Bull Slurm related developments

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Bull
atos technologies

Bull slurm strategy

REDUCED
ENERGY
CONSUMPTION

Increase resource usage

Reduce power bill

Increase usability

Support for heterogeneous resources

- These developments have as goal to extend the job specification language of SLURM to support **MPMD** (Multiple Program Multiple Data)

- With the support of heterogeneous resources, the idea is to introduce a new type of jobs named **job packs** which will be described by a set of pack groups, each pack group having the same resources requirements.
  Example of executions illustrating the targeted capability :
  - srun -n 2 -c2 ./app1 : -n 4 --mem-per-core 256 --gres=gpu:2 ./app2

Slurm User Group 2016 presentation: Job Packs - A New Slurm Feature For Enhanced Support of Heterogeneuous Resources, Andry Razafinjatovo, Martin Perry, and Yiannis Georgiou (Bull), Matthieu Hautreux (CEA)
https://slurm.schedmd.com/SLUG16/Job_Packs_SUG_2016.pdf

Powercap with RAPL

REDUCED ENERGY CONSUMPTION

- Powercapping based on **layouts**, **power plugin** and **RAPL**
  - RAPL ensures hardware powercap guarantee Run cluster within the power budget
  - RAPL provides a good estimate of socket power consumption -> Adapt layouts regularly to reflect real values
  - Adapt power based on real power consumption (capture the application behavior) Allow more jobs to take advantage of the unused power

Slurm User Group 2016 presentation: Improving system utilization under strict power budget using the layouts, Dineshkumar Rajagopal, Yiannis Georgiou, and David Glesser
https://slurm.schedmd.com/SLUG16/slug16_powercap.pdf

High Definition Power and Energy Monitoring

REDUCED ENERGY CONSUMPTION

- Proposing a new plugin acct_gather_energy/hdeem
  - Based on the new **Bull - FPGA hardware** supported through *ipmi-raw*
  - Decrease overhead on the application (CPU and Memory) since the collection is done internally within the FPGA
  - Improved accuracy for both power profiling per components (100Hz) and nodes (1000Hz)
  - Improved precision for energy consumption per job based on nodes (1000Hz) measurements

Slurm User Group 2016 presentation: High definition power and energy monitoring support, Thomas Cadeau and Yiannis Georgiou

https://slurm.schedmd.com/SLUG16/slug_power_hdeem.pdf

Lustre and Infiniband accounting

- Capture accounting information for both **Infiniband network and Lustre filesystem** per step/job.
- Make the data available in the Slurm DB and through **sstat and sacct** commands.
- Based upon the new **TRES** (Trackable Resources) functionality

Tools for Slurm experimentations

- Enable **SLURM simulation** in large scales for large time durations
  - **Slurm User Group 2016 presentation:** Simunix, a large scale platform simulator, David Glesser and Adrien Faure https://slurm.schedmd.com/SLUG16/slug16_simunix.pdf
  - the code is still under development

Tools for Slurm experimentations

- Provide the material for a complete tutorial with **Hands-On** for administration and usage of Slurm:
  - **Docker containers** and step-by-step procedure for **deployment of a small Slurm cluster on your PC**.
  - Slides for installation, configuration and usage
  - Training through simple exercises

  - The code is **open-source** here: https://github.com/RJMS-Bull/slurm-tutorial

    Looking forward for your comments, questions and contributions

Ongoing research activities

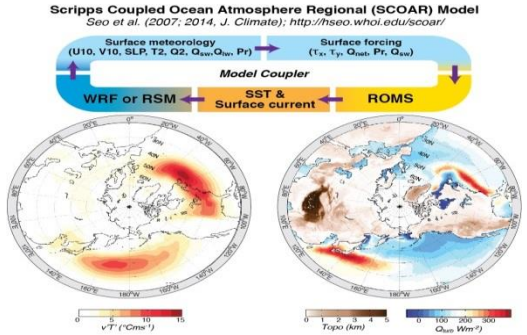
- Scheduling
  - EnergyCap Scheduling : particular energy budgets for certain time durations.
  - Multi-objective resource selection
  - Machine Learning Optimizations
- Hybrid environments
  - Tighter integration with Singularity for deploying of customized user environments
  - Deploy Big Data workflows and Cloud environments upon HPC clusters

