High Throughput Computing

Broderick Gardner
SchedMD

SLUG 2019

Copyright 2019 SchedMD
www.schedmd.com

Focus

through·put
/ˈTHro͞o ̩po͝ot/
noun
noun: **throughput**; plural noun: **throughputs**
the amount of material or items passing through a system or process.

How many small, short jobs can we push through the cluster per minute?

Copyright 2019 SchedMD
www.schedmd.com

Topics

General tuning and recommendations

Test Configuration

Submission rate

Tunable parameters

Feature impact

Copyright 2019 SchedMD
www.schedmd.com

General Recommendations

- Prioritize higher clock speed over core count for `slurmctld` host
  - `slurmctld` is highly threaded but not highly concurrent
  - So Core i7/i9 over Xeon

Copyright 2019 SchedMD
www.schedmd.com

General Recommendations

- Prioritize higher clock speed over core count for `slurmctld` host
  - `slurmctld` is highly threaded but not highly concurrent
  - So Core i7/i9 over Xeon
- `StateSaveLocation` should be on a dedicated fast filesystem
  - Particularly if it is shared with a backup controller in a High Availability configuration
  - IOPS to this filesystem is one of the main bottlenecks to job throughput
    - At least 1 directory and 2 files created per job

Copyright 2019 SchedMD
www.schedmd.com

General Recommendations

- Prioritize higher clock speed over core count for `slurmctld` host
  - `slurmctld` is highly threaded but not highly concurrent
  - So Core i7/i9 over Xeon
- `StateSaveLocation` should be on a dedicated fast filesystem
  - Particularly if it is shared with a backup controller in a High Availability configuration
  - IOPS to this filesystem is one of the main bottlenecks to job throughput
    - At least 1 directory and 2 files created per job
- SlurmdSpoolDir should be local to the node, eg. a tmpfs
- Reduce the debug level of slurmctld and slurmd, particularly if they log to a slow or nonlocal filesystem

Copyright 2019 SchedMD
www.schedmd.com

Accounting and Throughput

Database and slurmdbd

- Reasonably fast filesystem
- InnoDB parameters
  - Recommended minimums to the right
- `CommitDelay`
  - Seconds between database commits
  - From `man slurmdbd.conf`: “In testing, 1 second improves the slurmdbd performance dramatically and reduces overhead.”

```
# /etc/my.cnf
[mysqld]
innodb_buffer_pool_size=1G
innodb_log_file_size=64M
innodb_lock_wait_timeout=900
```

```
# slurmdbd.conf
CommitDelay=1
```

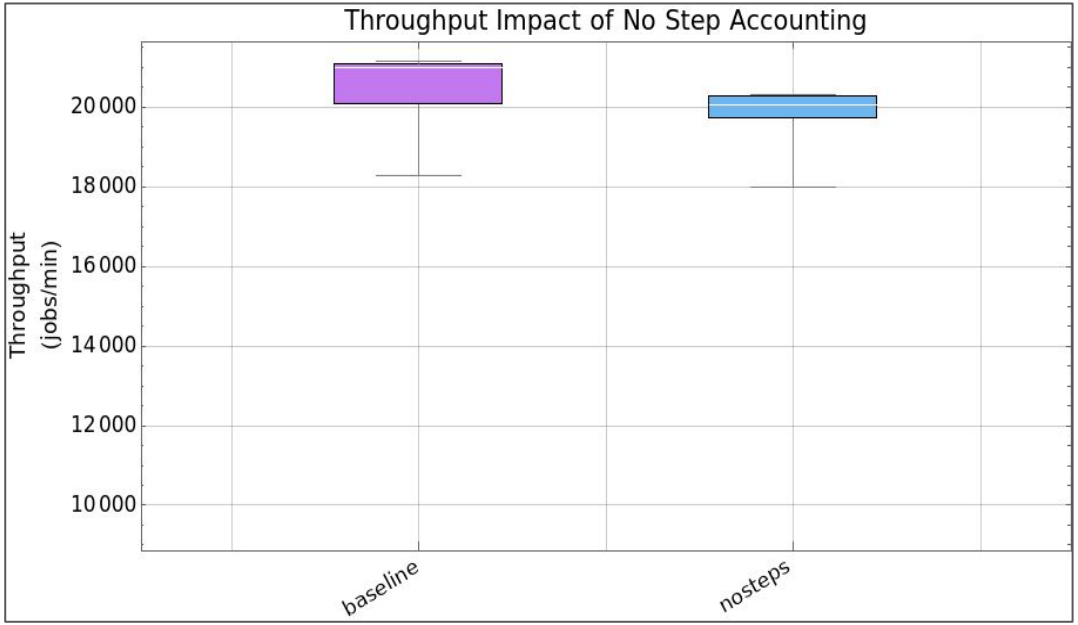
- Following these guidelines, the slurmdbd should not bottleneck job throughput

Copyright 2019 SchedMD
www.schedmd.com

Accounting Throughput Impact

```
# slurm.conf
AccountingStorageEnforce=nosteps
```

- Disables step accounting
- My testing shows minimal difference
- You could try this to see if accounting is your bottleneck



Copyright 2019 SchedMD
www.schedmd.com

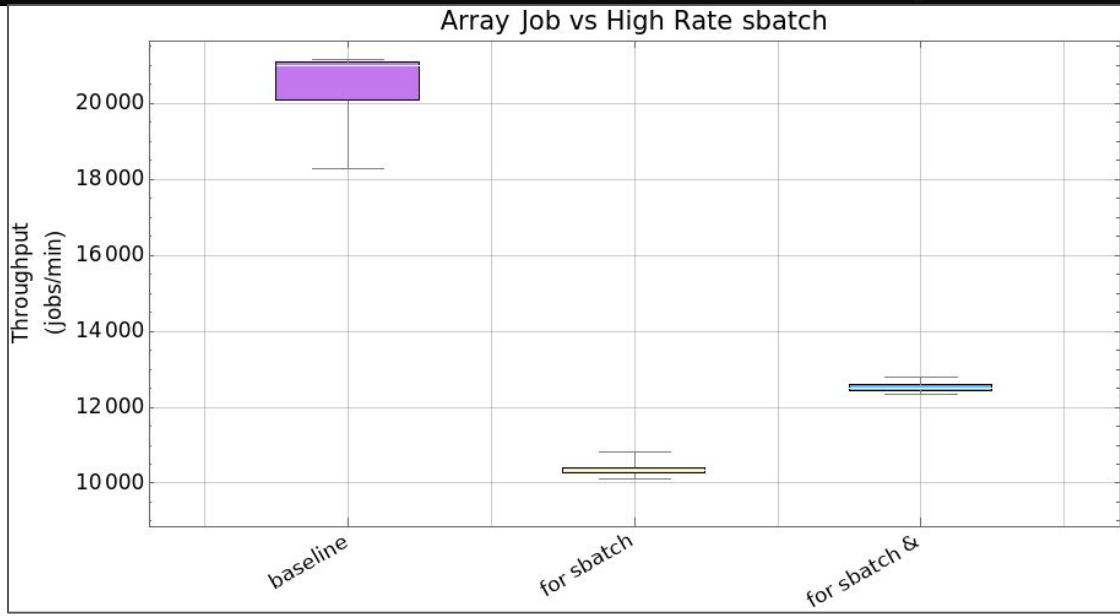
Submission Rate

Array Jobs FTW

```
# slurm.conf
MaxArraySize=100000
```

```
$ sbatch --array=1-10000 job.sh
```

```
for i in {1..10000000}; do
sbatch --partition=smd ntpbatch.sh &
done
```



Copyright 2019 SchedMD
www.schedmd.com

Tunable Parameters - Main Scheduler

`max_rpc_cnt`

- Keep high to allow scheduler to run under high slurmctld RPC load

```
# slurm.conf
SchedulerParameters=max_rpc_cnt=400,\
sched_min_interval=50000
```

`sched_min_interval`

- microseconds
- Rate limit starting the quick scheduler due to many jobs ending

Copyright 2019 SchedMD
www.schedmd.com

Tunable Parameters - Main Scheduler

`sched_max_job_start`

- Set to a reasonable number of jobs started at once

`batch_sched_delay`

- in seconds
- Allow delayed starting of batch jobs during high submission rate

```
# slurm.conf
SchedulerParameters=max_rpc_cnt=400,\
sched_min_interval=50000,\
sched_max_job_start=300,\
batch_sched_delay=20
```

Copyright 2019 SchedMD
www.schedmd.com

Tunable Parameters - Backfill Scheduler

Do you need it? Short, tiny jobs will not benefit.

