LCI Advanced Workshop 2025: **Security in Slurm**

Josh Burks
HPC Systems Analyst
Arizona State University Research Computing
josh.burks@asu.edu

Learning Goals

- Understand Slurm’s built-in security mechanisms
- Recognize weaknesses in traditional HPC security models
- Explore built in options for hardening Slurm clusters
- Explore advanced tools (SPANK, containers, UserBasedFirewall)
- Identify ongoing risks beyond Slurm’s scope

Historical HPC Security Model

- “Hard exterior, soft interior”
  - External security: VPNs, bastion hosts, MFA
  - Internal security: basic POSIX permissions, SELinux often disabled
- Users don’t have full free roam, but inside is loosely controlled
- Onion model: layers exist, but mostly at the perimeter
- Malicious insiders (or compromised accounts) remain a threat

Unencrypted HPC Communications

- MPI and RDMA traffic are unencrypted
- Often bypass host firewalls (RDMA direct access)
- Mitigation:
  - VLAN separation for management vs. compute
  - UserBasedFirewall for cross-user traffic control

Slurm Security Layers

- Transport Security (TLS + certmgr)
- Job & Node Isolation (MCS, containers, /proc controls)
- Authentication & Authorization (PAM, Slurm Adopt, AdminLevels)
- Data Privacy & Audit Control (PrivateData)

PrivateData

- Restrict visibility of accounts, jobs, usage, reservations
- Protects sensitive data in shared accounting systems

```
#slurm.conf
PrivateData=jobs,accounts,events,jobs,nodes,partitions,rese
rvations,usage,users

#slurmdbd.conf
PrivateData=accounts,events,jobs,reservations,usage,users
```

Node Sharing & /proc Security

- Node sharing risks ⟶ job snooping
- /proc isolation with hidepid=1
  - Users may not access any /proc/<pid>/ directories but their own, protected against local eavesdroppers.
  - Reduces exposure of other users’ processes

```
# /etc/fstab
proc /proc proc hidpid=1 0 0
```

Job Container Tmpfs

- Isolated /tmp file systems
- Configurable job-level filesystem isolation
- If userA writes sensitive data to /tmp, normally userB could see this
- By bind-mounting /tmp to a private per-job mount, userB can only see userB’s /tmp

Job Container Tmpfs

```
#slurm.conf
JobContainerType=job_container/tmpfs
ProlögFlags=Contain


#job_container.conf
AutoBasePath=true
BasePath=/mnt/job_tmp # Real location where data lives
Dirs=/tmp,/dev/shm # Paths bind-mounted under the basepath
Shared=true # Required when using autofs
```

MCS (Multi-Category Security)

- Tenant isolation via categories
- Ensures jobs with different categories never share nodes
- Useful where data may be seen my members of a group, but not across groups on a shared system
  - mcs/none disables MCS labels and functionality.
  - mcs/account MCS labels equal the job's --account
  - mcs/group MCS labels equal to the job's user group
  - mcs/user MCS labels equal to the username of the job's --uid
  - mcs/label MCS labels are arbitrary strings

PAM Slurm Adopt

- PAM plugin that prevents users from sshing into nodes on which they don’t have a running job
- Prevents rogue or orphaned processes
- The user’s connection is “adopted” into the extern step cgroup of the job so that they cannot exceed cgroup limits
- All processes created by the user and the user’s connection are killed when the job ends

PAM Slurm Adopt

```
#/etc/pam.d/sshd
account     required       pam_nologin.so
account     include        password-auth
...
-account     required       pam_slurm_adopt.so \
                           action_generic_failure=deny \
                           action_adopt_failure=deny
```

PAM Slurm Adopt + SELinux

- PAM Slurm Adopt requires a custom SELinux module to work in an environment where SELinux is enabled

```
module pam_slurm_adopt 1.0;
require {
    …
}
allow sshd_t
…
```

TLS + certmgr + certgen

- New plugins in Slurm 25.05
- Encrypts all Slurm RPC traffic
- Protects job submissions, scheduling, accounting
- Uses s2n (signal-to-noise) github.com/aws/s2n-tls
    - dnf install s2n-tls-devel

TLS + certmgr + certgen

```
#slurm.conf

TLSType=tls/s2n

TLSParameters=ca_cert_file=/etc/pki/slurm_ca.pem

CertmgrType=certmgr/script

CertgenType=certgen/script


#slurmdbd.conf

TLSType=tls/s2n

TLSParameters=ca_cert_file=/etc/pki/slurm_ca.pem
```

