High Scalability Resource Management with SLURM
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What is SLURM

- Simple Linux Utility for Resource Management

- Performs resource management within a single cluster
- Typically used with an external scheduler (e.g. Moab or LSF)

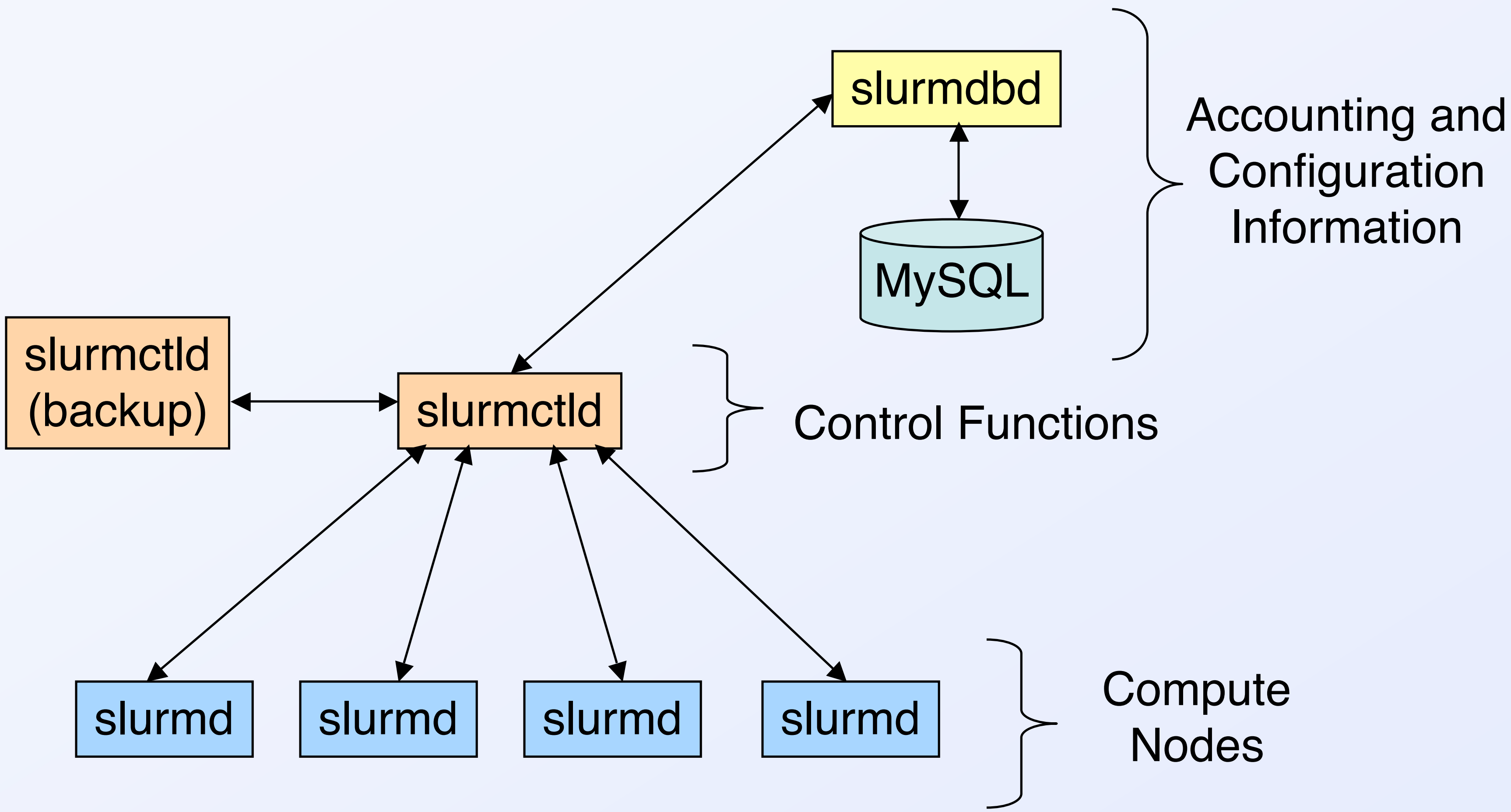
- Arbitrates requests by managing queues of pending work
- Allocates access to computer nodes and their interconnect
- Launches parallel jobs and manages them (I/O, signals, time limits, etc.)