If you do, here are some parameters to consider.

```
# slurm.conf
SchedulerParameters=max_rpc_cnt=400,\
sched_min_interval=50000,\
sched_max_job_start=300,\
batch_sched_delay=20,\
bf_resolution=600,\
```

`bf_resolution`

- in seconds
- Set high to speed up scheduler

Copyright 2019 SchedMD
www.schedmd.com

Tunable Parameters - Backfill Scheduler

`bf_min_prio_reserve`

- Prefer system utilization over priority below a threshold priority

`bf_min_age_reserve`

- in seconds
- Prefer system utilization over priority for jobs pending less than a threshold time

```
# slurm.conf
SchedulerParameters=max_rpc_cnt=400,\
sched_min_interval=50000,\
sched_max_job_start=300,\
batch_sched_delay=20,\
bf_resolution=600,\
bf_min_prio_reserve=2000,\
bf_min_age_reserve=600
```

Copyright 2019 SchedMD
www.schedmd.com

Test Configuration

```
# slurm.conf
ClusterName=caesar
TopologyPlugin=topology/tree
FastSchedule=1
SchedulerType=sched/backfill
JobCompType=jobcomp/none

NodeName=DEFAULT State=UNKNOWN CoresPerSocket=4 ThreadsPerCore=2 RealMemory=7940
NodeName=smd1_[0-15] NodeHostname=smd1 Port=19100-19115
NodeName=smd2_[0-15] NodeHostname=smd2 Port=19100-19115
NodeName=smd3_[0-15] NodeHostname=smd3 Port=19100-19115
NodeName=smd4_[0-15] NodeHostname=smd4 Port=19100-19115
PartitionName=smd Nodes=smd[1-4]_[0-15] PriorityJobFactor=1000
```

Copyright 2019 SchedMD
www.schedmd.com

Test System

slurmctld host

```
$ lscpu | egrep 'Model name|CPU MHz'
Model name:    Intel(R) Core(TM) i9-9900K CPU @ 3.60GHz
CPU MHz:       4700.000
$ grep "MemTotal" /proc/meminfo
MemTotal: 16255456 kB
$ udevadm info --query=all --name=/dev/nvme0n1 | grep ID_MODEL
E: ID_MODEL=Samsung SSD 970 EVO Plus 500GB
$ uname -sr
Linux 5.2.14-zen2-1-zen
```

```
$ srun --partition=smd /usr/bin/lscpu | grep 'Model name'
Model name:    Intel(R) Xeon(R) CPU E31230 @ 3.20GHz
$ srun --partition=smd /bin/uname -sr
Linux 5.0.0-15-generic
```

Copyright 2019 SchedMD
www.schedmd.com

Throughput Measurement

```
$ cat s_jobspermin.sh
#!/bin/bash
# Returns number of jobs completed in each minute since $1 or an hour ago
timeback=$(date +%FT%R -d "-1 hour");
if [[ -n $1 ]]; then
      date -d "$1" > /dev/null 2>&1;
      if [[ $? -eq 0 ]]; then
            timeback=$(date +%FT%R -d "$1");
      else
            exit
      fi;
fi;
echo "Since $timeback";
SLURM_TIME_FORMAT="%FT%H:%M" sacct -Xa --noheader -S$timeback -Enow -oEnd --state=CD |\
      awk '{sums[$1]++}END{for (s in sums) print s, sums[s]}' |\
      sort
```

Copyright 2019 SchedMD
www.schedmd.com

Test Jobs

- Test array job

```
$ cat tpbatch.sh
#!/bin/sh
#SBATCH --array=0-1000000
#SBATCH --ntasks=1
#SBATCH --output=/dev/null
#SBATCH --time=00:01
srun /bin/true

$ sbatch --partition=smd tpbatch
```

Copyright 2019 SchedMD
www.schedmd.com

Usefulness and Limitations

- Test configuration is highly idealized
- The goal is to expose the relative impact of Slurm-specific features, parameters, and configurations
- Hardware is held constant and so is not considered here
- Running massive numbers of tiny jobs is not efficient or recommended due to job launch overhead
  - If the workflow can be adapted to it, job steps would be better

Copyright 2019 SchedMD
www.schedmd.com

Feature Impact

- What impact do each of Slurm's major features have on throughput performance?
  - Cgroups, accounting, cons_tres, etc.
- We will start with a baseline configuration with features tuned and turned off for the highest possible throughput
- Then we will measure the independent impact of each feature

Copyright 2019 SchedMD
www.schedmd.com

Test Configuration

```
# slurm.conf
ProctrackType=
     proctrack/cgroup
     proctrack/linuxproc
JobAcctGatherType=
     jobacct_gather/none
     jobacct_gather/linux
     jobacct_gather/cgroup
PriorityType=
     priority/basic
     priority/multifactor
SelectType=
     select/cons_res
     select/cons_tres
```

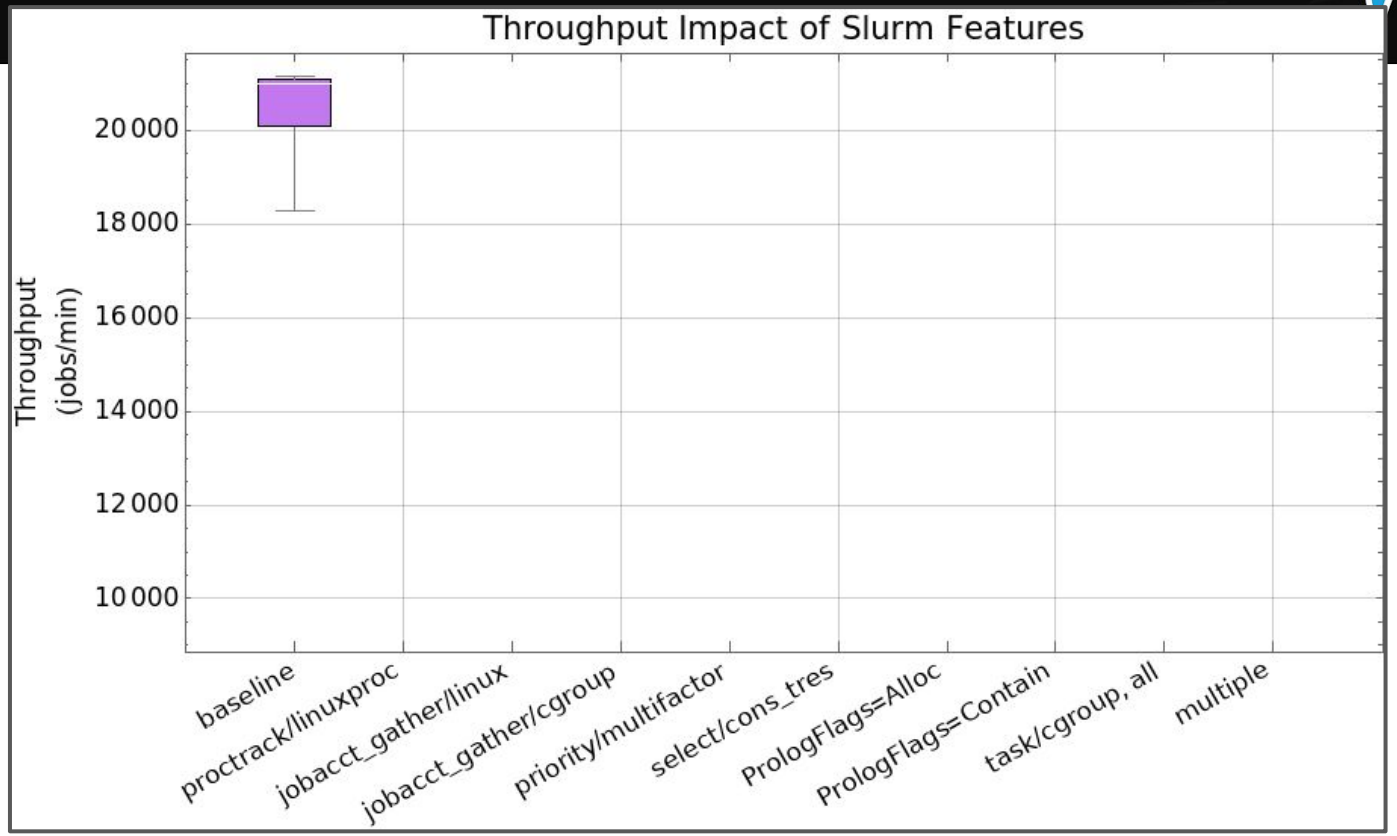
```
PrologFlags=
     None
     Alloc
     Contain
TaskPlugin=
     task/affinity
     task/affinity,task/cgroup
SlurmctldDebug=
     error
     debug2
SlurmdDebug=
     error
     debug2
```