TLS + certmgr + certgen

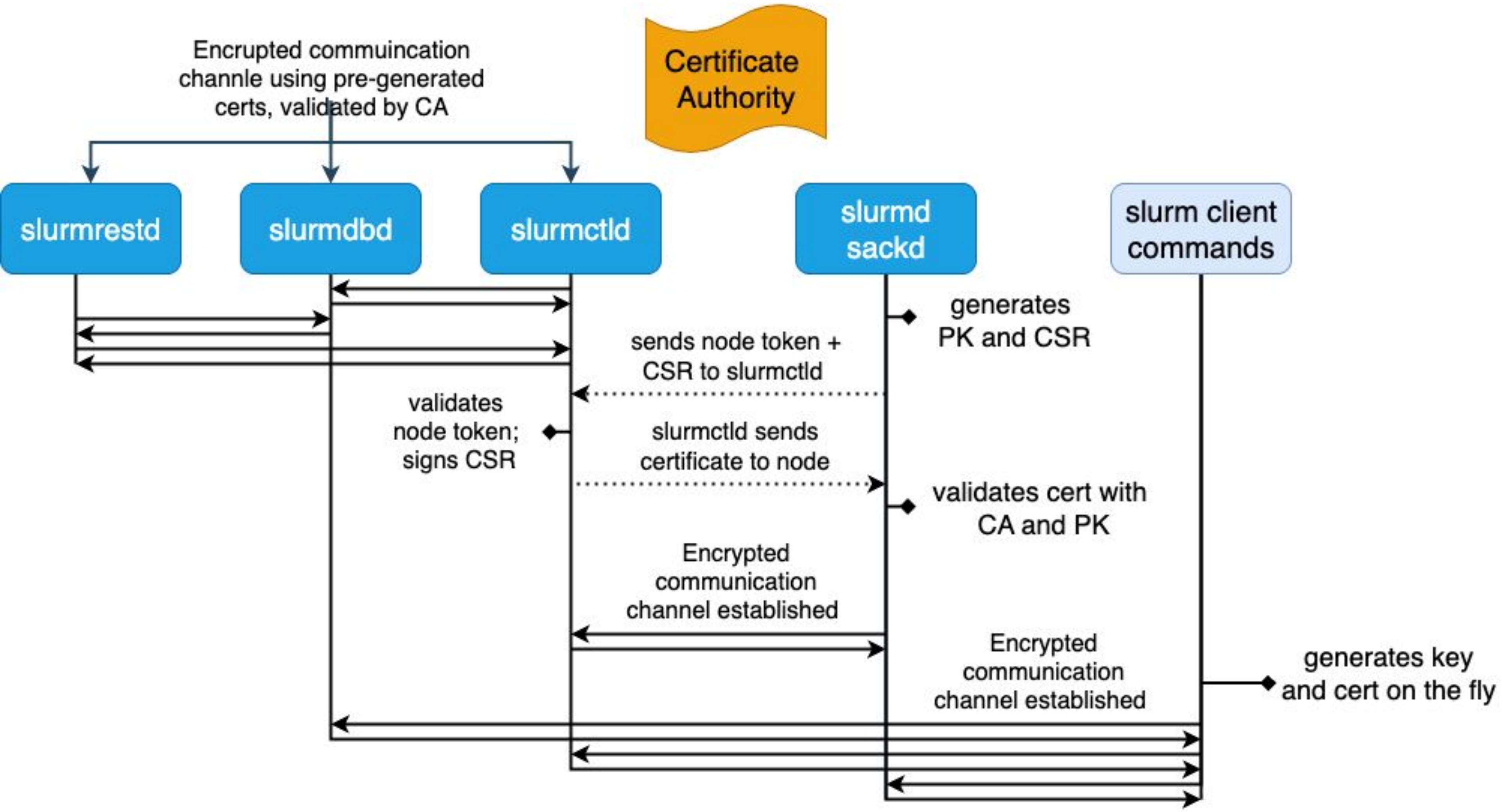
- certmgr plugin manages certificates for slurmd/sackd
- certgen plugin generates key/cert pairs on the fly for client commands

- slurmctld, slurmdbd, and slurmrestd all have unique certificates
- slurmd boot with a pre-shared token
- slurmd generates a private key
- slurmd sends token+certificate signing request to slurmctld
- slurmctld validates token is owned, and returns a certificate
- sackd follows the same process

Note:

- all certificates are signed by a common certificate authority
- slurmd must be started with –ca-cert-file

TLS + certmgr + certgen



Encrupted commuincation channle using pre-generated certs, validated by CA
Certificate Authority
slurmrestd
slurmdbd
slurmctld
slurmd sackd
slurm client commands
generates PK and CSR
sends node token + CSR to slurmctld
validates node token; signs CSR
slurmctld sends certificate to node
validates cert with CA and PK
Encrypted communication channel established
Encrypted communication channel established
generates key and cert on the fly

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Beyond Slurm: Network Security

- MPI & RDMA unencrypted
- Infiniband fabric controls: partition keys, SR-IOV
- VLAN separation (mgmt vs compute)
- UserBasedFirewall for user-to-user traffic control
  - github.com/mit-llsc/UserBasedFirewall

Firewalling & Ports

- Limit which hosts can connect to Slurm daemons
- Use firewalls to restrict RPC traffic
- Control SlurmctldPort and SlurmdPort
- Limit ephemeral ports srun can use
- CommunicationParameters=block_null_hash (new in 21.08.8)
- ,NoCtldInAddrAny,NoInAddrAny

Firewalling & Ports

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- Block null hash (new in 21.08.8)

```
#slurm.conf
SlurmctldPort=6817
SlurmdPort=6818
SrunPortRange=61000-62000
CommunicationParameters=block_null_hash,NoCtldInAddrAny,NoInAddrAny
```

Prolog/Epilog for Security

- Use them to sanitize hosts between jobs
- Reset GPUs, wipe sensitive data
- Purge old mounts
- Ensure the job directory is private

SPANK Plugins

- Extend Slurm job launch with site-specific security policies
- Examples: enforce job isolation, restrict env vars, audit logging
    - github.com/BYUHPC/oodproxy

DOS & Abuse Prevention

- Rate-limit per-user RPC
- Limit number of jobs a user can submit
- Prevent sbatch fork-bombs

```
#slurm.conf
SlurmctldParameters=rl_enable
```

Staying Secure with Slurm

- Watch SchedMD advisories for CVEs
- Paid customers get early advisories
- Patch early, test often
- Security is an ongoing process

Putting It All Together

- TLS + certmgr -> encrypted daemon comms
- MCS + containers + hidepid -> isolate jobs and processes
- PAM + SPANK -> enforce user/job controls
- Prolog/Epilog sanitization -> clean nodes securely
- PrivateData + auditing -> protect accounting
- Network firewalls + VLANs + fabric keys -> protect backplane
- Fairshare enforcement and rate limiting RPC -> prevent abuse

Q & A

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