- Developed by LLNL with help from HP, Bull, Linux NetworX, and others

Design objectives

- High scalability
  - Thousands of nodes
- Reliable
  - Avoid single point of failure
- Simple to administer
- Open source (GPL)
- Extensible
  - Very flexible plugin mechanism

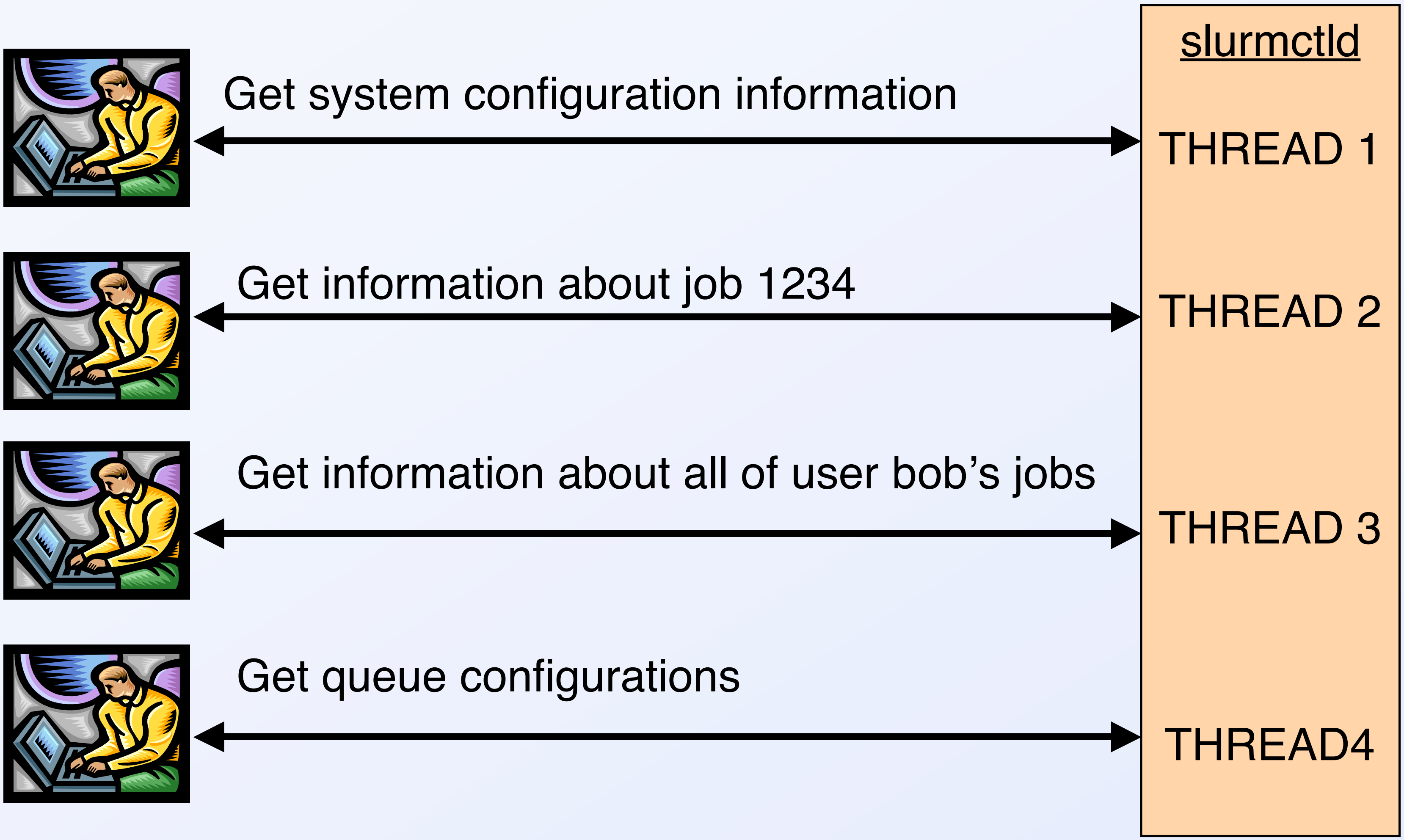
SLURM architecture overview



How we achieve high scalability

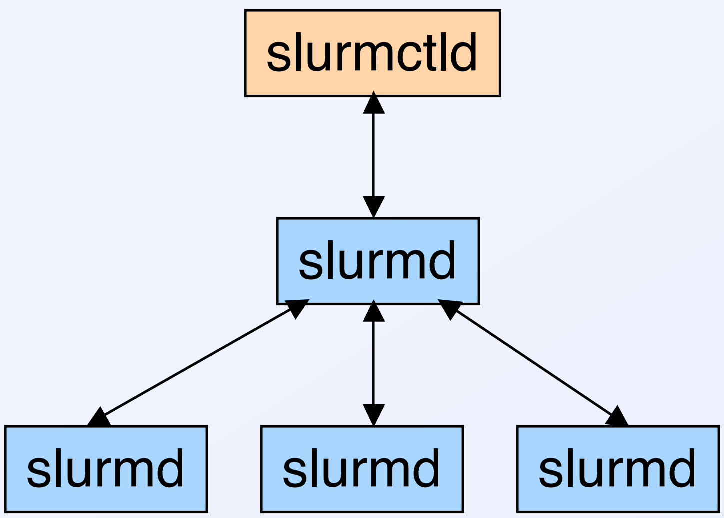
- High parallelism
  - Dozens of active threads are common in the daemons
  - Independent read and write locks on various data structures
  - Offload as much work as possible from slurmctld (SLURM Control Daemon)

Example of parallel slurmctld operations



Hierarchical communication

- Slurmd daemons (one per compute node) have hierarchical communications with fault-tolerance and configurable fanout



Most of the communications overhead is pushed down to slurmd daemons.

Synchronizes system noise to minimize impact upon applications.

Slurmd provides fault-tolerance and combines results into <u>one</u> response message, dramatically reducing slurmctld's overhead.

Non-killable processes

- Non-killable processes (typically hung on I/O to global file system) are not uncommon so we try to minimize their impact
- SLURM supports configurable timeout and program to execute when non-killable processes are found so that system administrators can respond quickly to problems
- SLURM will release a resource for reuse by another job once all processes associated with the previous job on that node complete. There is no need to wait for <u>all</u> processes on <u>all</u> nodes to complete

Highly efficient algorithms

- Bitmap operations used for much of the scheduling work
- RPCs use simple binary information rather than XML (which is more flexible, but slower)

Nodes in selected partition AND	11111111111111110000
Nodes with selected features AND	11111111000000000000
