Implementing an access matrix

There is too much information required in an access matrix.

We have cells for every combination of domains and objects.

We could implement it as a sparse matrix but most OSs use one of two possible representations (and sometimes a mixture of both).

- Only hold information on the rows – each row corresponds to the access rights of a domain over all objects it can use. If the domain has no rights over an object no information is stored. This approach is known as *capability lists*.
- Only hold information on the columns – each column represents the access rights held over this object. No information is stored about domains that have no access. This approach is known as *access lists*.

Confused Deputy Problem

This is connected with the changing domains problem from last lecture.

A deputy is a process with special access rights to objects. e.g., the Unix `passwd` program has access to the password files.

Another process has access to the deputy. e.g., you can change your own password.

The process asks the deputy to do something for it. e.g., change someone else's password

The deputy can do this but should it?

If the deputy doesn't check we have a security hole.

Capabilities remove this hole.

Capabilities

A capability is a permission to access an object in certain ways.

Capabilities are stored with domains. They always refer to the object and the access rights.

So a domain has a capability list.

<f1, “read,write”>

<f2, “execute”>

<d2, “control”>

When a process needs to access a protected resource the capability is passed with the request. The capability is checked by the reference monitor to make sure the access is permitted.

We need to ensure that a process executing in a domain cannot freely change any of its capabilities.

The capability list is itself a protected object.

Keeping capabilities safe

How do we stop a process altering its capabilities?

In particular we don’t want a process making new capabilities without strict controls.

So capabilities should not be forgeable.

We can use hardware or encryption.

On a single machine we can store all capabilities in protected kernel memory (so that the user level process cannot directly access them or add to them).

Tagged architectures – some machines have extra bits for every word in memory. Thus integers can be distinguished from strings from floats from capabilities. Only the OS is allowed to create or change capabilities.

With distributed systems we need to encrypt capabilities. With a public key anyone can check them but they cannot be created.

Use of capabilities

Regardless of how they are protected – capabilities must only be created by the OS.

When a new object is created the OS should construct an owner capability for the creator process.

Usually the owner can pass the capability on to other processes (or domains).

Like a secure password – secure because the capability cannot be forged or altered.

We must also ensure that capabilities can't be snooped off the network.

Capabilities are now widely used – many microkernel OSs (like Mach) use capabilities.

Kerberos tickets are capabilities.

Problems with capabilities

- It is difficult to determine which domains have access rights to a given object.
  - not only are the capabilities associated with domains but they can also be passed on – keeping track of them is a problem.
- Similarly because it is difficult to find references to all domains with particular capabilities it is difficult to revoke access permissions.

Revoking capabilities

- keep track of all domains with the capability (made difficult if they have the capability to pass on capabilitites)
- indirection – the capability is not really to the object but to an intermediate object which points to the object (we change the pointer to null). All domains with the old capability no longer have access.
- reacquisition - have an expiry time and then request the capability again. (In this case we need another way of determining if the capability should be given.)

Access Control Lists

Each object has a list of domains and their access rights. This list is an ACL.

An access control list (ACL) could look like:

<d1, "read,write">
<d2, "execute">
<d3, "control">

When a request comes to the object from a specific domain for a particular access the reference monitor checks the ACL to see if the access is allowed.

ACLs don't have any revocation problems. The ACL just gets changed.

AFS vs NTFS ACLs

AFS uses ACLs for its access permissions. But these are only on directories. It has a number of possible permissions:

Flag	Rights per user or group in ACL
`r`	open and read a file or directory contents
`l`	lookup within a directory
`w`	open and write a file
`i`	insert files in a directory
`d`	delete a file or directory
`a`	modify attributes including rename
`k`	lock files

There are also shorthand forms:
write = `rlwidk` read = `rl` all = `rlwidak`

NTFS - it is possible to access a file even if you don't have the directory permissions.