Underline indicates baseline configuration

Copyright 2019 SchedMD
www.schedmd.com

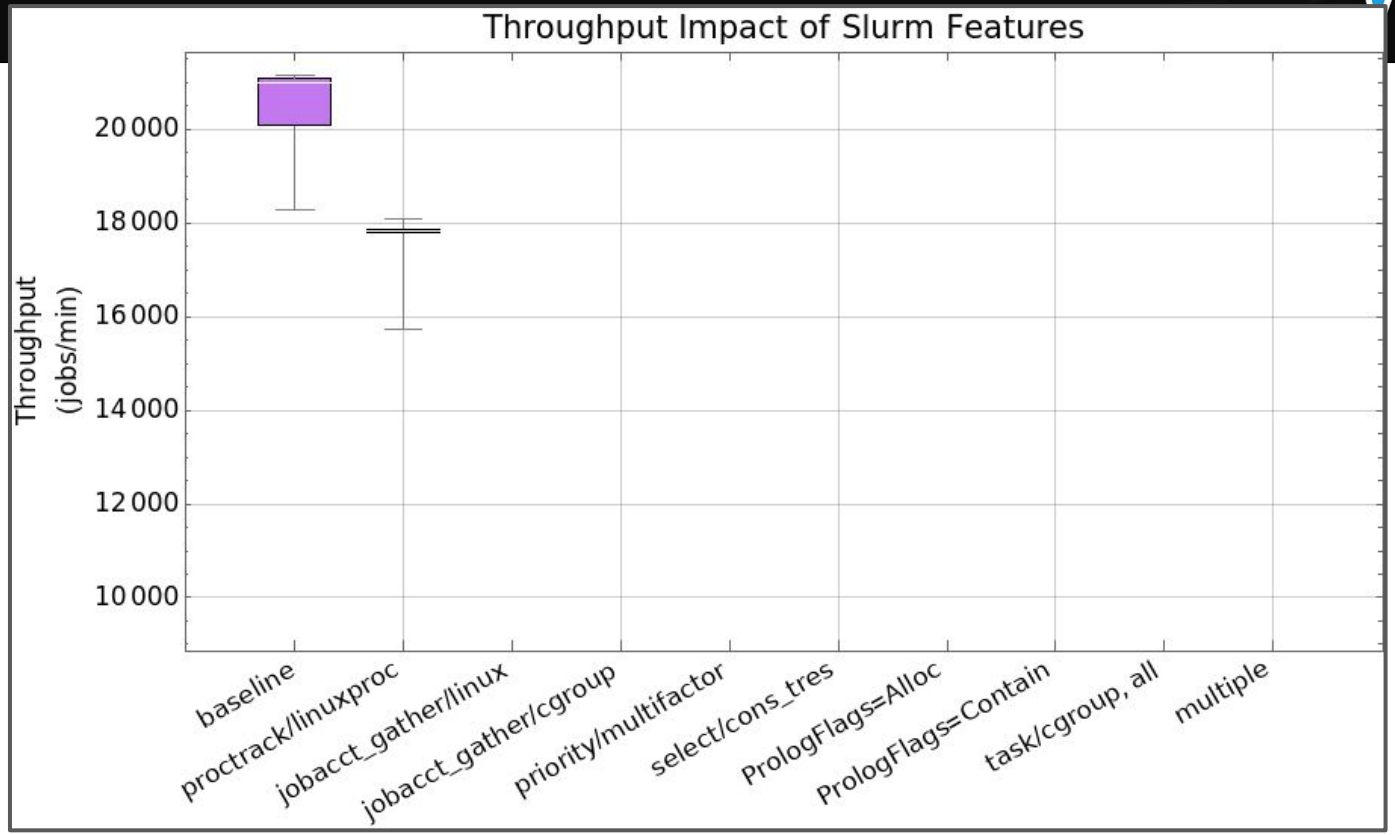
Baseline configuration

-



ProctrackType=proctrack/linuxproc

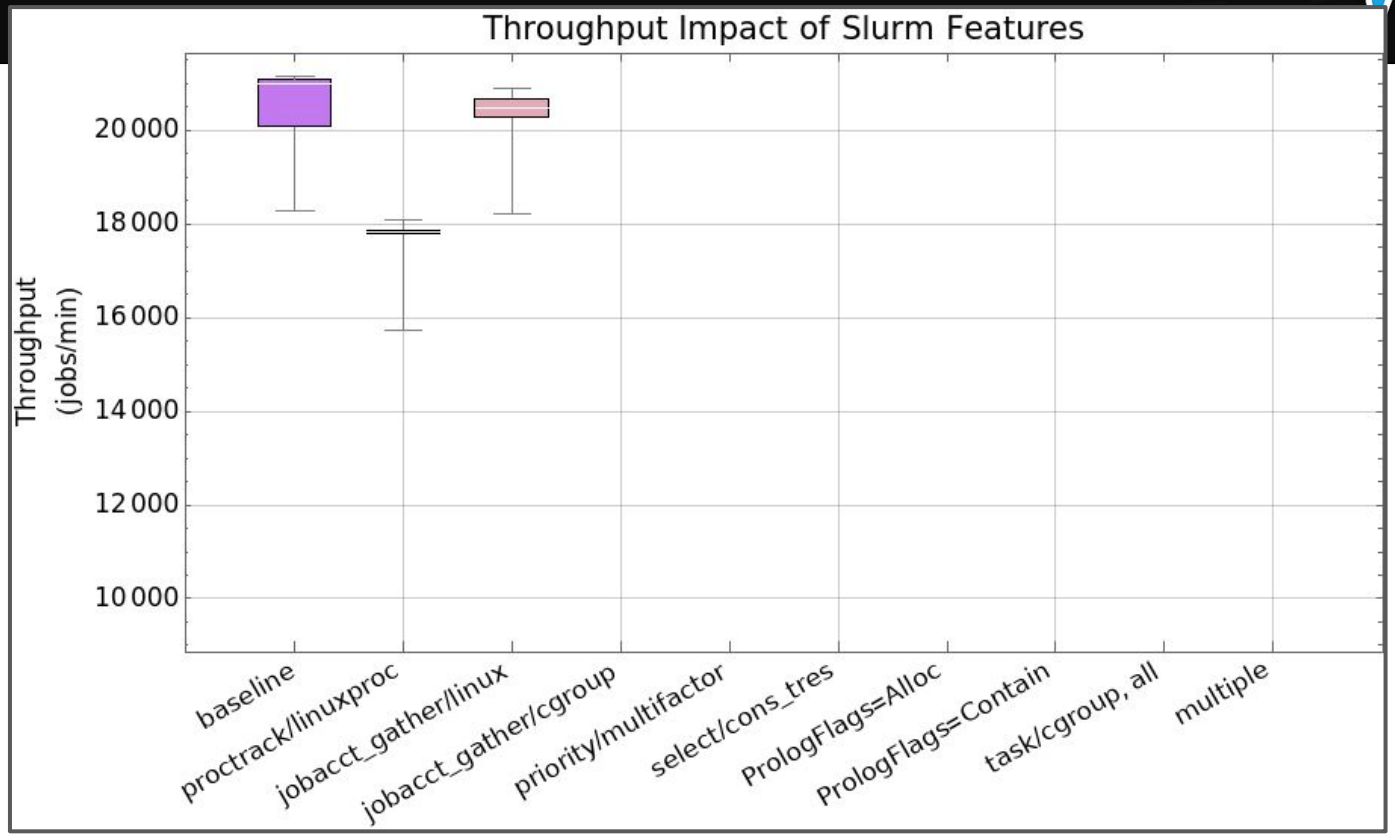
Impact: Small



