A lightweight access control mechanism for Lustre in wide area domains

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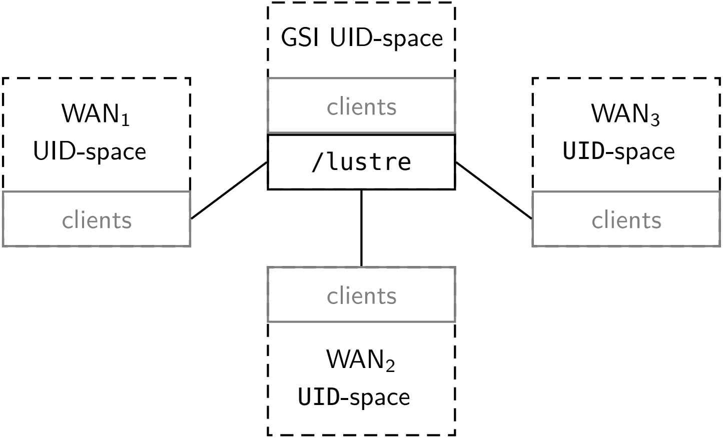
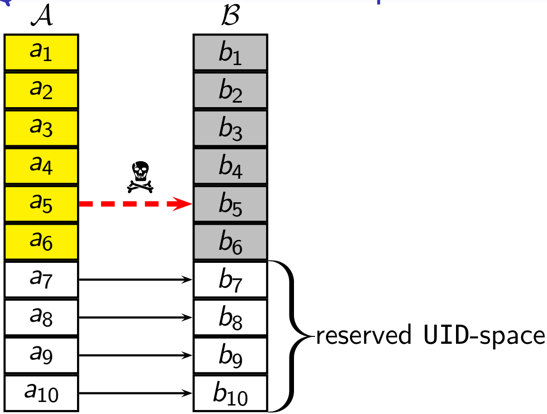
Motivation

Lustre employed in wide area networks (WAN) *can* result in UID/GID conflicts (overlaps) and thus in uncontrolled data modification and deletion.



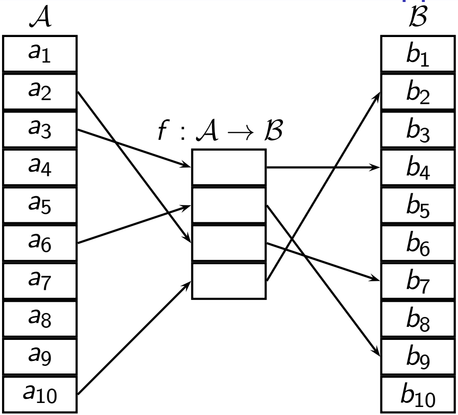
For the sake of simplicity GID is omitted here and in some remaining slides.

☠ Lustre Reserved UID-space Problem ☠



- Users of UID-space $\mathcal{A}$ access data in UID-space $\mathcal{B}$ under their UID of $\mathcal{A}$.
- Use reserved UID-space, *however* we have *no* mechanism to control whether reserved UID-space is truly employed.

Lustre UID Mapping (Problem)

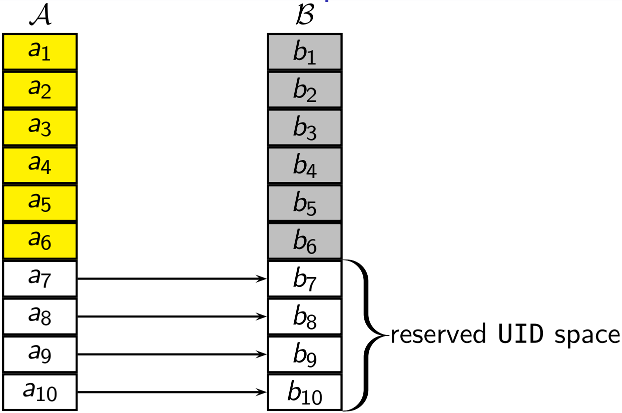


What happens when *frequently* users are deleted, added, etc. and the mapping is not updated (keep synchronized)?

Suppose each domain $\mathcal{A}, \mathcal{C}, \mathcal{D}, \ldots$ have ≥ 1000 many Lustre users. We have to maintain in central domain (here $\mathcal{B}$) $|\mathcal{A}| + |\mathcal{C}| + |\mathcal{D}| + \ldots$ many mappings (e.g. $a_2 \mapsto b_7, a_6 \mapsto b_9, \ldots$).

- This can be problematic in large scale environments.

Lustre Reserved `UID`-space Access Control



Control data access *directly* in Lustre MDT-Layer based on:

- Network address (range) e.g. 10.[1-8].1.[1-128]
- Network type e.g. `tcp0` or `ib0`

Lustre Network Ident.

- `UID`/`GID` (range) e.g. [0-32000] [100-500]

Lustre Reserved UID-space Access Control (cont.)

- Do not have to specify a mapping for every single UID and GID. Use ranges e.g. [40000-50000].
- Enforce that UID's and GID's of reserved space are taken only.

