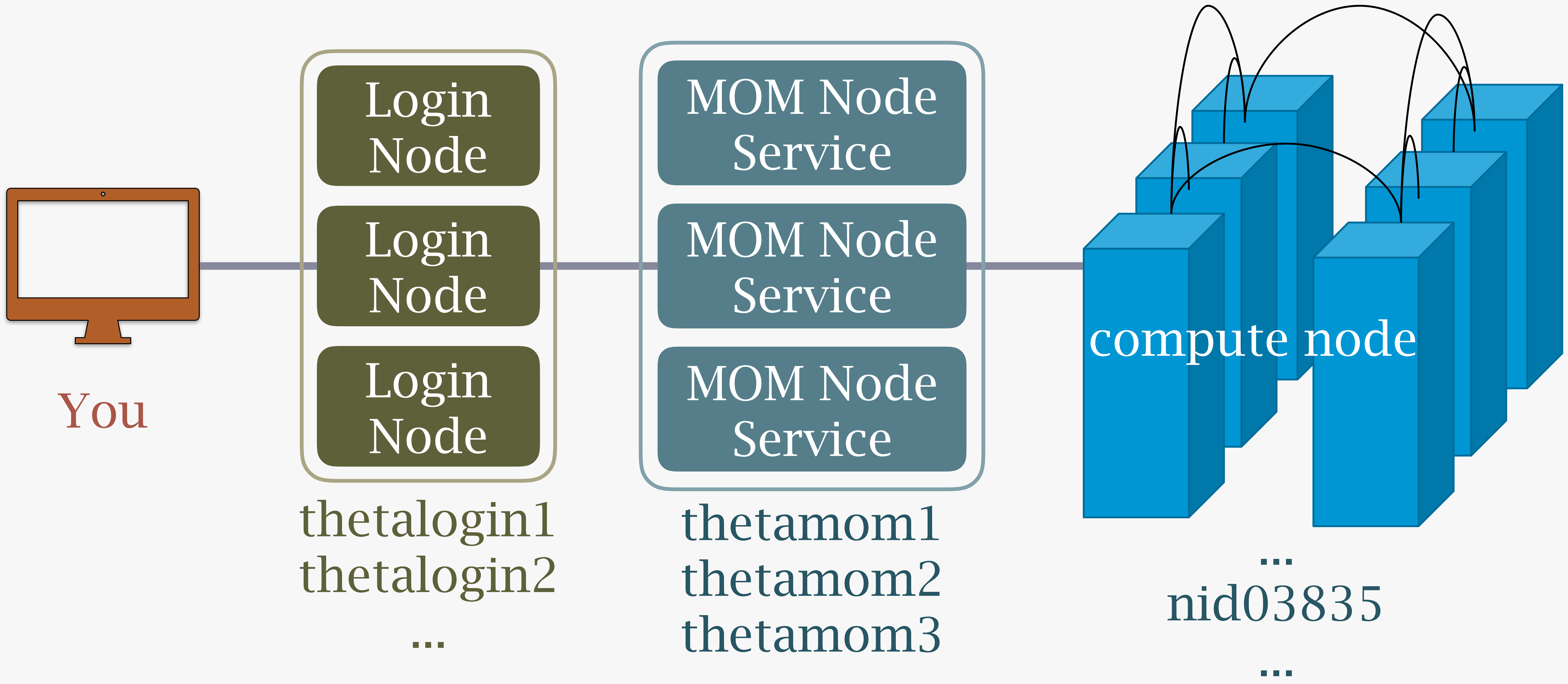
Start using Apache Spark on Cooley/Theta

```
/soft/datascience/Spark_Job/submit-spark.sh \
     -A ALLOCATION -t 10 -n 2 -q debug-cache-quad \
     run-example SparkPi

/soft/datascience/Spark_Job/submit-spark.sh \
     -A ALLOCATION -t 10 -n 2 -q debug-cache-quad \
     --class YOUR.SPARK.APP.CLASS \
     local:///ABSPATH/TO/YOUR/SPARK/APP.jar [EXTRA_ARGS ...]

/soft/datascience/Spark_Job/submit-spark.sh \
     -A ALLOCATION -t 10 -n 2 -q debug-cache-quad \
     PATH/TO/YOUR/PYSPARK/SCRIPT.py [EXTRA_ARGS ...]
```