JobAcctGatherType=jobacct_gather/linux

-

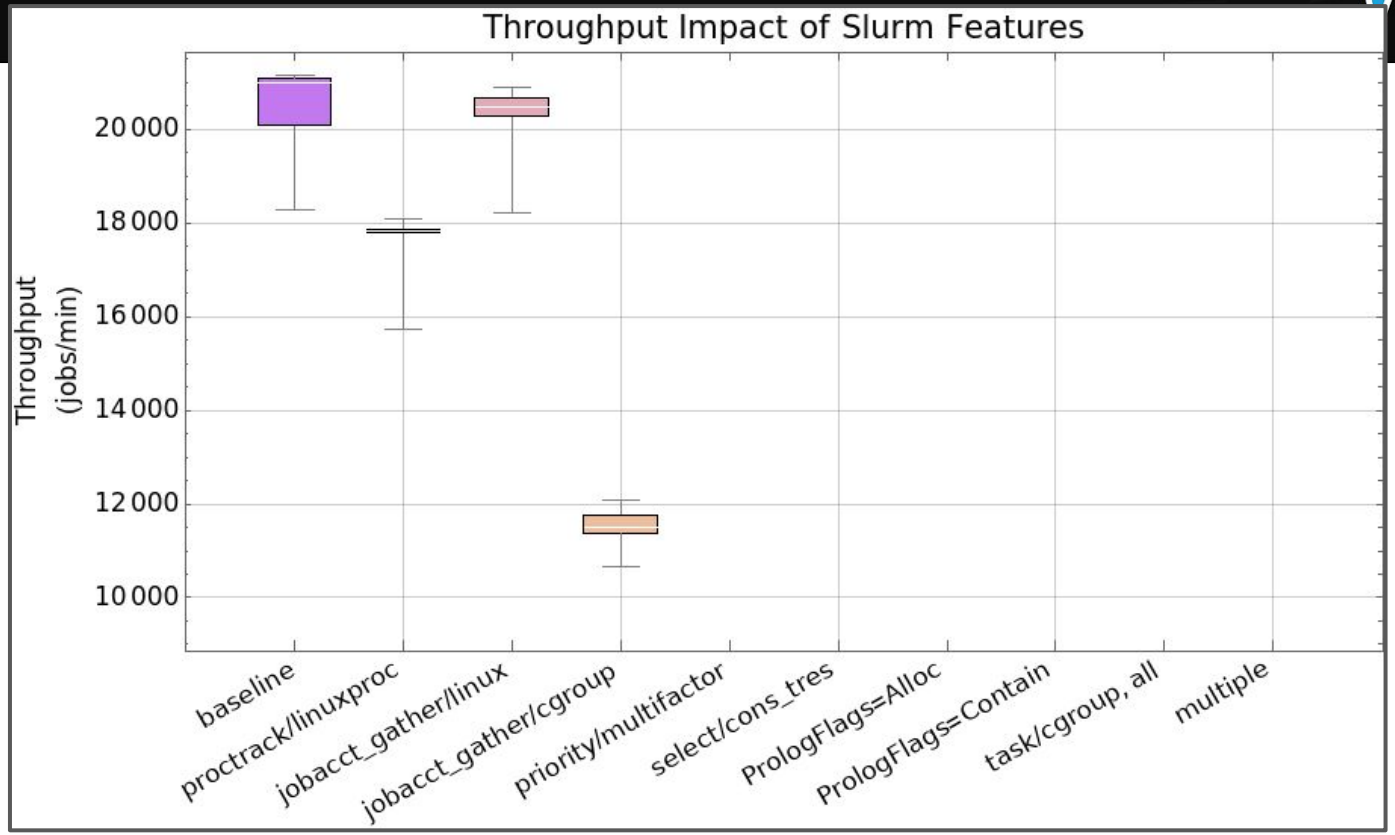
Impact: Negligible



JobAcctGatherType=jobacct_gather/cgroup

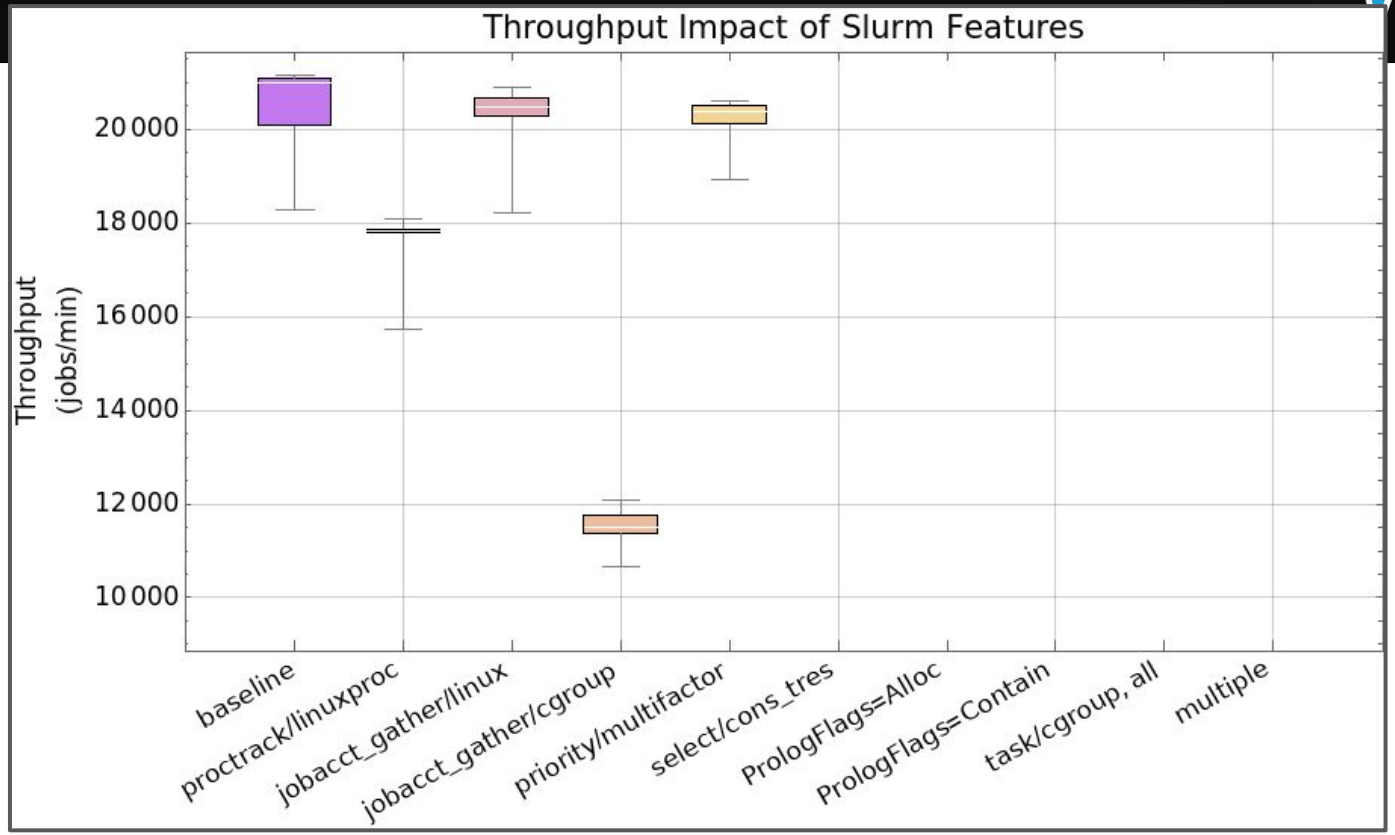
-

Impact: Large



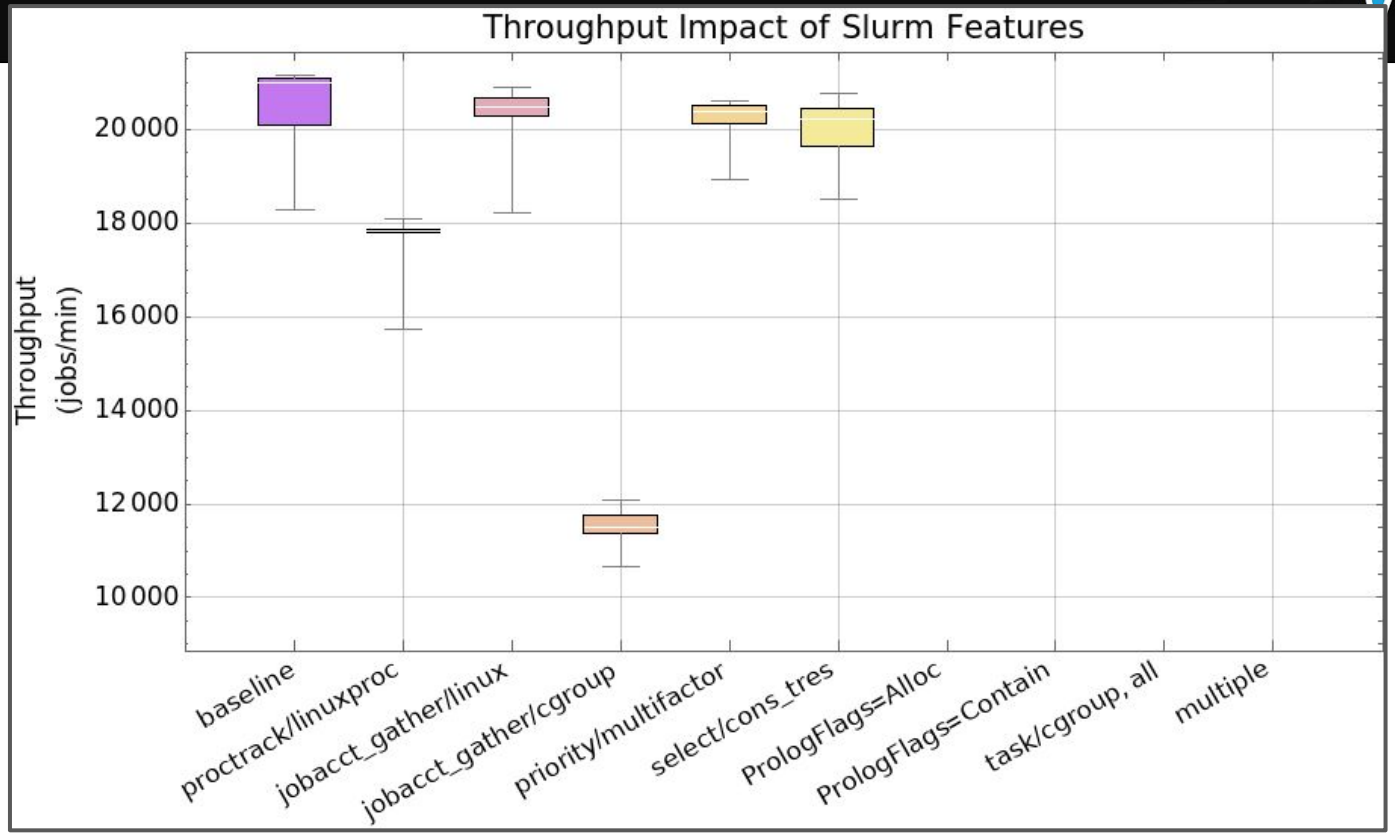
