TSIT01 Computer Security
Föreläsning 8: Lösenordsglagring, Unix, Windows, Virtualisering

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Agenda

- Password storage
- Unix authentication
- Windows authentication
- Sandboxing via chroot
- Virtualization
Storing passwords

• When a system requires a password to login, the password must be stored in some way

• Danger: Somebody gets to see the password list

• Examples: LinkedIn security break in 2012 (100 million users affected)

• A growing concern, since passwords are used in apps, sites as well as e-mail
Password storage is a rapidly growing problem

- You can’t just store password in plain text!
- Solution: Don’t store the password $p$, store its hash $H(p)$
- When a password $p'$ is entered, compute $H(p')$ and compare with $H(p)$.
- For a secure hash function $H$, $p = p'$ implies $H(p) = H(p')$
- Danger: Dictionary / Rainbow tables
Hashing passwords is not enough

- Hashed can still reveal identical passwords

<table>
<thead>
<tr>
<th>User</th>
<th>Password Hash</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stephen</td>
<td>39e717cd3f5c4be78d97090c69f4e655</td>
</tr>
<tr>
<td>Lisa</td>
<td>f567c40623df407ba980bfad6dff5982</td>
</tr>
<tr>
<td>James</td>
<td>711f1f88006a48859616c3a5cbcc0377</td>
</tr>
<tr>
<td>Harry</td>
<td>fb74376102a049b9a7c5529784763c53</td>
</tr>
<tr>
<td>Sarah</td>
<td>39e717cd3f5c4be78d97090c69f4e655</td>
</tr>
</tbody>
</table>
Another weakness of hashed passwords

- For a given hash function, one can pre-compute common passwords
- This is a space-time tradeoff. More space = less time
Using a dictionary for attack

1. Prepare list of common words (i.e. English dictionary)
2. For each word $w$, compute $H(w)$
3. Store $w$ and $H(w)$
4. Now compare hashes with known hashes
Dictionary attacks are useful

- The size of a dictionary can be reduced with a rainbow table
- Main problem: Hashes are too predictable across users and systems
- Solution: Add a random, public, salt $s$ before hashing
- Password database contains $H(p|s)$ and $s$
- When checking an entered password $p'$, compute $H(p'|s)$ and compare with database
- Salt should be unique for every user
Hashing and salting

Password hashes are now unpredictable even when using common passwords
Things are looking better

How Dropbox securely stores your passwords

Devdatta Akhawe | September 21, 2016

It’s universally acknowledged that it’s a bad idea to store plain-text passwords. If a database containing plain-text passwords is compromised, user accounts are in immediate danger. For this reason, as early as 1976, the industry standardized on storing passwords using secure, one-way hashing mechanisms (starting with Unix Crypt). Unfortunately, while this prevents the direct reading of passwords in case of a compromise, all hashing mechanisms necessarily allow attackers

Dropbox published a very interesting blog post on their approach for storing passwords securely (read it!)
';--have i been pwned?

Check if you have an account that has been compromised in a data breach

etnoy@broach.se

Oh no — pwned!
Pwned on 3 breached sites and found 1 paste (subscribe to search sensitive breaches)

Notify me when I get pwned
Donate
**Dropbox:** In mid-2012, Dropbox suffered a data breach which exposed the stored credentials of tens of millions of their customers. In August 2016, they forced password resets for customers they believed may be at risk. A large volume of data totalling over 68 million records was subsequently traded online and included email addresses and salted hashes of passwords (half of them SHA1, half of them bcrypt).

**Compromised data:** Email addresses, Passwords

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**Last.fm:** In March 2012, the music website Last.fm was hacked and 43 million user accounts were exposed. Whilst Last.fm knew of an incident back in 2012, the scale of the hack was not known until the data was released publicly in September 2016. The breach included 37 million unique email addresses, usernames and passwords stored as unsalted MD5 hashes.

