Mac OS X Security Framework

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http://www.occam.com/osx/
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I'm assuming basic familiarity with UNIX operating system design

Where I'm coming from:

- UNIX user and some-time admin since 1990
- Full-time UNIX admin since 1995
- NeXTstep/OS X user and admin since 1991

This presentation primarily covers Mac OS X 10.3.2
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Overview

- Provides infrastructure for security-related functionality to Mac OS X apps
  - Privileged access, encryption, certificate handling, password storage, etc.

Examples

- Login Window uses the framework to authenticate graphical logins
- Installer and Software Update verify permission to install software
- Finder permits superuser-level access
- Disk Copy creates encrypted disk images
- Apple Mail Server supports SSL connections
- Keychain Access is entirely dependent on the Security framework
Security framework and associated components
Overview

What is a Mac OS X framework?

Like a versioned shared library, encapsulated with resources in a structured directory with a .framework extension (a "bundle")

Resources include headers, images, NIBs, property lists, etc.

[Show framework]

Panther (Mac OS X 10.3) splits Security framework into more pieces

/System/Library/Frameworks/Security.framework provides the bulk of the API (in C)

/System/Library/Frameworks/SecurityFoundation.framework provides an abstracted Objective-C API to Authorization Services

/System/Library/Frameworks/SecurityInterface.framework and /System/Library/PrivateFrameworks/SecurityHICocoa.framework provide Obj-C APIs for GUI elements
Daemons

- Introduction
- Security Server
- Security Agent
Every app linked to the Security framework maintains its own instance of the framework in its address space.

Think of the large box in the Security framework diagram as the address space of a single process.

To put distance between apps and sensitive data, external daemons handle most passwords and private keys.

Daemon executables located in `/System/Library/CoreServices/`
The Security Server processes authorization requests, stores keys in memory, performs cryptographic computations on keys, evaluates ACLs in keychains, and manages keychain master keys.

**Executable is named** SecurityServer

**Started by** SecurityServer startup item (in /System/Library/StartupItems/)

**Contacted via a privileged Mach IPC port, providing some assurance that processes are talking to the right daemon when making sensitive requests.**
The Security Agent handles user interaction, acquiring user secrets (passwords, biometric data, smart card keys, etc.), thus further separating such data from the app requesting access.

Executable is named SecurityAgent.

When the Security Server requires user interaction, it launches a Security Agent running under the user's UID.

The Agent remains to handle further requests until the user logs out.

Interacts with user via onscreen dialogs.

Any Security framework requests are sent to the user at the graphical console, even if the request came from another user's process.

If no one is logged into the console, requests automatically fail.

Darwin, lacking Aqua GUI, doesn't include the Security Agent, and many Security framework capabilities don't work with Darwin.
Authorization Services

- Introduction
- Policy Database
- Sequence of Events
- AuthorizationExecuteWithPrivileges
- Command-Line Tools
Authorization Services enables programs to determine whether a user should be permitted to take certain actions.

This is what give members of group `admin` much of their privileged access.

Kind of like `sudo`, but primarily intended for GUI functions.

[Examples: System Preferences, Finder]

An action is associated with an authorization `right`, configured in a `policy database`.
The policy database is an XML file, /etc/authorization.

Fills a role analogous to *sudoers*, by defining authorization requirements.

Example entry in /etc/authorization, used by authopen:

```xml
<key>sys.openfile.</key>
<dict>
  <key>class</key>
  <string>user</string>
  <key>group</key>
  <string>admin</string>
  <key>mechanisms</key>
  <array>
    <string>builtin:authenticate</string>
  </array>
  <key>shared</key>
  <false/>
  <key>timeout</key>
  <integer>300</integer>
</dict>
```
After transformation into NeXT property list format with `/usr/bin/pl < /etc/authorization:

"sys.openfile." = {
    class = user;
    group = admin;
    mechanisms = ("builtin:authenticate");
    shared = 0;
    timeout = 300;
};

sys.openfile.: The name of the right

This is a wild card entry, indicated by the trailing dot

class: Requirement for successful authorization

The user class requires membership in a specified group

group: Users who authenticate as members of group admin satisfy the requirements for this right
Authorization

sys.openfile. (cont'd.)