PriorityType=priority/multifactor

Impact: Negligible



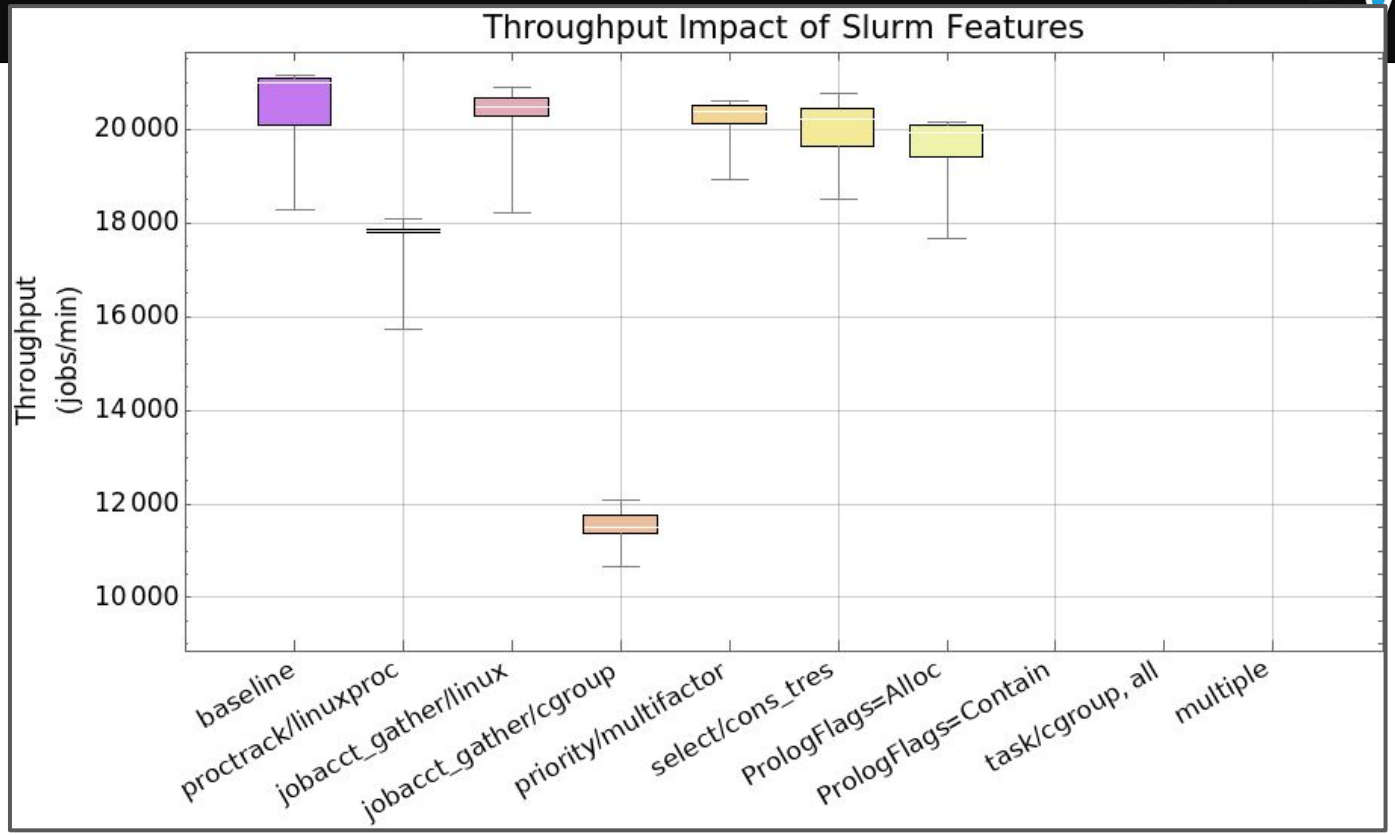
SelectType=select/cons_tres

Impact: Negligible



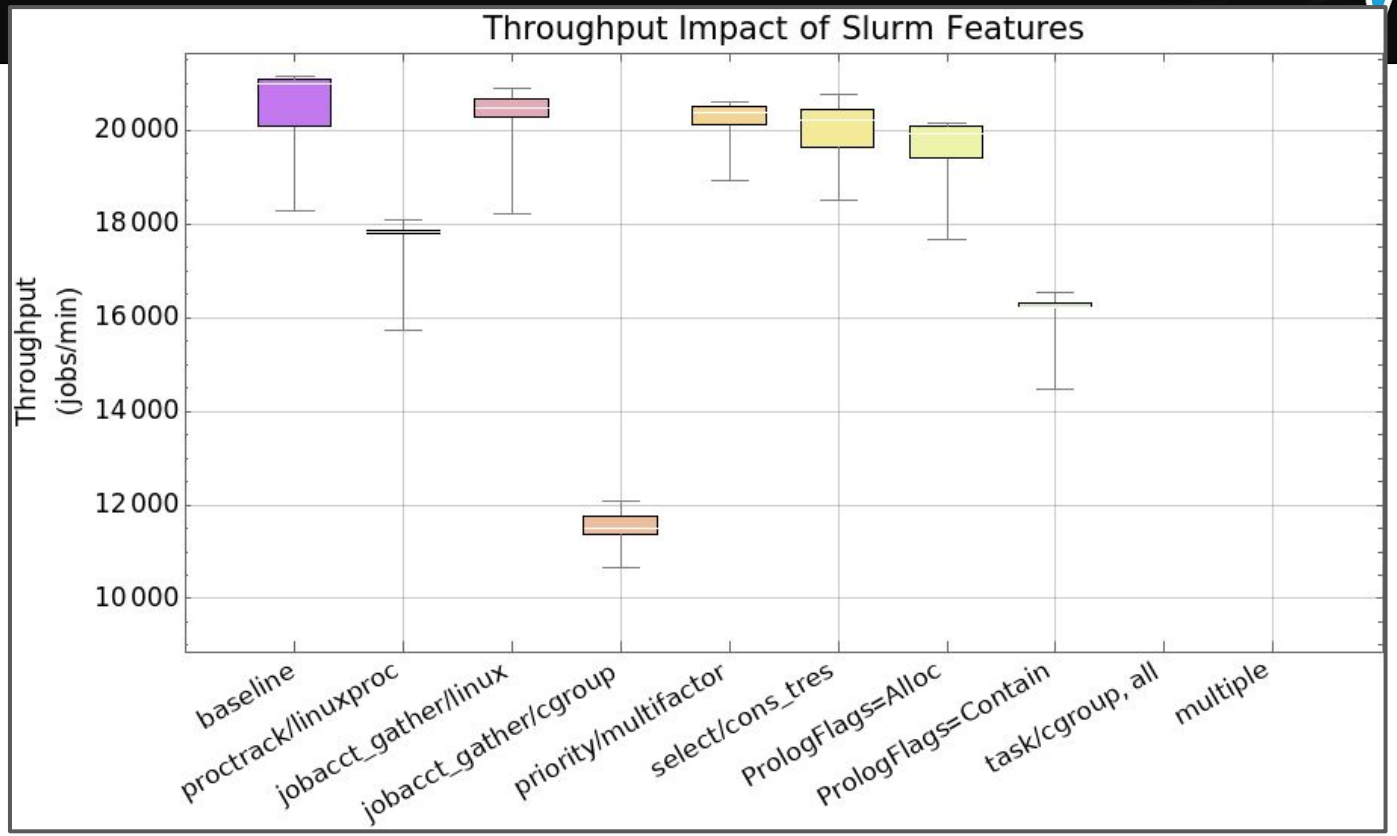
PrologFlags=Alloc

Impact: Small



PrologFlags=Contain