**Compromised data:** Email addresses, Passwords, Usernames, Website activity

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**Plex:** In July 2015, the discussion forum for Plex media centre was hacked and over 327k accounts exposed. The IP.Board forum included IP addresses and passwords stored as salted hashes using a weak implementation enabling many to be rapidly cracked.

**Compromised data:** Email addresses, IP addresses, Passwords, Usernames
Protecting yourself against password leaks

**Figure:** A password manager such as KeePass and LastPass generates strong, unique passwords for each site
Unix(es)

• Unix started out as a departure from the design philosophy of Multics
• Multics was very complex, Unix was meant to be simple
• Unix is not really used anymore . . .
• . . . but there are many Unix-based systems today
• GNU/Linux, OSX/iOS, Android, FreeBSD, OpenBSD . . .
• Most Unix-like systems inherit the access controls from traditional Unix
Environmental creep in Unix

- Unix was initially used by a small number of skilled and trustworthy people
- Security mechanisms were there to protect from mistakes, not adversaries
- The course books talks of a “success disaster”, where Unix became popular and had to be extended again and again
- Patching new holes is not a viable security method
- ...but over the years, Unix has improved its reputation
Unix(es)

- Most secure operating systems have a *security architecture*.
- Unix has a colorful history of versions.
- Generally needs a skilled admin.
- Unix systems are extensible and are very widely used, from small embedded devices to extremely large data centers.
Configuration in Unix

- System configuration resides in the `/etc` directory
- Much of the configuration is world-readable, but needs root privileges for writing
- Stored in a file hierarchy, not a database as such
- (although in modern Linux distributions there is a program database that registers what is installed)
Centralized configuration in Unix

- Networked Unix machines are often jointly administered
- User accounts can be administered in a central machine through Network Information Service (NIS or YP), Lightweight Directory Access Protocol (LDAP) or plain Kerberos
- Centralized file systems can be shared via Network File System (NFS)
- ...however each service often needs individual care
Principals in Unix

- Principals are users and groups, with a *user* or *group* identity (uid or gid)
- uid:s and gid:s are 32-bit numbers
- Some uid:s have special meanings, that may be different between systems (0=root)

/etc/passwd

```
username:password:UID:GID:ID string:home directory:login shell

root:x:0:0:root:/root:/bin/bash
mail:x:8:8:mail:/var/mail:/bin/sh
news:x:9:9:news:/var/spool/news:/bin/sh
uucp:x:10:10:uucp:/var/spool/uucp:/bin/sh
pulse:x:110:119:PulseAudio daemon,,,:/var/run/pulse:/bin/false
jonfo33:x:1000:1000:Jonathan Jogenfors,,,:/home/jonfo33:/bin/bash
```
Principal in Unix

/etc/passwd

username:password:UID:GID:ID string:home directory:login shell

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news:x:9:9:news:/var/spool/news:/bin/sh
uucp:x:10:10:uucp:/var/spool/uucp:/bin/sh
pulse:x:110:119:PulseAudio daemon,,,:/var/run/pulse:/bin/false
jonfo33:x:1000:1000:Jonathan Jogenfors,,,:/home/jonfo33:/bin/bash

- The username can (typically) be eight characters long, and is used for login
- Access control is via uid
## Principals in Unix

### /etc/passwd

<table>
<thead>
<tr>
<th>Username</th>
<th>Password</th>
<th>UID</th>
<th>GID</th>
<th>ID String</th>
<th>Home Directory</th>
<th>Login Shell</th>
</tr>
</thead>
<tbody>
<tr>
<td>root</td>
<td>x</td>
<td>0</td>
<td>0</td>
<td>root:</td>
<td>/root:/bin/bash</td>
<td></td>
</tr>
<tr>
<td>mail</td>
<td>x</td>
<td>8</td>
<td>8</td>
<td>mail:</td>
<td>/var/mail:/bin/sh</td>
<td></td>
</tr>
<tr>
<td>news</td>
<td>x</td>
<td>9</td>
<td>9</td>
<td>news:</td>
<td>/var/spool/news:/bin/sh</td>
<td></td>
</tr>
<tr>
<td>uucp</td>
<td>x</td>
<td>10</td>
<td>10</td>
<td>uucp:</td>
<td>/var/spool/uucp:/bin/sh</td>
<td></td>
</tr>
<tr>
<td>pulse</td>
<td>x</td>
<td>110</td>
<td>119</td>
<td>PulseAudio daemon,</td>
<td>/var/run/pulse:/bin/false</td>
<td></td>
</tr>
<tr>
<td>jonfo33</td>
<td>x</td>
<td>1000</td>
<td>1000</td>
<td>Jonathan Jogenfors,</td>
<td>/home/jonfo33:/bin/bash</td>
<td></td>
</tr>
</tbody>
</table>

