Lustre* Security Today and in the Future

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Lustre* security infrastructure has had some gaps

Uses standard POSIX file access control at filesystem level, like NFS

Has not previously had strong user or client authentication at the server

- Depends on network access control - address filtering or physical isolation
- Clients are trusted to provide accurate user identification

But... multiple industries require strict access controls to sensitive data

- Protected and personally-identifiable health information
- Classified data segregated based on multiple classification levels

New security capabilities are emerging

Existing and new security-related features are becoming available

- SELinux file labeling and Mandatory Access Control
- Nodemaps to classify clients by their NID with UID/GID maps per nodemap
- GSS/Kerberos node and user authentication and network encryption
- GSS/Shared Secret Key node authentication and network encryption
- Namespace subdirectory mounts

Security Component Overview

Authentication: Identification of an entity or principal

- *“I am who I say I am”* - e.g. Kerberos, SSK

Authorization: Grant access rights to an asset for authenticated principal

- *“I’m allowed to connect to this service”* – e.g. Kerberos, SSK
- *“I’m allowed to access these files”* – e.g. SELinux, UNIX permissions

Encryption: Help protect information from unauthorized interception

- *"I can safely communicate over this untrusted network"* - e.g. Kerberos, SSK

SELinux - Community 2.8, Enterprise Edition 3.0

Label files and enforce security policy based on process context

- Access enforced by kernel, users can't change policy
- Allow SELinux labels and policies to be set for all files
- Label stored in xattr, client open fetches label, caches it
- Allows enabling enforcement (MLS, RBAC) on *clients*

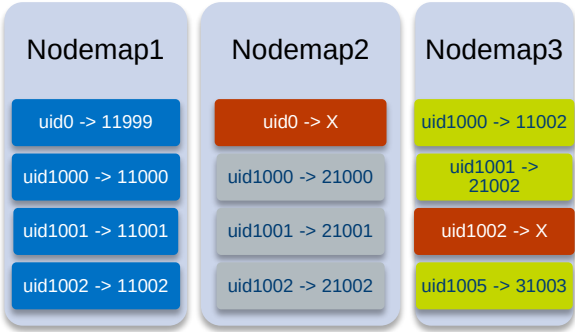
Limitations of current implementation

- No SELinux enforcement by *server* processes yet
  - Root compromise on client could disable SELinux
  - This is a significant problem beyond the scope of Lustre
  - Allow only trusted clients to connect using **Kerberos** or **SSK**
- Certification test cases not public, tied to specific hardware/software config

UID/GID Mapping - Community 2.8/2.9

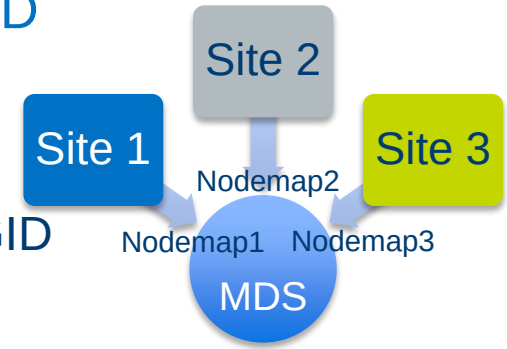
Identify clients from different administrative domains

- Group clients by NID into a *nodemap* on MDS/OSS
- Administrator sets *uidmap/gidmap* for each nodemap
- Link client to a specific nodemap at connection time



MDS and OSS map client's UID/GIDs to server UID/GID

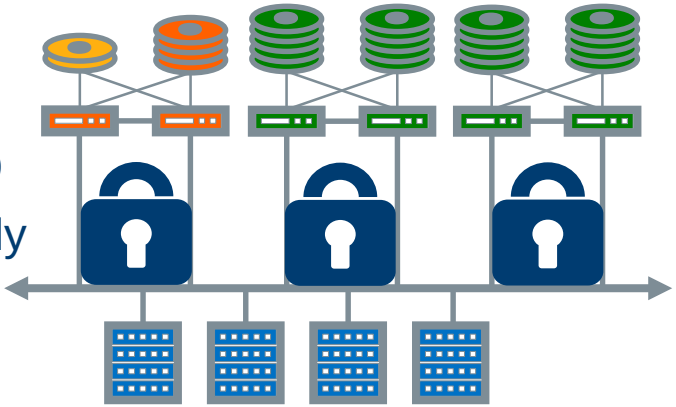
- UID/GID authentication on MDS, quota on MDSs/OSSs
- Map client root to non-0 UID or squash it, per nodemap
- Map unknown UID/GIDs to per-nodemap squash UID/GID
- Or reject access from unknown UID/GIDs completely
  - Only clients from that site can access owned by them



