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# Slurm

The Simple Linux Utility for Resource Management

# Overview and Timetable

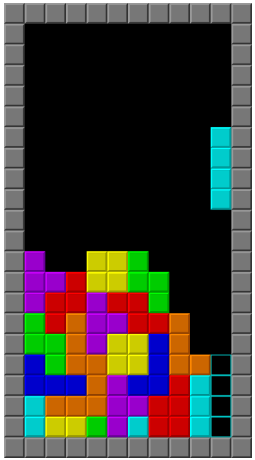
- Slurm concepts, installation and configuration — 30 min
  - What is Slurm and how does it work?
  - How to install Slurm?
  - How to configure a Slurm cluster?
- Excercise: Building a Slurm cluster — 60 min

# Table of contents

# Slurm


- Fault-tolerant resource manager and scheduler
- Interface between the users and the computing nodes
- Matches job requirements with available resources
- Maintains a queue of pending jobs on the cluster
- Prioritizes jobs based on configurable parameters

# Slurm plays Tetris ...



Source: https://en.wikipedia.org/wiki/Tetris

# Slurm terminology: Hardware

**Node**

- A physical server in the cluster.
- Has an IP, (usually) a name via DNS, one or multiple CPUs, RAM, maybe GPUs, maybe additional Networkcards, etc.

**Board**

- Refers to a mainboard of a node.
- Nodes (usually) only have one board.

**Socket**

- A phyiscal, **populated**, CPU Socket on a mainboard of a node.
- The number of sockets is the number of physical CPUs in a node.

**CPU**

- In Slurm, a CPU always refers to a single CPU core
- Physical CPUs however usually have multiple of them.

# Slurm terminology: Job

- A Slurm Job is the execution unit that Slurm works on.
  - Wraps a program and its parameters.
- Jobs are submitted by a user and then scheduled by Slurm to be executed on the cluster.
  - Always have resource requests attached to them.
  - Can have an allocation.
- Jobs always have a state (e.g. PENDING, RUNNING or COMPLETED).
  - Also always have a numerical ID.

# Slurm terminology: Jobsteps and Tasks

**Jobstep**

- A Slurm Job might consist of multiple jobsteps.
  - Also always wrap around a program and its parameters.
  - Need to be manually created inside the job's program.
- Jobsteps are executed on a single node or multiple nodes sequentially or in parallel.
- In Slurm's accounting, job steps can be accounted for individually.

**Task**

- A Jobstep can consist of mulitple tasks
  - A Slurm task can be compared to a process.
  - Tasks always run on a single node, but can occupy multiple CPU cores.

**Difference**: Tasks have a less overhead, but cannot be started on other nodes

# Slurm terminology: Allocations

- In Slurms terms: "A claim on resources".
- Contains the resources *allocated* to a job.
  - Might span multiple nodes, or be just a fraction of a CPU.
  - Can also contain RAM, GPUs, Network slices, even software licenses
- A job *might* have an allocation, or not.

# Slurm terminology: Partitions

- Are sets of nodes which are (usually) of the same hardware(-type).
  - E.g. All nodes with a certain identical CPU are in one partition.
  - This is not required, partitions can also contain different node types.
- Jobs can be submitted to a certain partition or multiple partitions simultaneously.
  - will then run on the next free node(s) of this partition(s).
  - Usually used to ensure that a job runs on certain hardware.
- Partition can overlap (i.e. one node can be in multiple partitions)
- Partitions are **not** queues.

# Slurm daemons: `slurmctld`

- The Slurmctld (Slurm-Controller-daemon) is the cluster master of Slurm.
- Has the overview over the entire cluster
  - Knows all pending jobs
  - Knows the state of all running jobs
  - Knows the state of all the clusters resources
- Performs the scheduling, assigning jobs to resource allocations
- Regularly sends job state information to the database
- Multiple additional controllers can act as failovers

# Slurm daemons: `slurmdbd`

- The Slurmdbd (Slurm-Database-daemon) maintains the accounting database of Slurm.
- The database holds the job information of all jobs that ran on the cluster.
  - The database itself is an external program (like `mariadb`)
  - The `slurmdbd` acts as an interface to it
- These information can then be used for accounting or debugging purposes.
- If the `slurmdbd` fails, new accounting information are stored inside the `slurmctld`

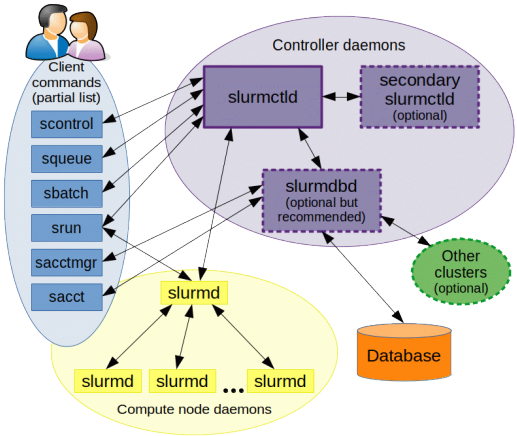
# Slurm daemons: `slurmd`

- The Slurmds (Slurm-daemon's) make up the actual cluster
- Run on each node of the cluster
- Advertising themselves to the `slurmctld`
- If a job comes in, they are creating an (isolated) allocation and run the program