- There is no distinction between uid:s on different systems
- ...so watch out when you mount removable disks
Authentication in Unix

- Standard user authentication is via password, but other methods are supported
- Modern Unix variants use hashed, salted passwords
- The `/etc/passwd` file is world-readable
- Passwords (hashes) are today stored somewhere more hidden
Authentication in Unix: The shadow file

- The shadow file contains the encrypted passwords
- Only readable by root, all other users have no permissions
- Specifies password change intervals and account expiry dates

/etc/shadow

root:$6$saltsalt$yeaRight:15642:0:99999:7:::
decamon:*:15453:0:99999:7:::
bin:*:15453:0:99999:7:::
sys:*:15453:0:99999:7:::
jonfo33:$6$sosalys$youthinkIputmypasswordhere:15642:0:99999:7:::
Group principals in Unix

- Groups have their own ids, gid, which is a number
- Users can belong to more groups than their primary group (user accounts lists them)
- Groups can have passwords, allowing users to directly associate with their permissions

/etc/group

```
group name:group password:GID:list of usernames
root:x:0:   
adm:x:4:jonfo33
news:x:9:  
lpadmin:x:109:jonfo33,janla64
jonfo33:x:1000:jonfo33
```
Special principals in Unix

- Are used for login, audit logging, I/O access, upgrading (system) programs, and so on
- root can do almost anything
- … including removing the “almost” in the last sentence
- … but cannot decrypt users’ password
- Others include daemon, bin, sys, games, man, lp, mail, news, uucp, backup, irc, gnats, nobody, syslog, avahi, pulse, speech-dispatcher, haldaemon, …
Subjects in Unix

- Subjects are processes
- Unix keeps track of active processes, each with a process id, pid
- Each process has a real uid/gid, inherited from the parent process
- Each process has an effective uid/gid, inherited from the parent process or the current file being executed (suid)
- A process can decide to drop privileges once started
Objects in Unix

- Objects are registered as (i)nodes in a tree
- A node can be a file, a directory or an I/O device, all visible in the “file” tree
- Owner/group is by uid/gid

<table>
<thead>
<tr>
<th>mode</th>
<th>File type and access rights</th>
</tr>
</thead>
<tbody>
<tr>
<td>uid</td>
<td>Owner</td>
</tr>
<tr>
<td>gid</td>
<td>Group</td>
</tr>
<tr>
<td>mtime</td>
<td>Modification time</td>
</tr>
<tr>
<td>itime</td>
<td>Inode modification time</td>
</tr>
<tr>
<td>block count</td>
<td>File size</td>
</tr>
<tr>
<td></td>
<td>Physical location</td>
</tr>
</tbody>
</table>
Some more words on permission bits

/home/jonfo33/:
-rw-r-r-  jonfo33  users  tsit02-lecture-05.pdf
-rw-----  jonfo33  users  tsit02-exam.pdf
drwxrwx--  jonfo33  icg  ourproject

- rwxrwxrwx

Read, write, and execute permissions for all other users.

Read, write, and execute permissions for the group owner of the file.

Read, write, and execute permissions for the file owner.