Example submitting interactive jobs on Theta

```
thetalogin$ /soft/datascience/Spark_Job/submit-spark.sh \
            -A datascience -t 60 -n 2 -q debug-cache-quad -I
...
SPARKJOB_JOBID=325700
...
# Spark is now running (SPARKJOB_JOBID=325700) on:
# nid03835      nid03836
declare -x SPARK_MASTER_URI="spark://nid03835:7077"
# Spawning bash on host: nid03835
...
nid03835$ export PYSPARK_DRIVER_PYTHON=jupyter
nid03835$ export PYSPARK_DRIVER_PYTHON_OPTS="notebook --no-browser --
ip=nid03835 --port=8008"
nid03835$ /soft/datascience/apache_spark/bin/pyspark \
          --master $SPARK_MASTER_URI

local$ ssh -L 8008:localhost:8008 theta ssh -L 8008:nid03835:8008 thetamom1
```

Theta


You
Login Node
Login Node
Login Node
thetalogin1
thetalogin2
...
MOM Node Service
MOM Node Service
MOM Node Service
thetamom1
thetamom2
thetamom3
compute node
...
nid03835
...

Spark Job (Script for working with COBALT)

- Installed under `/soft/datascience/Spark_Job`
- Designed to minimize the changes required for deploying on Theta
- Check out the readme file: `/soft/datascience/Spark_Job/readme`
- Look in the example directory: `/soft/datascience/Spark_Job/example`
- Under heavy development, guaranteed interface: `submit-spark.sh`
- Absolute stability, use explicit version number, eg: `/soft/datascience/Spark_Job_v1.0.2`

Spark Job [submit-spark.sh] usage

```
submit-spark.sh [options] [JOBFILE [arguments ...]]

JOBFILE (optional) can be:
    script.py           pyspark scripts
    bin.jar             java binaries
    run-example CLASS   run spark example CLASS
    scripts             other executable scripts (requires `-s`)

Required options:
    -A PROJECT          Allocation name
    -t WALLTIME         Max run time in minutes
    -n NODES            Job node count
    -q QUEUE            Queue name

Optional options:
    -o OUTPUTDIR        Directory for COBALT output files (default: current dir)
    -s                  Enable script mode
    -m                  Master uses a separate node
    -p <2|3>            Python version (default: 3)
    -I                  Start an interactive ssh session
    -w WAITTIME         Time to wait for prompt in minutes (default: 30)
    -h                  Print this help message
```

Environment Variables (Information)

- The scripts set a few environment variables for informational purposes, and for controlling the behavior.

- Information (taken from the command line, the job scheduler, the system):

```
SPARKJOB_HOST="theta"
SPARKJOB_INTERACTIVE="1"
SPARKJOB_JOBID="242842"
SPARKJOB_PYVERSION="3"
SPARKJOB_SCRIPTMODE="0"
SPARKJOB_SCRIPTS_DIR="/lus/theta-fs0/projects/datascience/xyjin/Spark_Job"
SPARKJOB_SEPARATE_MASTER="0"
SPARKJOB_OUTPUT_DIR="/lus/theta-fs0/projects/datascience/xyjin/Spark_Job/example"
SPARK_MASTER_URI=spark://nid03838:7077
MASTER_HOST=nid03838
```

Environment Variables (Customizable)

```
SPARK_HOME="/soft/datascience/apache_spark"
SPARK_CONF_DIR="/lus/theta-fs0/projects/datascience/xyjin/Spark_Job/example/242842/conf"
PYSPARK_PYTHON="/opt/intel/python/2017.0.035/intelpython35/bin/python"
SPARKJOB_WORKING_DIR="/lus/theta-fs0/projects/datascience/xyjin/Spark_Job/example/242842"
SPARKJOB_WORKING_ENVS="/lus/theta-fs0/projects/datascience/xyjin/Spark_Job/example/242842/envs"
```

- The above is the environment set up when running a job under `OUTPUTDIR` `/projects/datascience/xyjin/Spark_Job/example`
- The variable `SPARKJOB_OUTPUT_DIR` contains the directory path
- `SPARKJOB_WORKING_DIR` and `SPARKJOB_WORKING_ENVS` depends on `SPARKJOB_OUTPUT_DIR`

Customizable Variables in `env_local.sh`

- See `/soft/datascience/Spark_Job/example/env_local.sh`
- You can use SPARKJOB_HOST to detect the running system.

```
if [[ $SPARKJOB_HOST == theta ]];then
   module rm intelpython35
   module load miniconda-3.6/conda-4.4.10
   export PYSPARK_PYTHON="$(which python)"
fi
```

- On Cooley, interactive Spark jobs setup IPython notebook by defaults. You can change it here, along with setting up your other python environment.

```
unset PYSPARK_DRIVER_PYTHON
unset PYSPARK_DRIVER_PYTHON_OPTS
```

Customizable Variables in `env_local.sh`

- Create `spark-defaults.conf` file affecting Spark jobs submitted under the current directory where this file resides, c.f. `$SPARK_CONF_DIR`