Nodes with available resources	00111000000011100001
Select from these nodes-->	00111000000000000000

Hostlist expressions used in configuration file

- Configuration file size is relatively independent of cluster size

```
# slurm.conf
# plugins, timers, log files, etc.
#
NodeName=tux[0-1023] SocketsPerNode=4 CoresPerSocket=4
#
PartitionName=debug Nodes=tux[0-15] MaxTime=30:00
PartitionName=batch Nodes=tux[16-1023] MaxTime=1-00:00:00
```

Hostlist expressions used in most commands

$ squeue

PARTITION	AVAIL	TIMELIMIT	NODES	STATE	NODELIST
debug	up	30:00	16	idle	tux[0-15]
batch	up	1-00:00:00	32	alloc	tux[16-47]
batch	up	1-00:00:00	976	idle	tux[48-1023]

$ sinfo

JOBID	PARTITION	NAME	USER	ST	TIME	NODES	NODELIST
1234	batch	a.out	bob	R	10:14	16	tux[16-31]
1238	batch	my.sh	alice	R	8:57	16	tux[32-47]

Results

- SLURM is running on about 35% of the Top500 systems
- Total execution time (resource allocation, launch, I/O processing, resource deallocation)
  - 32 nodes 0.1 second
  - 256 nodes 1.0 seconds
  - 1k nodes 3.7 seconds
  - 2k nodes 19.5 seconds
  - 4k nodes 56.6 seconds

Same system

Two different systems with different configurations

- Virtual machine with 64k nodes has been emulated

Special note on task launch

- Some vendors supply proprietary task launch mechanisms (e.g. IBM BlueGene *mpirun*)

- For compatibility with existing vendor tools and/or infrastructure (rather than for performance reasons), the vendor supplied task launch mechanism can be used with SLURM performing the resource management
  - Current model on IBM BlueGene systems

For more information about SLURM

- Information: https://computing.llnl.gov/linux/slurm/
- Downloads: http://sourceforge.net/projects/slurm/
- Email: jette1@llnl.gov
- SLURM BOF in Hilton (directly across the street)
  - Thursday 20 November 3PM to 5PM
  - Room: Salon D

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