File type:
- indicates regular file
  d indicates directory
Access control in Unix

- Owners get access according to the “user” bits
- Members of the object’s group get the “group” permission
- All other get the “other” access permissions
- The owner and root can change object permissions
- It is possible to give more access to “others” than to the owning “user”
- The “sticky” bit can handle one special case: job queues and mail directories
Limitations to access control in Unix

- Files have only one owner and one group
- Permissions are read, write, and execute
- All other access rights must be mapped to basic file permissions
- Other operations need to be done through suid applications
- Complex security policies are often impractical
Deleting files in Unix

- Deleting a file in Unix means removing the directory item that points to the data of the files.
- The actual data is not erased from disk (memory, ...).
- To actually be removed, the data must be wiped securely before the link is removed.
- Secure wipe is to overwrite the data with zeros or noise.
Audit logs in Unix

- Unix logs some security-relevant events into the directory `/var/log/`
- Logging is provided by `syslogd` (or modern replacements such as `syslog-ng`)
- Logs can include valid and invalid login attempts including `sudo`
- Note: `suid` binaries are not logged by default
- The system can be rigged to shut down if it is not possible to log a security-relevant event
Sandboxing in Unix

- There are a few ways we can strengthen access control even further
- The Unix chroot system call can create sandboxed “jails”
- Within such a sandbox, a process is restricted to that sandbox
- This can protect against secondary damage from privilege escalation bugs
- Android versions before 4.3 had primitive sandboxes in form of directories with restricted permissions
- Android versions after 4.3 have SELinux-enforced sandboxes
Chroot: limitations and gotchas

- However, a root user can still create device files
- The device file /dev/mem gives direct access to the computer memory
- Almost all jail breaking requires root privileges
- From previous lecture: Must protect lower layers from tampering
- Possible solution: No files inside chroot with setuid/setgid permissions, or mount filesystem with the nosuid option

Fun with chroot: “An evening with Berford in which a Cracker is Lured, Endured and Studied” from 1991.
Windows

- Windows was not designed with security in mind
- Comes from single-user PCs, security was mostly to prevent mistakes
- Security features were added as needed
- This is not a generally viable method
- ...but over the years, Windows has improved its reputation
Windows

- Windows does have a *security architecture*
- Generally needs a skilled admin (but with a different skillset)
- Lots of development from DOS via Windows 1.0-3.1, 95, 98, 2000, NT, XP and Vista to Windows 7, 8 and 10
- Available mechanisms are less straightforward and much more sophisticated than in Unix
- This opens up for more mistakes as well as it makes far better adjusted controls possible
Configuration: The Windows Registry

- System configuration resides in the Registry in Windows
- Much of the configuration is world-readable, but needs supervisor privileges for writing
- This is a proper database, and can be accessed via the Registry Editor
- One problem is (was) that many applications assume they can write into the Registry directly
Configuration: The Windows Registry

- Registry integrity is crucial for Windows security
- Registry entries are confusingly called “keys”
- One “key” contains all user profiles
- One “key” defines the local software configuration
- One “key” defines system hardware at startup
- One “key” defines the environment for the current user
Configuration: The Windows Registry

- Registry integrity is crucial for Windows security
- Registry entries are confusingly called “keys”
- A possible problem is the behaviour if one key is missing, e.g., if the key
  
  HKEY_LOCAL_MACHINE\SYSTEM\CurrentControlSet\Control\SecurePipeServers\Winreg

  is missing, the registry can be accessed from a remote machine exactly as on the local machine
Centralized configuration in Windows

- Networked Windows machines are often jointly administered in a Domain
- All machines in a Domain share user accounts database and security policy
- Domains can form a hierarchy
- Each Domain has a Domain Controller (DC), acting as a trusted third party in authentication, for example
- Many services are available, configuration is of course needed
Principals in Windows

- Principals are local users, aliases, domain users, groups, or machines, and each have a security identifier (SID)
- The SID has the format S-R-I-S-S-...-RID, where R is revision, I is identifier authority (48 bit), S is up to 14 subauthority fields, and RID is a relative id, all 32 bit