- **mechanisms:** Actions taken to authorize
  - In this case, user authentication is performed

- **shared:** If true, other applications need not reauthorize (within the timeout period)
  - In this case, authorization credentials are not shared with other apps

- **timeout:** After the specified number of seconds since last acquisition of the right, the credentials cached by the Security Server are dropped, requiring reauthorization
  - A **timeout** of 0 means that reauthorization is never required
Another example, used by the Login Window application:

```plaintext
"system.login.console" = {
    class = "evaluate-mechanisms";
    mechanisms = (  
        "loginwindow_builtin:login",
        authinternal,
        "loginwindow_builtin:success",
        "builtin:getuserinfo",
        "builtin:sso"
    );
};
```

Requested by Login Window after bootup, causing the Security Server to start a Security Agent (running as root) to display the login dialog

Upon login, this Agent is killed

Class of `evaluate-mechanisms` causes Security Server to execute each of the routines listed for the `mechanisms` key

The `authinternal` mechanism creates a shared credential that negates the need for reauthentication by applications after logging in
Another example, used by PAM:

```
"system.login.tty" = {
    class = "evaluate-mechanisms";
    mechanisms = ("push_hints_to_context",authinternal);
};
```

Requested by the `pam_securityserver.so` module, referenced in several service config files in `/etc/pam.d/`

There is a `system.login.pam` right, which is unused (Huh?)

Thanks to this, successful password-based authentication through a PAM-enabled service results in the creation of a shared credential within the context of that service (SSH session, etc.)

Possible for remote logins due to `push_hints_to_context`, which forwards auth info to the Security Server, bypassing the Security Agent (which normally needs to put up a graphical dialog)

[Demonstrate using `authorize` and `sudo`]
Another example:

```
"system.login.screensaver" = {
    class = rule;
    rule = "authenticate-session-owner-or-admin";
};
```

The rule class uses an entry defined in the rules section of 
/etc/authorization to determine how authorization is performed

Rules offer reusable collections of values

```
"authenticate-session-owner-or-admin" = {
    "allow-root" = 0;
    class = user;
    group = admin;
    mechanisms = ("builtin: authenticate");
    "session-owner" = 1;
    shared = 0;
};
```

- `allow-root`: If true, user logged in as root requires to authentication
- `session-owner`: Right granted by successful authentication as user whose GUI session is up on the system's console
Default entry applies when requested right doesn't match any other entry:

```
"" = {
    class = rule;
    rule = default;
};
```

The default rule produces a shared credential if a person can authenticate as an administrative user, which times out in 5 minutes:

```
default = {
    class = user;
    group = admin;
    mechanisms = ("builtin: authenticate");
    shared = 1;
    timeout = 300;
};
```
Changes to `/etc/authorization` take effect on the fly, no signaling of SecurityServer required (unlike syslogd, xinetd, etc.)

[Show `/etc/authorization`, processed through `/usr/bin/pl`]

Naming conventions

Most rights prefixed by `system`, indicating they're provided with the OS

Entries by third parties are encouraged to follow a convention like that used for Java classes: reversed DNS domain name associated with the organization, followed by segments describing the right (e.g., `com.occam.syslog.reload`)
When an application requests authorization for an action (such as starting a network service from System Preferences), here's what happens:

1) The application uses the Authorization Services API to contact the Security Server, requesting a named right (like `system.preferences`)

2) The Security Server looks for the right in the policy database (`/etc/authorization`), and determines the requirements

3) If the right requires authentication, and the Security Server doesn't already possess cached credentials that can be shared with the application, it triggers the Security Agent

4) The Security Agent prompts the user logged into the console, then attempts to auth the user through the Directory Services framework

5) Directory Services reports success or failure, which is passed back through the Security Agent to the Security Server

6) The Security Server returns result to the application
The **AuthorizationExecuteWithPrivileges (AEWP)** routine lets a program specify an external command to be run with superuser privileges.