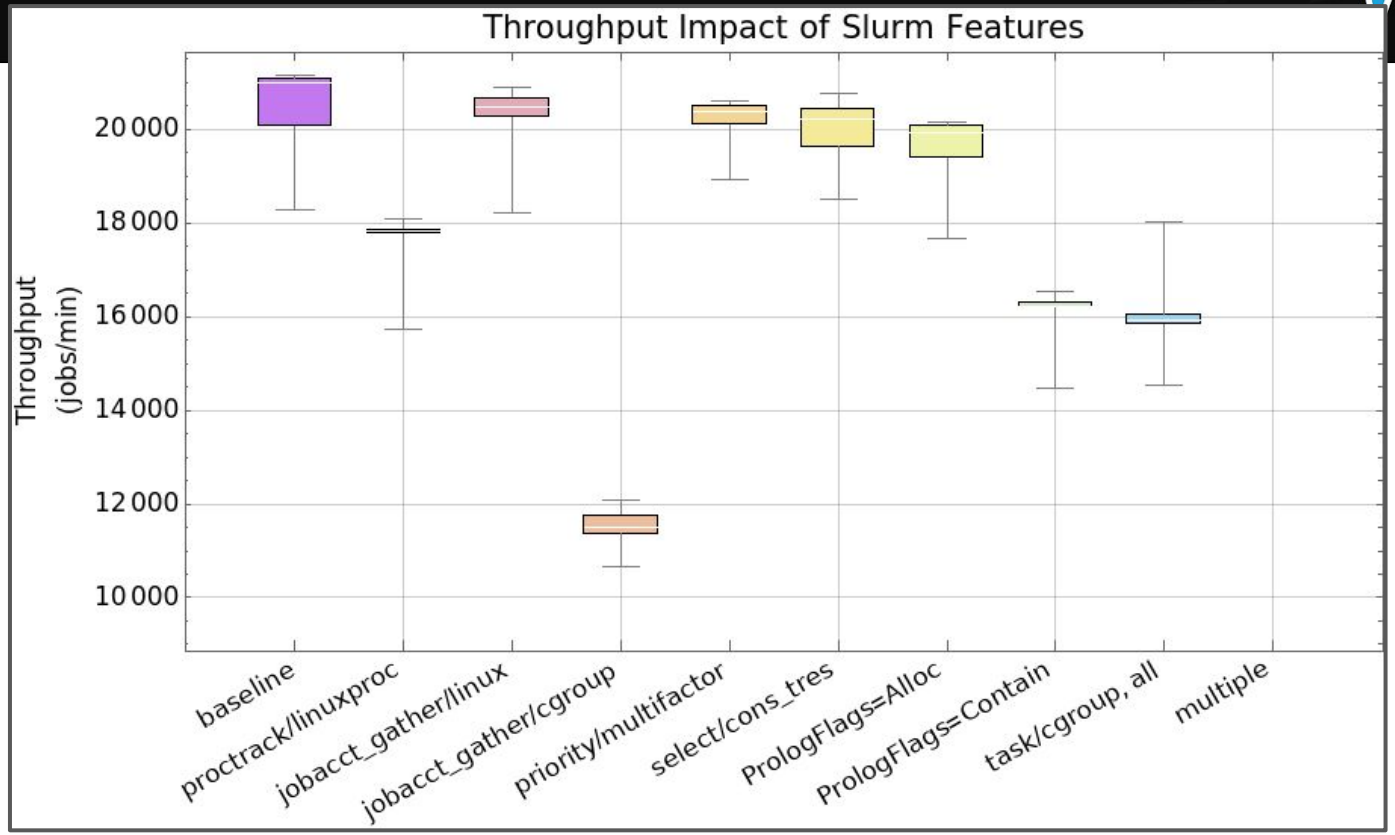
Impact: Large



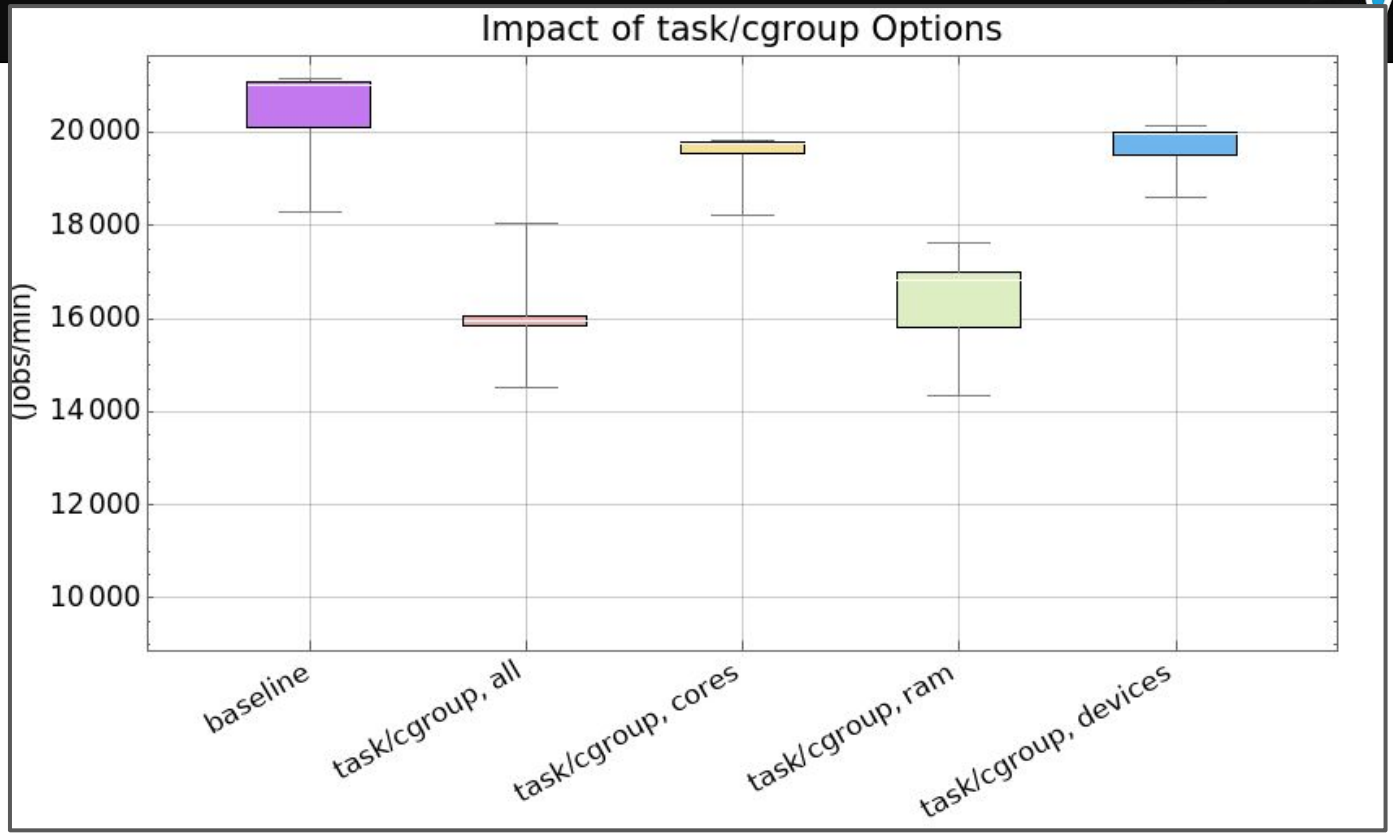
TaskPlugin=task/affinity,task/cgroup

```
# cgroup.conf
ConstrainCores=yes
ConstrainRamSpace=yes
ConstrainSwapSpace=yes
ConstrainDevices=yes
```