Flag	Files	Directories
`R`	read contents	read contents
`W`	modify contents	modify contents
`X`	execute	can cd to
`D`	delete	delete
`P`	permissions change	perm. change
`O`	ownership change	ownership change

Checking your ACLs

OSs that support ACLs provide tools to deal with them e.g. `getfacl/setfacl`

NT has `cacls`

```
>cacls profile

C:\Documents and Settings\...\system
   \profile

   BUILTIN\Users:R

   EC\rshe019:F

   NT AUTHORITY\SYSTEM:F

   BUILTIN\Administrators:F
```

F – means full access.

Problems with ACLs

They slow down file search operations – all ACLs (which can be long) have to be checked for all directories.

AFS imposes a limit, commonly set to 20.

They are considered by some as unnecessarily complex:

"Ironically, for all the flexibility that ACLs offer, they have proven to be confusing and difficult to understand, and the extra functionality they provide is dwarfed by the feeling of dread which they instill in administrators and users alike." – Mark Burgess, *Principles of Network and System Administration*

Many prefer the simplicity of Unix file protection mechanism.

Reducing information

We still have the problem with lots of permission information in our systems.

Both ACL and capability systems can have default access to objects to reduce the amount of necessary information.

ACLs (with hierarchical objects, such as files) can inherit permissions from objects above them.

A capability to a directory could give you access to all files in the directory.

This is less flexible. What if we want to put a hidden file in the directory which we don't want accessed?

UNIX permissions

UNIX associates permission bits with every file.

read/write/execute bits for files associated with the files owner, the group and everyone

You can change the permission code of a file or directory only if you own it or if you have superuser authority.

The permissions are:

- `r` Read permission.
- `w` Write permission.
- `x` Execute permission for files, search permission for directories.
- `X` Execute permission only if file is a directory or at least one execute bit is set.
- `s` Set-user-ID or set-group-ID permission.

There is also a sticky bit – `t` permission but this depends on the version of UNIX.

Remember that the permissions for owner, group and everyone are checked in that order. So what permissions do I have on this file?

```
-r---w-rwx   1 robert-s staff      program
```

Adding levels to Unix like systems

The OS is divided into separate domains.

- kernel
- system and user applications

applications are separate from each other

Each domain only has the minimum permissions (on files, sockets, directories) it needs to do its job.

Each domain has limited access to system calls and file types (e.g. httpd_t)

Use a strict file typing system.

There is no global superuser.

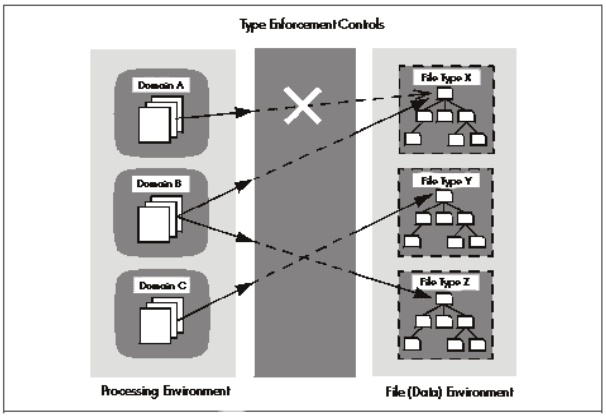
Each domain has its own administrator and the administrator of one domain has no power over another.

So how is global administration done?

The system is restarted with a different administration kernel (without any connections to networks)

Domains & types

The checking of access is built-in to the kernel and cannot be circumvented.



SELinux

Security Enhanced Linux

Mandatory Access Control (MAC) to all objects represented by the file system (including processes)

Extended attributes associated with each file (device etc). Stored in the inode.

Policies are represented by policy files.

Policies are a set of rules governing things such as the roles a user has access to; which roles can enter which domains and which domains can access which types.

Particular roles can be associated with servers. This way if one role gets compromised it only affects its domains and types.

Normal Unix permission bits are checked first and then SELinux checks.

Before next time

Read from the textbook

15.2.4 – Stack and Buffer Overflow

15.4 – Cryptography as a Security Tool

If you want an extra introduction on cryptography and other security matters (not necessary for the course) try *Computer Security*, Dieter Gollmann, Wiley, 1999.

15.1 – The Security Problem

15.5 - User Authentication