Command invoked by `/System/Library/CoreServices/AuthorizationTrampoline`, **which is setuid root**

Access to **AEWP** controlled by `system.privilege.admin` right in `/etc/authorization`, **and is thus limited to root and to those in the admin group**

Since granting an app full superuser privileges to run an arbitrary command opens the possibility of a security hole, Apple warns against use in its developer documentation.

Used by some software, such as installers that set the `setuid` bit on binaries that copy files to restricted areas.

Be sure you trust software that asks you to authorize a privileged action.
/usr/libexec/authopen

- Lets authorized users read and write files to which they wouldn't normally have access

Example:

```
nidump group . | authopen -w /etc/group
```

- Request made for `sys.openfile./private/etc/group` right

- Note symlink resolution

- If authorization successful, text from standard input replaces contents of `/etc/group`

- Man page contains more details
authorize

Available from http://www.occam.com/tools/

Takes name of right as argument, returns result of authorization attempt

Not really intended for high-security uses

Opportunity for malicious interference in exchange of information between authorize and tool invoking it

Better to include calls to Authorization Services in same code performing privileged actions, rather than calling an external authorization tool

sudo is more flexible for CLI uses than authorize

Mainly intended to demonstrate how /etc/authorization works

Could also be useful for casual authorization scenarios
authorize.c

#include <stdlib.h>
#include <Security/Authorization.h>

int main(int argc, char *argv[]) {
    char *commandName = argv[0];
    char *rightName;

    if (argc == 2)
        rightName = argv[1];
    else {
        fprintf(stderr, "usage: %s
authorization_right_name\n", commandName);
        exit(EXIT_FAILURE);
    }

    OSSStatus status;
    AuthorizationItem right = { rightName, 0, NULL, 0 };
    AuthorizationRights rightSet = { 1, &right };
    AuthorizationFlags flags = kAuthorizationFlagDefaults |
        kAuthorizationFlagExtendRights |
        kAuthorizationFlagInteractionAllowed;
authorize.c (cont'd.)

status = AuthorizationCreate(&rightSet, 
    kAuthorizationEmptyEnvironment, flags, NULL);

if (status == errAuthorizationSuccess) {
    fprintf(stdout, "success\n");
    exit(EXIT_SUCCESS);
} else {
    fprintf(stdout, "failure\n");
    exit(EXIT_FAILURE);
}

Compile with cc -framework Security -o authorize authorize.c
Common Data Security Architecture

- Introduction
- Modules
- System Services
- STOS Projects
The Common Data Security Architecture (CDSA) is a standard originally developed by Intel, and now promoted by The Open Group.

Apple has implemented it as part of the Mac OS X Security framework.

Nearly all of it part of open-source Darwin project.

At the base are plug-in modules of various types.

Access to module functionality is through the Common Security Services Manager (CSSM) API, the centerpiece of the CDSA.
CSP (Cryptographic Service Provider): Random number generation, encryption/decryption, key generation, hashes, digital signatures

Symmetric encryption algorithms: ASC (Apple Secure Compression), RC2, RC4, RC5, DES, 3DES, AES/Rijndael

Asymmetric encryption algorithms: FEE (NeXT's Fast Elliptic Encryption), RSA, DSA, Diffie–Hellman

Message digesting algorithms: MD2, MD5, SHA–1

Pseudo–random number generation algorithm: Yarrow

DL (Data Library): File–based storage of certificates, keys, etc.