<table>
<thead>
<tr>
<th>Principal</th>
<th>SID</th>
</tr>
</thead>
<tbody>
<tr>
<td>Everyone</td>
<td>S-1-1-0</td>
</tr>
<tr>
<td>SYSTEM</td>
<td>S-1-5-18</td>
</tr>
<tr>
<td>Administrator</td>
<td>S-1-5-21-&lt;local authority&gt;-500</td>
</tr>
<tr>
<td>Administrators</td>
<td>S-1-5-32-544</td>
</tr>
<tr>
<td>Domain admins</td>
<td>S-1-5-21-&lt;domain authority&gt;-512</td>
</tr>
<tr>
<td>Guest</td>
<td>S-1-5-21-&lt;authority&gt;-501</td>
</tr>
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</tr>
<tr>
<td>Guest</td>
<td>S-1-5-21-&lt;authority&gt;-501</td>
</tr>
</tbody>
</table>

- local users and aliases are administered locally
- domain users and groups are administered by the DC
- groups can be nested, aliases cannot
- SIDs are (statistically) unique, using pseudorandom numbers
Special principals in Windows

- Is used for login, audit logging, I/O access, upgrading (system) programs, and so on
- Administrator can do almost anything
- ... including removing the “almost” in the last sentence
- ... but cannot decrypt users’ password
- Others include LocalSystem, Administrators, Domain admins, Domain Users, Everyone, Interactive, Network, CreatorOwner, ...
Priviliges in Windows

Here, “priviliges” are not generic root priviliges, nor access to objects belonging to some group; instead typical priviliges can be:

- Backing up files and directories
- Generating security audits
- Managing and auditing security logs
- Taking ownership of files and other objects
- Enabling computer and user accounts to be trusted for delegation
- Shutting down the system
Subjects in Windows

- Subjects are processes and threads
- Windows stores security credentials in an access token, that contains
  - User SID
  - Group SIDs
  - Privileges (to system resources, the union of the above privileges)
  - Defaults for new objects (owner SID, group, and DACL, see below)
  - Miscellaneous (session ID and token ID)
- The token does not change once created, which is more efficient, but TOCTTOU may be a problem
Objects in Windows

- Objects are the passive parts in an access operation
- Windows objects can be active, "executive objects", like processes and threads
- Registry entries, devices, . . ., are also objects
- Standard file system objects too
- Each object has a security descriptor listing access control data for it
Objects in Windows

- **Owner SID**
- **Primary Group**
- **DACL**
- **SACL**

- (The Primary Group is for POSIX compliance)
- The Discretionary ACL (DACL) determines access properties
- The System ACL (SACL) defines the audit policy
Permissions in Windows

- An D/SACL is a list of Access Control Entries (ACEs), that in Windows contains

<table>
<thead>
<tr>
<th>Type (allow, deny, monitor)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inheritance and audit flags</td>
</tr>
<tr>
<td>Access mask</td>
</tr>
<tr>
<td>ObjectType</td>
</tr>
<tr>
<td>InheritedObjectType</td>
</tr>
<tr>
<td>SID (that the ACE applies to)</td>
</tr>
</tbody>
</table>
Permissions in Windows

- Standard permissions are modify/read-and-execute/read/write/full-control
- There are also Advanced permissions, for example subdividing “read” into read-data/read-attributes/read-extended-attributes/read-permissions

Folders have a different behaviour from Unix

- In Unix, each directory in the path is checked for access rights
- In Windows, the path is (only) an identifier, so only the DACL of the target object is checked
- A file may be accessible even when a folder (tree) is not
Permissions in Windows

- In Windows, the path is a (only) an identifier, so only the DACL of the target object is checked
- However, access rights can be inherited in Windows
- This is actually the default, but can be chosen per-folder

Order of precedence

- Deny before Allow
- Explicit before inherited
- Parent before grandparent (before great-grandparent)

This makes fine-tuned control possible (via ACLs), while keeping the admin complexity down (via inheritance)
Deleting files in Windows