Job Packs – A New Slurm Feature For Enhanced Support of Heterogeneous Resources

Yiannis Georgiou, Atos
Andry Razafinjatovo, Atos
Martin Perry, Atos
Matthieu Hautreux, CEA

Multiple Program Multiple Data usage

- Application lilfecycle is more and more complex, usage of MPMD programming will allow:



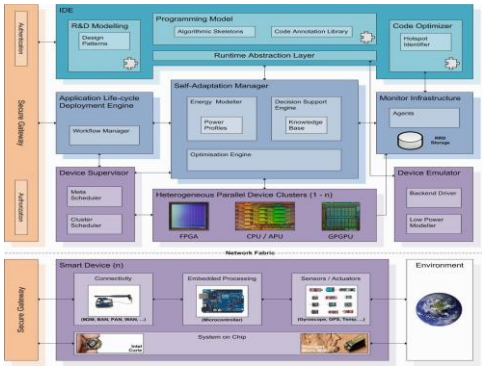
to be more **precise**
by using coupled applications

to be more **accurate**
by validating results
through vizualisation

to be more **performant**
by using software/hardware
accelerators

Considering energy efficiency from code design to execution for heterogeneous architectures

- Atos/Bull leading the Tango project (Transparent Heterogeneous hardware Architecture deployment for eNergy Gain in Operation)
- Extension of currently available programming models and resource and job management systems to support complex heterogeneous architectures
- Code optimizer engine with the aim of optimizing code mapping. to reduce power consumption by the application.
- Power-awareness integrated in the whole software development optimization and execution process



http://www.tango-project.eu

Karim Djemame, Django Armstrong, Richard E. Kavanagh, Jean-Christophe Deprez, Ana Juan Ferrer, David Garcia Perez,Rosa M. Badia, Raúl Sirvent, Jorge Ejarque, Yiannis Georgiou:
TANGO: Transparent heterogeneous hardware Architecture deployment for eNergy Gain in Operation. CoRRabs/1603.01407 (2016)

Slurm SPMD Support

- Conventional Slurm jobs/steps support the SPMD (Single Program Multiple Data) programming model.

- The job/step may be allocated a diverse collection of resources (nodes with different characteristics), but the allocated resources are managed as a single group. A single type of executable (program) is run on the allocated resources. Example:

```
srun –w bignode1,smallnode1 –n2 ./myprog
```

Limited MPMD Support

- Slurm also supports a limited form of MPMD (Multiple Program Multiple Data), with the srun **--multi-prog** option.

- This option allows multiple programs to be executed by a single step, but the allocated resources are still managed as a single group and the user has limited control over which program is run on which node. Example:

```
srun –w bignode1,smallnode1 –n4 --multi-prog prog.conf
```

Need For Enhanced MPMD Support

- For some multi-program applications, it is desirable to target a particular program to a particular subset of the allocated resources. For example:
  - A node with lots of memory for the serial startup/wrapup phase.
  - Lots of nodes with GPU for the parallel phase.
  - Nodes with fast I/O to store the results.

  For MPI applications, the programs may need to belong to a common MPI_COMM_WORLD.

Introducing Job Packs

- Job Packs is a new Slurm feature providing enhanced support for the MPMD model.
- A Job Pack is a group of **co-scheduled** jobs.
- Each job has its own group of resources, but no job is scheduled until the resources required for all of the jobs in the pack are available.
- Multiple steps may be launched concurrently for some or all of the jobs in the same pack. The steps may be combined into a single MPI application.
- This allows the user to allocate multiple, heterogeneous groups of resources and launch multiple program types concurrently, targeting each program to a group of resources tailored to its requirements.