CSP/DL: Manages keychains

X509CL (Certificate Library): Manages X.509 certificates in memory

X509TP (Trust Policy): Determines validity of X.509 certs
Atop the CSSM, Apple provides higher-level APIs as part of the Security framework

- Secure Transport: Implements SSL/TLS
  - Offers cleaner integration and abstraction for developers, and possibly greater performance, but OpenSSL is more familiar and cross-platform
- Certificate, Key, and Trust Services: Manages certs and public keys
- Keychain Services: Programmatic interface to keychains

Several projects involving Apple's CDSA implementation:

- Apache SSL module using CDSA instead of OpenSSL
- PGP implementation using CDSA
- OpenSSH on CDSA
Keychains

- Introduction
- Keychain Contents
- Sequence of Events
- Keychain Files
- Tools
A keychain is a file containing keys, certificates, passwords, and other secured data.

Contents are encrypted, protected by an access password.

Convenience: a single password unlocks access to a multitude of passwords used for web sites, mail servers, file shares, etc.

Makes it practical to use unique, well-chosen passwords for each...
Keychains contain three kinds of objects: keys, access control lists (ACLs), and other items.

Storage and access of objects in keychains is done by the AppleCSPDL module, via Keychain Services and the CSSM.

Each key in the keychain has an ACL, processed by the Security Server, which determines which applications can access it, and how.

An app is identified by a hash of the invariant parts of the app binary.

Thus, application access to keys must be re-established after a software update.

Provides reasonable assurance that app is the same as when the user gave it permission to access a key.

Only way to modify ACLs is by user direction through a Security Agent, and the Security Server will only accept ACL changes from an Agent that it has started.
Keychain items you see in Keychain Access aren't actually keys

Each item (password, secure note, etc.) is stored in the keychain, and encrypted with its own key, which is also stored in the keychain

ACLs are applied to per-item encryption keys, but they're made to look as if they're properties of the items the keys protect

A master signing key is used to sign the per-item keys and their ACLs

Per-item keys and the master signing key are themselves encrypted with a master key

ACLs can't be encrypted, since they're needed to determine whether access to encrypted keys should be permitted

The master key is encrypted with the keychain password

The master key and master signing key are also stored in the keychain, making the keychain file completely portable, requiring only the password to unlock its contents
Keychains

- Keychain items you see in Keychain Access aren't actually keys
  - Each item (password, secure note, etc.) is stored in the keychain, and encrypted with its own key, which is also stored in the keychain
  - ACLs are applied to per-item encryption keys, but they're made to look as if they're properties of the items the keys protect
- A master signing key is used to sign the per-item keys and their ACLs
- Per-item keys and the master signing key are themselves encrypted with a master key
- The master key is encrypted with the keychain password
- The master key and master signing key are also stored in the keychain, making the keychain file completely portable, requiring only the password to unlock its contents
Here's what happens when an app desires access to a keychain item:

1) App makes a request with Keychain Services, through the CSSM, which calls on the AppleCSPDL

2) If the default keychain is locked, AppleCSPDL retrieves the encrypted master key and hands it to the Security Server

3) The Security Server has a Security Agent prompt the user for the keychain password, which is passed back to the Security Server

4) The Security Server uses the password to decrypt the master key, then caches it in memory (A keychain is unlocked when the Security Server has its decrypted master key cached in memory.)

5) Once the keychain is unlocked, the AppleCSPDL retrieves the desired item, the item's encryption key, and the key's ACL, handing them to the Security Server
Accessing a keychain item (cont'd):

6) The Security Server verifies the signature on the key and ACL with the master signing key

7) If the signature checks out, the Security Server processes the ACL, resulting in denial, permission, or another prompt through the Security Agent

8) If access is permitted, the Security Server decrypts the keychain item and hands it to the AppleCSPDL, which passes it back up the software stack to the application

Note that the application process never sees the user's keychain password, nor any of the decrypted keys in the keychain
A keychain is created as `~/Library/Keychains/login.keychain` upon first login.

Keychain password same as login password, synced when changing login password through GUI.

If keychain and login passwords are the same, the keychain is automatically unlocked upon login.