Summary: Access control based on:

- Network address,
- Network type,
- UID, GID

For realizing this approach a Lustre kernel module called LustreUserGroupAccessControl (short `lugac.ko`) is developed.

LUGAC Kernel Module Usage

Load/unload module (is automatically loaded by mdt.ko dependency):

```
>insmod ./lugac.ko
[12778.295442] GSI Lustre UID/GID access control module lugac.ko version 0.3beta loaded
>rmmod lugac
[12793.754416] GSI Lustre UID/GID access control module lugac.ko version 0.3beta unloaded
```

Write rules:

```
>echo "192.168.[67-70].[1-16]@tcp0 [500-600] 1012" > /proc/lugac
>echo "10.10.1.1@tcp5 [100-200] [100-200]" > /proc/lugac
```

Read rules:

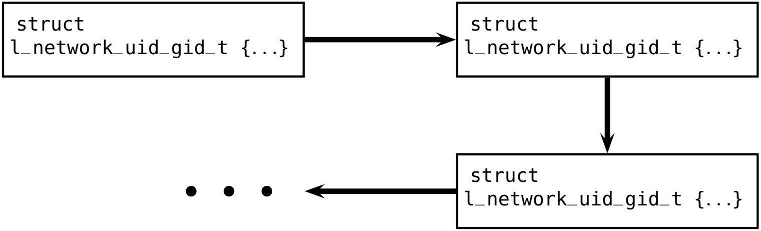
```
>cat /proc/lugac
[13297.755041] Listing GSI Lustre UID/GID access rules:
[13297.755049] 10.10.1.1@tcp5 [100-200] [100-200]
[13297.755059] 192.168.[67-70].[1-16]@tcp0 [500-600] 1012
```

Flush (delete) all rules:

```
>echo "flush" > /proc/lugac
[13402.185049] Deleting all GSI Lustre UID/GID rules.
>cat /proc/lugac
Listing GSI Lustre UID/GID access rules:
```

LUGAC Kernel Module Details

- Access control information are represented as `C structs` and stored as nodes in a linked-list. Linux kernel provides linked-list data-structure for "free" (see `#include <linux/list.h>`).



struct l_network_uid_gid_t {...}
struct l_network_uid_gid_t {...}
struct l_network_uid_gid_t {...}
• • •

```
typedef struct {
        gid_t from;
        gid_t to;
} gid_interval_t;
```

```
struct l_network_uid_gid_t {
        l_network_t l_network;
        uid_interval_t uid_iv;
        gid_interval_t gid_iv;
        struct list_head next; };
```

LUGAC Kernel Module Details (cont.)

Kernel module `lugac.ko`

- parses input strings via `/proc/lugac` and sets fields in `struct l_network_uid_gid_t`,
- iterates over linked-list and outputs fields in `struct l_network_uid_gid_t` (`cat /proc/lugac`),
- adds `struct l_network_uid_gid_t` into linked-list,
- deletes `struct l_network_uid_gid_t` from linked-list,
- exports a function (`allow_access_nugid`) which tells whether:
  - Network address,
  - Network type,
  - `UID`, `GID`

  is a member (of the interval/range) of the linked list.
- is documented with doxygen lugac_module.c#doxygen

LUGAC Kernel Module Integration into Lustre

Only tiny patches in MDT-Layer are required, e.g.

```
/* lustre/mdt/mdt_open.c */
int mdt_reint_open(struct mdt_thread_info *info, struct mdt_lock_handle *lhc)
{
    ...
    /* Lugac access control based on nid, uid and gid. */
    if (!allow_access_nugid(libcfs_nid2str(mdt_info_req(info)->rq_peer.nid),
                            uc->uc_uid, uc->uc_gid)) {
             CDEBUG(D_INFO, "Deny access for %s, uid: %d, gid: %d due to
                             missing entry in access control list\n",
                    libcfs_nid2str(mdt_info_req(info)->rq_peer.nid), uc->uc_uid, uc->uc_gid);
             GOTO(out, result = -EPERM);
    }
    ...
}
```

```
/* lustre/mdt/mdt_reint.c */
static int mdt_md_create(struct mdt_thread_info *info)
{
    ...
    /* Lugac access control based on nid, uid and gid. */
    if (!allow_access_nugid(libcfs_nid2str(mdt_info_req(info)->rq_peer.nid),
                            uc->uc_uid, uc->uc_gid)) {
             CDEBUG(D_INFO, "Deny access for %s, uid: %d, gid: %d due to
                             missing entry in access control list\n",
                    libcfs_nid2str(mdt_info_req(info)->rq_peer.nid), uc->uc_uid, uc->uc_gid);
             GOTO(out_put_parent, rc = -EPERM);
    }
    ...
}
```

See http://www.stibor.net/lugac/ for documentation and more details.

Other Approaches (UID Mapping)

- *Enabling Lustre WAN for Production Use on the TeraGrid: A Lightweight UID Mapping Scheme*, Joshua Walgenbach et al., TeraGrid 2010. For Lustre 1.6.x to 1.8.x. (see https://projectlava.xyratex.com/show_bug.cgi?id=13479).
- An extended version will be available in Lustre 2.6.0 (see also LAD'13 *Developing UID Mapping and a Stand Alone Security Mechanism for Lustre: Challenges and Successes*).