Job Packs User Interface

- A job pack is created with a single sbatch, salloc or (standalone) srun command.
- Multiple steps may be launched concurrently for one or more jobs in the pack with a single srun command.
- The sbatch, salloc and srun command syntax has been expanded to support this new functionality. The new syntax is fully backwards-compatible with the current syntax. The man pages have been updated with the new syntax.

Job Packs User Interface Detail

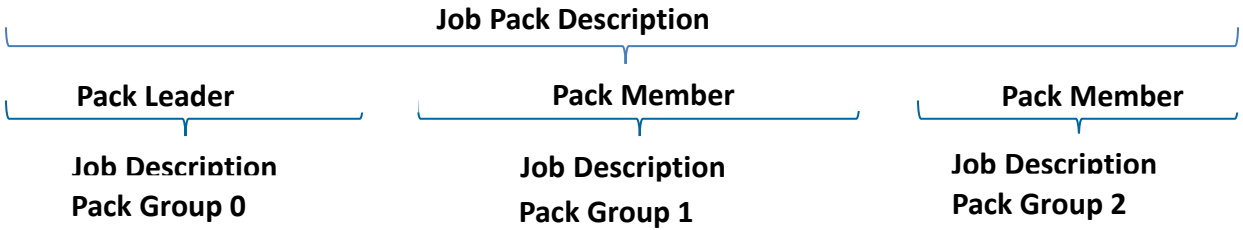
- A job pack is defined by a ***job pack description***.
- A job pack description consists of a series of colon-separated ***job descriptions***.
- Each job description defines a single job in the pack.
- A job pack may have an arbitrary number of jobs.
- Each job is assigned an index called a ***pack group*** based on the order of its job description in the job pack description.
- The first job has a pack group of zero and is the ***pack leader***. The remaining jobs in the pack are ***pack members***.

- srun is used to launch one or more concurrent steps for a job pack created by salloc or sbatch.
- The steps to be launched are defined by a series of colon-separated ***step descriptions***. A new srun option, ***--pack-group***, is used to identify each job for which a step is to be launched from a step description.

Job Packs User Interface Example

The following example uses salloc to create a job pack containing three jobs, the pack leader plus two pack members:

```
salloc  -p ctlnodes –N1 : -p computenodes –N10 : -p ionodes –N4
```



The following srun command launches one step for each job in the pack. Each step runs a different program:

```
srun --pack-group=0 ./controller : --pack-group=1 –n 20 ./worker :
--pack-group=2 –n 6 ./storer
```

Job Packs sstat & sacct Changes

- Two new fields have been added to the step accounting record and in-memory step record. sacct and sstat have been enhanced to report these new fields.

PackJobID	**Jobid of first step in multi-step srun**
PackStepID	**Stepid of first step in multi-step srun**

- This information is saved for every step in a multi-step srun, providing a unique identifier that ties together all of the steps launched by the same srun command.

Job Packs Additional Command Changes

- Additional command changes to support Job Packs:

squeue new option **--dependency** to display dependencies between the pack leader and pack members.

scontrol *show job* output enhanced to display dependencies between the pack leader and pack members.

scancel new option **--pack-member** required to cancel pack members.

srun **--label** option displays utaskids by default. utaskid is a new type of taskid that is unique for each task launched by the same srun command. For conventional (single-step) sruns, utaskid is the same as gtaskid.

Job Packs Configuration

- No new or changed Slurm configuration options are required to use Job Packs.

- A new debug flag, JobPack, has been defined to provide detailed log entries about Job Pack scheduling, allocation, and task management. The new log entries are prefaced with the string **JPCK**.

Job Packs Environment Variables

- Many new environment variables have been created to facilitate communication of Job Pack-related information between salloc/sbatch and srun, and between srun and slurmstepd. The new environment variables may also be of value for user software (monitoring, etc.)

- The Slurm documentation has been updated to describe these new variables.