GSS/Kerberos and GSS/Shared Secret Keys

Different approaches for achieving similar goals

Kerberos - Community Edition 2.8, Intel® EE 3.0



- Authentication for nodes, and for users on the MDS
- Well known protocol, effective, but complex to setup
- Cross-realm authentication hard technically/politically

IU SSK - scheduled for Community Edition 2.9

- Self-contained in Lustre, easier to configure
- Crypto keys associated with a nodemap, positively identify clients
- Configure different keys for client/subnet/site, replace separately
- Uses kernel high-performance CPU offload of crypto calculations

Intel® Cloud Edition can use IPSec on TCP, but not with IB/OPA RDMA

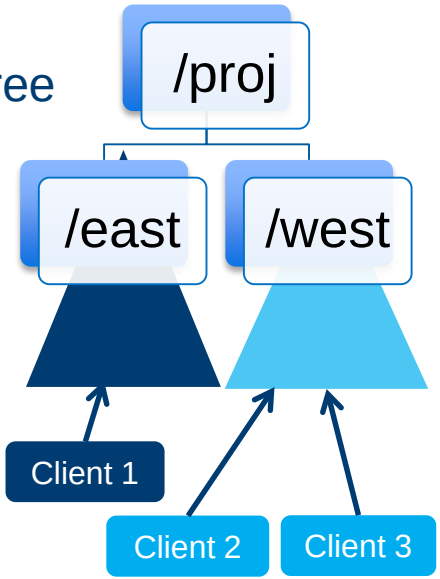
Subdirectory mounts/filesets - Community 2.9

Mount subdirectory of filesystem from MDS

- `mount -t lustre mgsname:/fsname/subdir /mnt/point`
- Client receives FID of subdir as root directory for mountpoint
- `.lustre` pseudo-directory not in subdirectory mount
- Client cannot look up names (`fid2path`) outside directory tree
- Clients normally share MDS and OSS resources
  - Unless admin isolates subtree to a dedicated DNE MDT

Not in itself a security feature, but can part of one

- Linked to nodemaps and secure client authentication
- Can provide isolated containers to identified clients



Security benefits of open development and review

All listed features openly developed and reviewed on *master* branch

- This leverages skills and perspectives from different organizations
- Increases pool of reviewers, more likely to find bugs
- Enhancements can target a wider variety of deployment scenarios

Good participation from multiple organizations

- UID/GID mapping, SSK design and code reviewed by several parties
- Testing of Kerberos and SELinux code by multiple vendors
- Review of Shared Key Crypto by Intel® internal security team ongoing

Growing developer community adds resources, interest, enhancements

Ongoing hardening of Lustre* code

Static analysis of entire code base for potential defects

- Several different tools being used - Coverity*, smatch, clang, and others
- Each one checks for different potential defects and security issues
- Some run on every patch, others run periodically on whole tree

Testing with fault injection to harden error handling paths and recovery

- Memory allocation errors, network message delay/loss

Dead code cleanup and simplification while adding several new features

- Fewer LOC = fewer defects, easier to understand and find higher-level bugs
- 2.5.0 to 2.8.0: 286k insertions - 257k deletions = net growth only +30kLOC

What is on the horizon?

Combining these features allows powerful new functionality

- Some final integration needed before they all work together seamlessly

Isolated subdirectory exports to clients => sub-filesystem containers

- Client auth + nodemap + subdir mount + rejection of unknown UID/GIDs
- SELinux + client auth to segregate files with different classification levels
- Allows multi-tenant cloud hosting, virtual environments, classified data

Need feedback from users and deployments for future directions

- Client-side data compression + encryption?
  - Per-user keys, secure on disk, safe erase, less overhead on server
- Need specific security threat model to determine gaps and priorities

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