Impact: Large



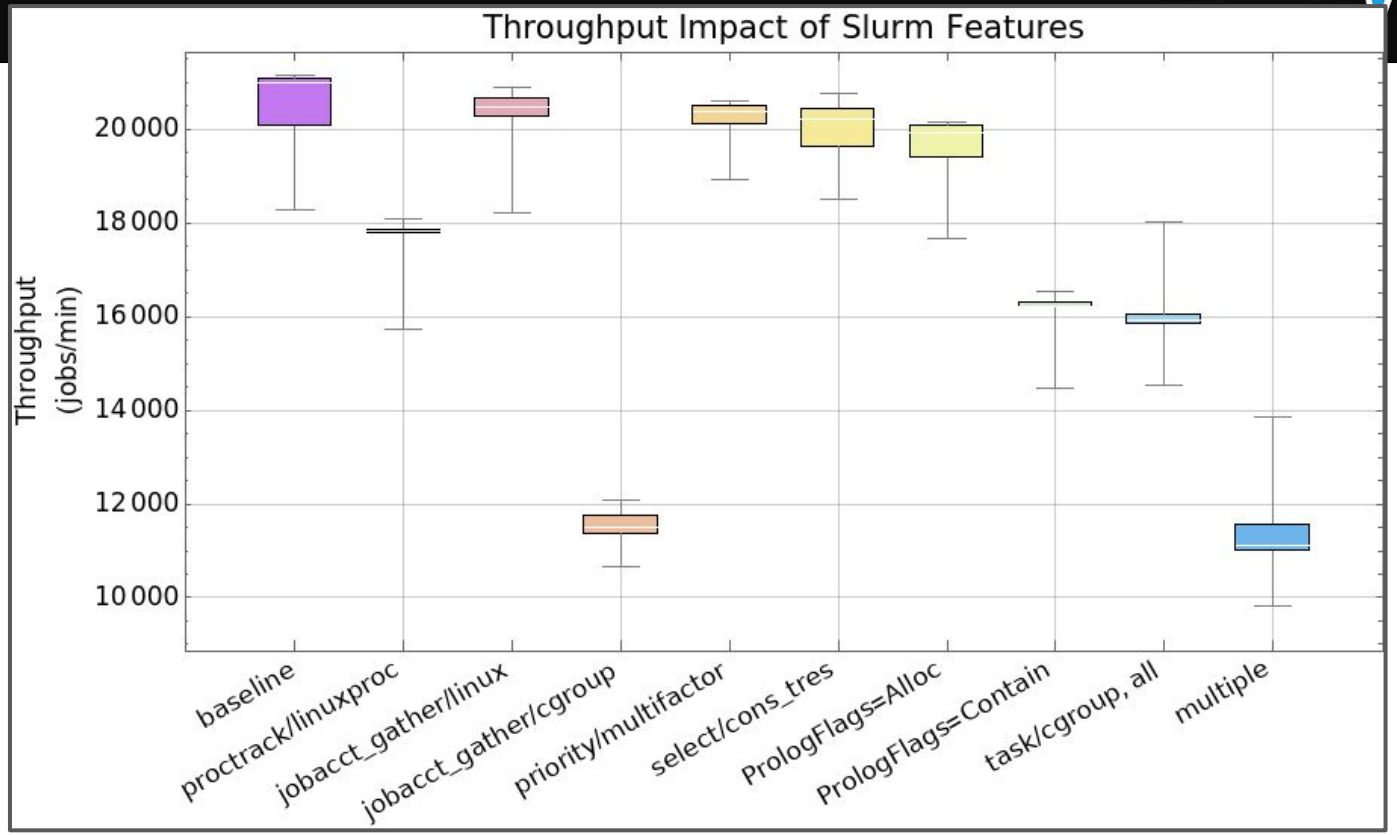
TaskPlugin=task/affinity,task/cgroup



Arbitrary Combination

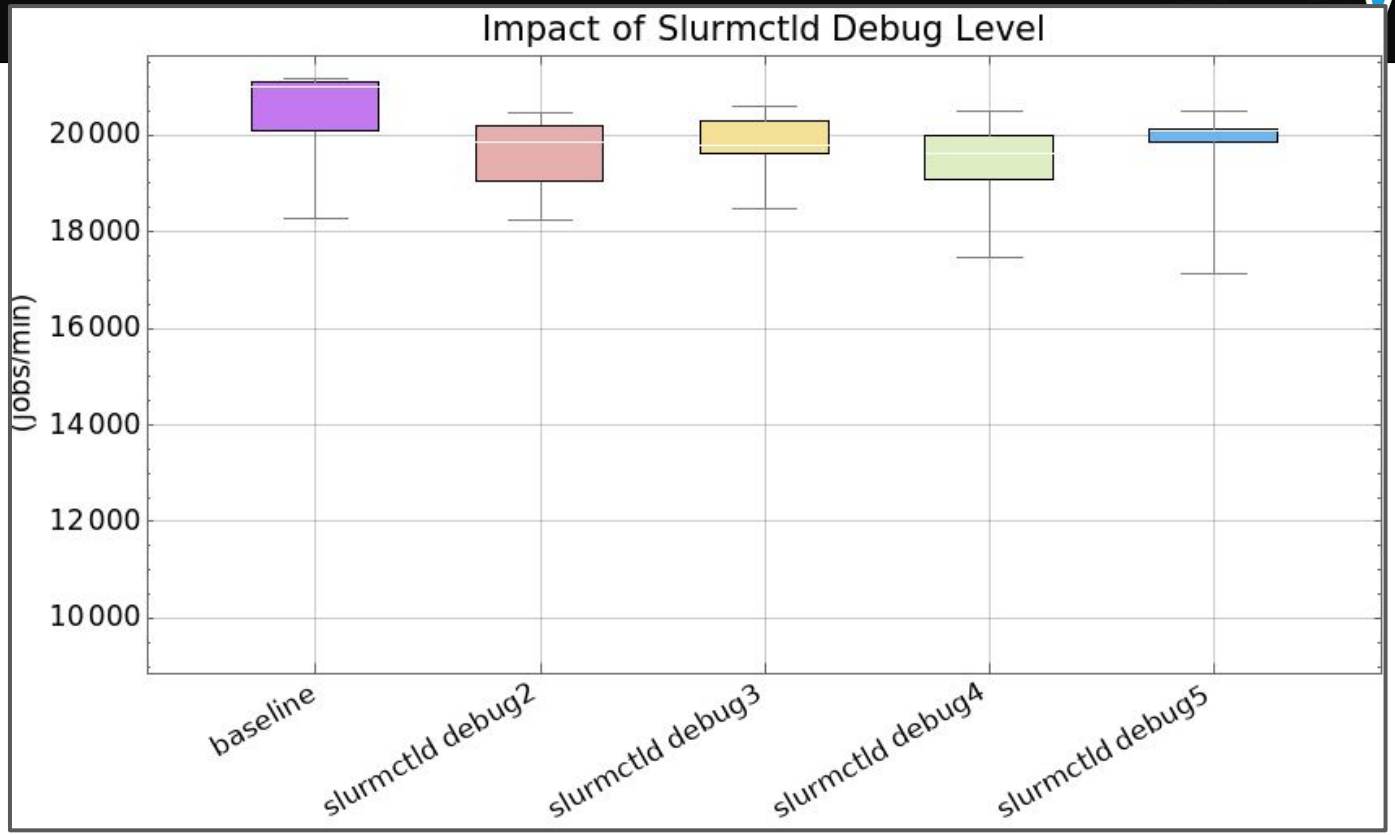
```
JobAcctGatherType=
      jobacct_gather/linux
ProctrackType=
      proctrack/cgroup
PrologFlags=Alloc,Contain
TaskPlugin=task/cgroup