# Slurm commands

| | |
|---|---|
| srun | Runs a given command as a Slurm job |
| sbatch | Submits a shell script as a Slurm job, to be executed on a node. |
| salloc | Creates a Slurm allocation and gives the user an interactive shell session on it. |
| squeue | Displays the current Slurm queue, so all currently running and waiting jobs |
| sinfo | Displays the current state of nodes and partitions of the cluster |
| sacct | Queries accounting data (so past Jobs of the cluster) |
| scontrol | Adminstrator tool to change the state of the cluster |

# Running a job in Slurm




Source:

https://slurm.schedmd.com/quickstart.html

**Program: `srun hostname`**

- `srun` is creating a job, sends it to the `slurmctld`
- The `slurmctld` looks for available resources and schedules the job
- The `slurmd` of the selected nodes create the allocation and connect with `srun`
- The `slurmd` run the program, forwarding `stdout`, `stderr`, `stdin` to `srun`

# Slurm plugin: MUNGE

MUNGE: `MUNGE Uid 'N' Gid Emporium`

- MUNGE is an authentication service for creating and validating users across the cluster.
- MUNGE runs as a service on each node, each sharing a common *`munge.key`*
- With MUNGE, individual Slurm components can authenticate the communications between each other:
  - MUNGE creates an encrypted, tamper-proof, *credential* object, containing the `UID` and `GID` of the current process
  - This *credential* can then be validated by another munge service running on another node.
- MUNGE is loaded into Slurm as a plugin.

# Installation overview

- Slurm as a program is written in C and intended for Linux based clusters.
  - Therefore it is build using the standard Linux build tool combo:
  - `configure`, `make`, `make install`
    - `configure` checks the current environment
    - `make` compiles the software
    - `make install` copies the compiled binaries to their designated places
- As usual, the `--prefix` flag for the configure script can be used to change the install directory.

# Dependencies

- Slurm uses an required and optional dependency system
  - The configure script checks which dependencies are available on the system
  - Slurm then builds only those components that are available.
- Some required dependencies:

```
gcc, gcc-c++, make, lbzip2, ...
```

- Some optional dependencies:

```
hwloc, lua, man2html, ...
```

# NFS Share

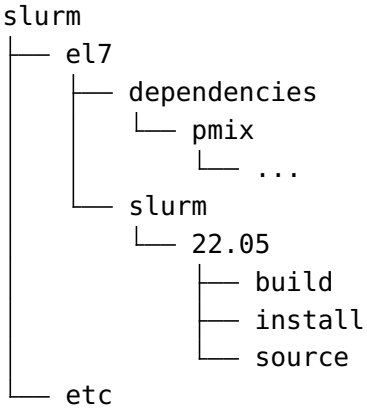
**Where to put the Slurm installation:**

- Slurm does support building `rpm` files directly.
  - Could be build directly into worker images with warewulf.
  - This would make updates more complex.
  - Also makes it impossible / very complex to have two versions of Slurm installed in parallel.
- Typically, Slurm is installed in a network share (like an NFS share)
  - This makes the `slurmd` binary available on each node immediately
  - Makes in-place updates easier
  - Allows two versions of Slurm to be installed in parallel.

# SysConfDir

- The SysConfDir is the directory where the configuration files are located
- Path gets build into the source code
  - However, on run time, the path can be changed via a flag
- Contains the `slurm.conf` file
  - All `slurmd` services need an **identical** `slurm.conf` file
- Some other configuration files are also needed from all `slurmds`
- $\Longrightarrow$ The SysConfDir is also placed on the NFS Share

# Installation directory tree




- Allows for multiple versions of Slurm to be installed in parallel
  - Easier for fallbacks in case of update problems
- Source code also remains available
  - Easier to apply patches in case bugs
- SysConfDir is also available on the NFS share
- Allows for multiple Slurm builds in parallel
  - Different OS versions require different Slurm build due to system dependencies

# slurm.conf

```
ClusterName=linux-cluster
SlurmctldHost=node-1
...
AccountingStorageType=accounting_storage/slurmdbd
AccountingStoreFlags=job_env,job_script
...
PartitionName=linux Nodes=node[1-2] Default=YES
↪  MaxTime=INFINITE State=UP
NodeName=node-2 NodeAddr=10.0.0.2 CPUs=4 Boards=1
↪  SocketsPerBoard=4 CoresPerSocket=1 ThreadsPerCore=1
↪  RealMemory=3667
```

# slurmdbd.conf

```
DbdAddr=10.0.0.1
DbdHost=localhost
...
StorageType=accounting_storage/mysql
StorageHost=localhost
StorageLoc=slurm_acct_db
```

# Further configuration files

`gres.conf` Contains definitions of **G**eneric **Res**ources, like GPUs or network interface cards

`cgroup.conf` Contains configurations for the linux `cgroup` system, used to fence off allocations against one another on the same node

`topology.conf` Contains the network topology (i.e. which node is connected to which switch). Based on it, the `topology` plugin can optimize allocations for low network latency

`plugstack.conf` Contains the paths to self-build Slurm plugins.

# Running Slurm

- Slurm serviecs are usually run as a `systemd` service
  - This allows them to run in the background,
  - automatically restart on error and
  - start on node boot automatically
- Systemd service files are placed at

```
/etc/systemd/system
```

- To start the Slurm services, run

```
systemctl start slurmd.service
```