Other Approaches (Kerberos Realm Mapping)

- [1] *Kerberized Lustre 2.0 over the WAN*, Josephine Palencia et al., TeraGrid 2010.
- [2] *Using Kerberized Lustre Over the WAN for High Energy Physics Data*, Josephine Palencia et al., XSEDE 2012.

In Lustre code:

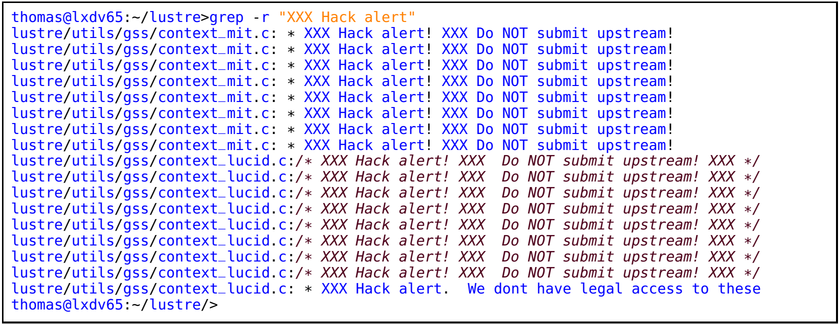
```
lustre/utils/gss/lsupport.h:#define MAPPING_DATABASE_FILE "/etc/lustre/idmap.conf"
```

```
/* lustre/utils/gss/lsupport.c */
static int read_mapping_db(void)
{
    char princ[MAX_LINE_LEN];
    char nid_str[MAX_LINE_LEN];
    char dest[MAX_LINE_LEN];
    char linebuf[MAX_LINE_LEN];
    char *line;
    lnet_nid_t nid;
    uid_t dest_uid;
    FILE *f;
    ...
    /* copernicus@ANDROMEDA.GALAXY 10.67.75.100@o2ib 1001 */
    if (sscanf(line, "%s %s %s", princ, nid_str, dest) != 3) {
                        printerr(0, "mapping db: syntax error\n");
                        continue;
    }
    ...
```

See userland tool lustre/utils/gss/l_idmap.c

Other Approaches (Kerberos Realm Mapping) Problems

1) Lustre Kerberos code needs to be cleaned up and improved:



```
thomas@lxdv65:~/lustre>grep -r "XXX Hack alert"
lustre/utils/gss/context_mit.c: * XXX Hack alert! XXX Do NOT submit upstream!
lustre/utils/gss/context_mit.c: * XXX Hack alert! XXX Do NOT submit upstream!
lustre/utils/gss/context_mit.c: * XXX Hack alert! XXX Do NOT submit upstream!
lustre/utils/gss/context_mit.c: * XXX Hack alert! XXX Do NOT submit upstream!
lustre/utils/gss/context_mit.c: * XXX Hack alert! XXX Do NOT submit upstream!
lustre/utils/gss/context_mit.c: * XXX Hack alert! XXX Do NOT submit upstream!
lustre/utils/gss/context_mit.c: * XXX Hack alert! XXX Do NOT submit upstream!
lustre/utils/gss/context_mit.c: * XXX Hack alert! XXX Do NOT submit upstream!
lustre/utils/gss/context_lucid.c:/* XXX Hack alert! XXX  Do NOT submit upstream! XXX */
lustre/utils/gss/context_lucid.c:/* XXX Hack alert! XXX  Do NOT submit upstream! XXX */
lustre/utils/gss/context_lucid.c:/* XXX Hack alert! XXX  Do NOT submit upstream! XXX */
lustre/utils/gss/context_lucid.c:/* XXX Hack alert! XXX  Do NOT submit upstream! XXX */
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lustre/utils/gss/context_lucid.c:/* XXX Hack alert! XXX  Do NOT submit upstream! XXX */
lustre/utils/gss/context_lucid.c:/* XXX Hack alert! XXX  Do NOT submit upstream! XXX */
lustre/utils/gss/context_lucid.c: * XXX Hack alert.  We dont have legal access to these
thomas@lxdv65:~/lustre/>
```

2) With hardware accelerated crypto instruction set (such as AES-NI) Lustre Kerberos bottlenecks cf. [1,2] can be attacked.

Summary

A lightweight access control mechanism for Lustre in wide area domains based on

- Network address,
- Network type,
- `UID`, `GID`

is developed.

Drawbacks, constraints and improvements:

- Force WAN domains to use predefined UID/GID spaces,
- From perspective of information security (plain IP) not secure (use IP-Sec as underlying protocol for securing IP).
- Employ efficient data-structures such as red-black trees (`#include <linux/rbtree.h>`) or hashing functions.
- Integrate `/proc/lugac` into proper Lustre `proc` namespace.

Outlook

Demand for employing Lustre in WAN is growing!

My personal view to tackle this demand: Cleanup Kerberos code to supply:

- Strong authentication and encryption by means of Kerberos.
- Kerberos Cross Realm UID/GID mapping and UID/GID access control.

Thank you & Questions?