Job Packs MPI MPMD Support

- Tight integration of srun with MPI MPMD
  - MPI support allows multiple steps launched concurrently by a single srun command, for one or more jobs in a job pack, to be combined into a single MPI application; that is, a single MPI_COMM_WORLD communicator with a single set of MPI ranks.
  - Users may also choose to run each step launched by a multi-step srun as a separate MPI application, using the new srun option **--mpi-combine=no**.
  - Job Packs support tight integration for srun through PMI-1 and PMI-2.
  - IntelMPI and OpenMPI implementations have been validated but others may also work if they support PMI-1 or PMI-2
  - We plan to add support for OpenMPIv2/PMIx.

Job Packs MPI MPMD Support - Example

```
[trek2] (slurm) mpihello> salloc -w trek7 --exclusive : -w trek8 --exclusive
 : -w trek9 --exclusive
salloc: Pending job allocation 10236
salloc: Pending job allocation 10237
salloc: Granted job allocation 10238
salloc: Nodes trek7 are ready for job 10238
salloc: Nodes trek8 are ready for job 10237
salloc: Nodes trek9 are ready for job 10236

[trek2] (slurm) mpihello> srun --pack-group=0 -n3 ./mpiexec1 : --pack-group=1
 -n3 ./mpiexec2 : --pack-group=2 -n3 ./mpiexec3  | sort
Hello world, I am mpiexec1, rank 0 of 9 - running on trek7
Hello world, I am mpiexec1, rank 1 of 9 - running on trek7
Hello world, I am mpiexec1, rank 2 of 9 - running on trek7
Hello world, I am mpiexec2, rank 3 of 9 - running on trek8
Hello world, I am mpiexec2, rank 4 of 9 - running on trek8
```

Job Packs Example

The following example illustrates the use of Job Packs with MPI.

```
$ srun -JLdr -w trek7 ./controller : -JMbr1 --gres=gpu -N2 --tasks-per-node=2 ./worker
                                   : -JMbr2 -pt96iopx -N2 ./storer &

$ squeue
             JOBID PARTITION     NAME     USER ST       TIME  NODES NODELIST(REASON)
             61661   t96iopx     Mbr2    slurm  R       0:03      2 trek[8-9]
             61662   trekall     Mbr1    slurm  R       0:03      2 trek[4-5]
             61663   trekall      Ldr    slurm  R       0:03      1 trek7

This is the controller, Name=Ldr Id=61663 MPI Rank 0 of 7, Running on host trek7
This is a worker, Name=Mbr1 Id=61662 MPI Rank 1 of 7, Running on host trek4
This is a worker, Name=Mbr1 Id=61662 MPI Rank 2 of 7, Running on host trek4
This is a worker, Name=Mbr1 Id=61662 MPI Rank 3 of 7, Running on host trek5
This is a worker, Name=Mbr1 Id=61662 MPI Rank 4 of 7, Running on host trek5
This is a storer, Name=Mbr2 Id=61661 MPI Rank 5 of 7, Running on host trek8
This is a storer, Name=Mbr2 Id=61661 MPI Rank 6 of 7, Running on host trek9
```

Limitations

- **Array jobs**
  - Job Packs **don’t support array jobs** “yet”. An error message is displayed in case array jobs are part of a job pack
- **Preemption**
  - **Job Packs** (pack leader and pack members) **cannot be preempted** by other higher priority jobs. This is an exception for now and it will be treated in an upcoming version.
  - The pack leader can preempt legacy jobs, but only the resource requirements of the leader will be used to find lower priority. (When the pack leader's request is evaluated, the members have already been allocated.)
  - **Pack members cannot preempt other jobs.** This is because, when a Job Pack is to be allocated, each member is allocated. When any member (or the leader) can't be allocated, the previous members are deallocated. If such a deallocated job had preempt a normal job, that normal job should still be running.
- **PMI-x**
  - PMI-x is not yet supported through the srun MPMD tight integration

Status & Documentation

- Job Packs will be available in the next Slurm Version (17.02).
- A Job Packs Guide is provided in the Slurm html documentation.
- Man pages for all affected commands have been updated.
- Next steps:
  - PMI-X support
  - Support of array jobs

Design & Development

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Thanks

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