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- The actual data is not erased from disk.
- To actually be removed, the data must be wiped securely before the link is removed.
- Secure wipe is to overwrite the data with zeros or noise.
Audit logs in Windows

- Windows logs security-relevant events in the security log
- The entries are generated by the Security Reference Monitor
- The object SACLs cause such events to be logged
- Other sources typically include valid and invalid login attempts, and privilege use

- A maximum log size can be set
- The system can be rigged to shut down if it is not possible to log a security-relevant event
Formal models and Windows

- Windows provides more fine-tuned access control
- Inheritance also plays a (bigger) role
- But the same critique holds; there is no check that the levels really form a hierarchy
- Although Windows UAC attempts to implement Biba, and almost succeeds
Unix vs Windows

- There are differences that you need to be aware of
- Windows is (was) more complicated, but also gives (gave) more control
- Be careful out there
Virtualization

- In the past decade, virtualization has become very popular
- A *virtual machine* (VM) is a simulated computer, which in turn runs an operating system
The virtual revolution

- Virtualization took off about a decade ago
- Report from Kapersky in 2012: 69% of US companies are using server virtualization
Full virtualization

- There are many forms of virtualization, with different architectures
- This lecture will cover full virtualization, where the guest OS has no idea it is ran on a VM
- Hypervisor or Virtual Machine Monitor takes care of managing the guests
Virtualization and security

- Virtualization allows a higher degree of isolation compared to chroot
- One compromised guest system typically does not compromise the host
- However, virtual machines can be complex and hard to analyze
- Virtualization can also increase flexibility, making systems easier to administer
Virtualization reduces administrative burden

- A new OS can be installed, configured, secured and tested in a VM
- The administrator then takes a snapshot of this VM
- This snapshot can then be distributed to many hosts
- If a guest system is compromised, it can be frozen (including RAM contents), which makes forensic analysis much easier
- A virtual machine can be migrated between hosts (often while running!)
- This makes it less of a hassle to install patches and reboot the host server
The Virtual Zoo

I've got a bunch of virtual Windows machines networked together, hooked up to an incoming pipe from the net. They execute email attachments, share files, and have no security patches.

Pretty, isn't it?

What is it?

There are mail, trojans, Warhol worms, and all sorts of exotic polymorphics. A monitoring system adds and wipes machines at random. The display shows the viruses as they move through the network.

Growing and struggling.

Between them they have practically every virus.

You know, normal people just have aquariums.

Good morning, Blaster. Are you and W32.Welchia getting along?

Who's a good virus? You are! Yes, you are!
Attacks on virtual machines

- Virtual machines are complex, with new possible attack vectors due to the complexity involved
- Simplest attack: VM detection
  - Timing attacks
  - Checking the local descriptor table
- Compromised guest system performs denial of service on host or other guests
  - Overloading
- Guest-to-guest communication
  - Shared memory and resources
Attacks on virtual machines

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- Compromised guest system performs denial of service on host or other guests
  - Overloading
- Guest-to-guest communication
  - Shared memory and resources
- Escaping the virtual machine
Virtual machine escape

- The most serious type of attack
- Usually grants privileged access to the host machine
- …which of course compromises all guests on that host
- Often caused by bugs in the hypervisor
- Example: Cloudburst attack on VMWare in 2009
Virtual machines as malware

- Subvirt was published in 2006 by King et al.
- Compromises a system by installing a virtual machine underneath it
Virtualization paved the way for cloud computing

- Virtual Private Server (VPS): A virtual machine sold as a service
- VPS allows customers root access within their VPS
- Example: Amazon AWS provides the Elastic Compute Cloud (EC2), where VPS instances can be managed and created
- EC2 can be rented in the following ways:
  - On-demand (hourly rates)
  - Reserved (long-term rental)
  - Spot (bid-based, runs jobs only if the spot price is below the bid price)
- Future trend: Centralization of computing
Jonathan Jogenfors

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