      ConstrainCores=yes
      ConstrainRAMSpace=yes
      ConstrainSwapSpace=yes
      ConstrainDevices=yes
PriorityType=
      priority/multifactor
```

Impact: Large



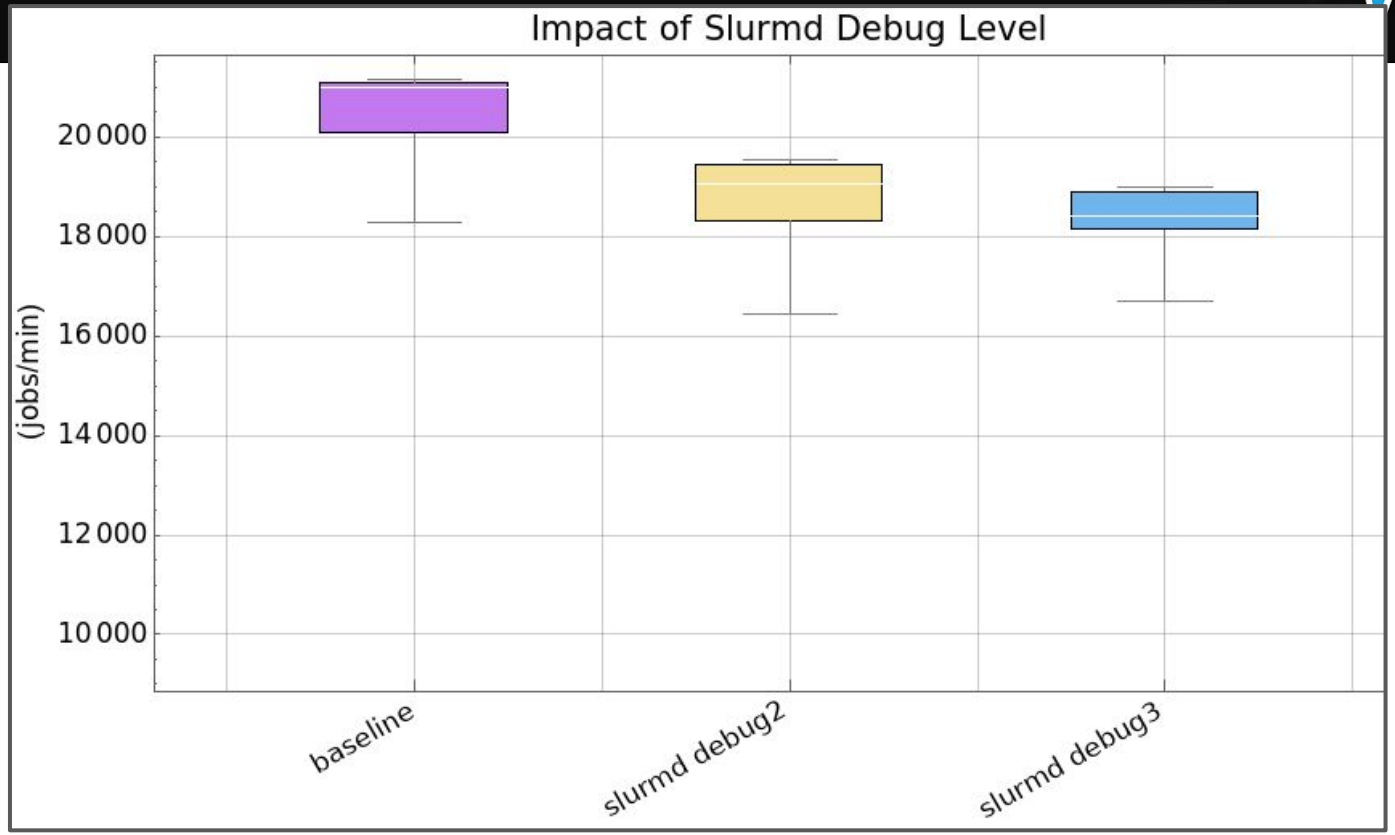
Slurmctld Debug Level

Small



Slurmd Debug Level

Small



Questions?

Copyright 2019 SchedMD
www.schedmd.com