- The parameters require tuning depending on the machine and workload.

```
[[ -s $SPARK_CONF_DIR/spark-defaults.conf ]] ||
   cat > "$SPARK_CONF_DIR/spark-defaults.conf" <<'EOF'
spark.task.cpus                                  4
spark.driver.memory                            32g
spark.executor.memory                         128g
spark.driver.extraJavaOptions   -XX:+UseParallelGC -XX:ParallelGCThreads=8
spark.executor.extraJavaOptions -XX:+UseParallelGC -XX:ParallelGCThreads=8
EOF
```

Spark on Theta

- Don't run Spark on the MOM node!
- Should the master share one node with the slaves?
- How many workers per node?
- How many executors per worker?
- How many tasks per executor?
- Is thread affinity useful?
- It all depends on your workload.

Tuning parameters (`spark-defaults.conf`)

Tune these numbers for your workload

```
spark.task.cpus                                        4

spark.rpc.netty.dispatcher.numThreads                  8

spark.scheduler.maxRegisteredResourcesWaitingTime   4000s
spark.scheduler.minRegisteredResourcesRatio            1
spark.scheduler.listenerbus.eventqueue.capacity   100000

spark.worker.timeout                               24000
spark.executor.heartbeatInterval                    4000s
spark.files.fetchTimeout                           12000s
spark.network.timeout                              24000s
spark.locality.wait                                 6000s

spark.driver.memory                                   16g
spark.executor.memory                                128g

spark.driver.extraJavaOptions   -XX:+UseParallelGC -XX:ParallelGCThreads=8
spark.executor.extraJavaOptions -XX:+UseParallelGC -XX:ParallelGCThreads=8
```

Tuning parameters (`spark-defaults.conf`)

Tune these numbers for your workload

```
spark.task.cpus 4
```

- JVM sees 256 cores on each Theta node
- By default, JVM launches 256 tasks simultaneously if memory allows
- This parameter makes JVM count each task as using 4 cores
- Applies for PySpark applications, too

Tuning parameters (`spark-defaults.conf`)

Tune these numbers for your workload

```
spark.rpc.netty.dispatcher.numThreads    8
```

- Undocumented configuration
- The default equals to the maximum number of thread, 256 on Theta
- In addition, follow this pull request on GitHub #23560 : [SPARK-26632][Core] Separate Thread Configurations of Driver and Executor

Tuning parameters (`spark-defaults.conf`)

Tune these numbers for your workload

```
spark.scheduler.maxRegisteredResourcesWaitingTime   4000s
spark.scheduler.minRegisteredResourcesRatio            1
```

- Wait for resources on-line to avoid performance impact in the beginning
- Depends on your resource usage

```
spark.scheduler.listenerbus.eventqueue.capacity   100000
```

- If you see related warnings
- It happens if you use large amount of nodes

Tuning parameters (`spark-defaults.conf`)

Tune these numbers for your workload

```
spark.worker.timeout                    24000
spark.executor.heartbeatInterval         4000s
spark.files.fetchTimeout                12000s
spark.network.timeout                   24000s
spark.locality.wait                      6000s
```

- WHO NEEDS FAULT TOLERANCE? What is your failure scenario?
- Your MPI program constantly tries to figure out if all the ranks are alive?

Tuning parameters (`spark-defaults.conf`)

Tune these numbers for your workload

```
spark.driver.memory              16g
spark.executor.memory           128g
```

- You absolutely must set these to some large number
- The default `1g` is too small unless you run multiple workers/executors

Tuning parameters (`spark-defaults.conf`)

Tune these numbers for your workload

```
spark.driver.extraJavaOptions   -XX:+UseParallelGC -XX:ParallelGCThreads=8
spark.executor.extraJavaOptions -XX:+UseParallelGC -XX:ParallelGCThreads=8
```

- Depending on you application
- Tuning GC is another work of art
- Make sure GC time does not dominate

Access the Web Interface

- Find the driver node ID, `nid0NNNN`

- Use SSH LocalForward

```
ssh -L 8080:localhost:8080 -L 4040:localhost:4040 -t theta \
  ssh -L 8080:nid0NNNN:8080 -L 4040:nid0NNNN:4040 thetamom1
```

- Go to http://localhost:8080 on your local machine

Other things to consider

- Number of partitions for your RDD
- Point `spark.local.dir` to the local SSD (access granted per project basis)
- Do not use "Dynamic Allocation" unless you have a strong reason
- Beyond the scope of this presentation: IO, streaming, ML, GraphX, other cluster managers, etc.
  - Please contact us
  - We are interested in Spark usage in scientific applications

Don't Panic

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