The **login keychain** is also the initial **default keychain**, meaning that new items are added to it, and that it's the default argument for many of the security utility's commands.

On first boot, the **SecurityServer startup item** uses `systemkeychain` to create `/Library/Keychains/System.keychain`.

Also creates `/var/db/SystemKey`, which presumably contains a randomly generated keychain password.

Used by system processes running as **root** (daemons, boot processes).
Keychain Access is the primary UI for keychain management.

In the Settings dialog (under the Edit menu), you can set the keychain to lock after some idle timeout, and/or when the machine sleeps.

"Locking" means to have the Security Server throw away its cached copy of the keychain's decrypted master key.

You should consider lowering the idle timeout.

Keychain First Aid (under Window menu) meant to fix certain problems that can corrupt a keychain, but with certain setups in the past it has caused more damage than it repairs.

Run it in Verify mode, and try to fix things manually.

Password Assistant (under Edit->Change Password...->Details->i) can help choose strong password.

Keychain Status menu bar item provides convenient access to functions.
### Keychain Access

**Keychain: login (unlocked)**

<table>
<thead>
<tr>
<th>Name</th>
<th>Kind</th>
<th>Created</th>
<th>Modified</th>
</tr>
</thead>
<tbody>
<tr>
<td>AppleID</td>
<td>application password</td>
<td>10/2/03 12:44 PM</td>
<td>10/2/03 12:44 PM</td>
</tr>
<tr>
<td>Buddha</td>
<td>AppleShare password</td>
<td>Today, 10:50 PM</td>
<td>Today, 10:50 PM</td>
</tr>
<tr>
<td>iTools</td>
<td>.Mac password</td>
<td>10/2/03 12:44 PM</td>
<td>10/2/03 12:44 PM</td>
</tr>
<tr>
<td>occam.com webserver</td>
<td>private key</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Private Stuff</td>
<td>secure note</td>
<td>Today, 10:51 PM</td>
<td>Today, 10:51 PM</td>
</tr>
<tr>
<td>Safari Forms AutoFill</td>
<td>application password</td>
<td>10/2/03 10:15 PM</td>
<td>10/2/03 10:15 PM</td>
</tr>
<tr>
<td><a href="http://www.occam.com">www.occam.com</a></td>
<td>certificate</td>
<td>--</td>
<td>--</td>
</tr>
</tbody>
</table>

**www.occam.com**
Expires Wednesday, November 5, 2003 6:53:46 PM US/Pacific

When using this certificate: [Use System Settings]

**Fingerprints**

- **SHA1**: 67 81 80 58 D9 4E 45 70 43 D9 FA 5C 45 10 B0 4C D0 97 DD AC
- **MD5**: 6A 1A B0 FF 7F 4D B5 11 36 DB 0C E1 44 D7 B9 19

**Type**: X.509 v3 root certificate

**Version**: 3

**Serial Number**: 12 34 56 78
The `security` command can help manage keychains from the CLI

- `security list-keychains`
- `security lock-keychain keychain`
- `security show-keychain-info keychain`
- `security dump-keychain keychain`

See man page for more
Resources

- Web Sites
- Mailing Lists
- Books
Resources

Web Sites

- Security Framework developer documentation

- Apple CDSA site

- Intel CDSA site

- The Open Group CDSA site
  - [http://www.opengroup.org/security/l2-cdsa.htm](http://www.opengroup.org/security/l2-cdsa.htm)

- CDSA specification
Resources

Mailing Lists

apple-cdsa (Apple)


Very low traffic, mostly developers

MacOSX-admin (Omni Group)

http://www.omnigroup.com/developer/mailinglists/macosx-admin/

Moderate to heavy traffic
Mac OS X Panther in a Nutshell
  - Chuck Toporek, Chris Stone

Mac OS X Panther for Unix Geeks
  - Brian Jepson, Ernest E. Rothman

Both contain references for Security framework–related CLI commands
  (written by yours truly)