Enhancing XFree86 Security

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Introduction

What is XFree86 ?

- a Free implementation of the X Window System,
  based on X.Org's sample implementation (X11R6.6).
- History: X386 (*Three Eight Six*) $\rightarrow$ XFree86 (*Free Eight Six*)
- Runs on: Unix™, SVR4, *BSD, Linux, Windows (Cygwin), Mac OS X, etc.
- Foundation for most modern GUIs and Desktops on Linux/Unix-like systems.

Security concerns - summary

Client side:

- ☐ Setuid clients
- ☐ Scripting toolkits

Networking:

- ☐ connection setup / connection sniffing

Server side:

- ☐ Server is setuid root

Various issues: xdm, xfs, proxies

Chapter 1

Client side security

Which problems ?

Traditional application level security: handling (and limiting) privileges

Some remaining issues:

- xterm (on systems where pty allocation needs root)
- xlock like applications
- ICCM and other scriptable X Toolkits and applications $\rightarrow$ out of the scope of this talk.

Chapter 2

Networking issues

Security at the transport level

Access control done mainly at the transport level:

if a client is able to get a connection to the X server, it can take full control of it:

- display windows
- get events
- send synthetic events to other windows
- change X resource database
- access server-side data (atoms, pixmaps, etc)
- tweak video modes

X11 Transport Security models

Transport types:

- TCP
- local (Unix domain sockets + SVR4 local) connections
- SYSV SHM

Authentication types:

- Host based - `xhost`
- Magic cookies - `xauth`
- XDM
- Kerberos, SUN-DES-1 (not widely used AFAIK)

Too many people still use `xhost +` . . .

Host-based access control

The server has a list of authorized hosts (really network addresses).

When a client tries to connect, its address is compared to the list.

If found $\rightarrow$ access granted.

Problems:

- any user on authorized hosts can connect
- some difficulties with multi-homed hosts

Magic cookie protocol

MIT-MAGIC-COOKIE-1

Cookie: a 128 bits random number

- generated at startup time
- stored in a file designated by the `XAUTHORITY` environment variable
- manipulated (exported/imported) by the `xauth` command.

The client sends the magic cookie to the X server in the initial connection request.

The server checks if the cookies matches. If yes, connection accepted

Access control often equivalent to Unix file system access rights to `.Xauthority`.

The cookie is sent in clear text over the network.

The XDM-AUTHORIZATION-1 protocol

Based on DES encryption - not exportable outside the US.

- create a 192 bit value with network address, port number, current time
- crypt it using a DES key
- send it to the server
- the server decrypts the packet, verify that the data is valid to allow access

The DES key is the shared secret.

Somewhat better than magic cookies, but not widely used.

Other access control protocols

SUN-DES-1

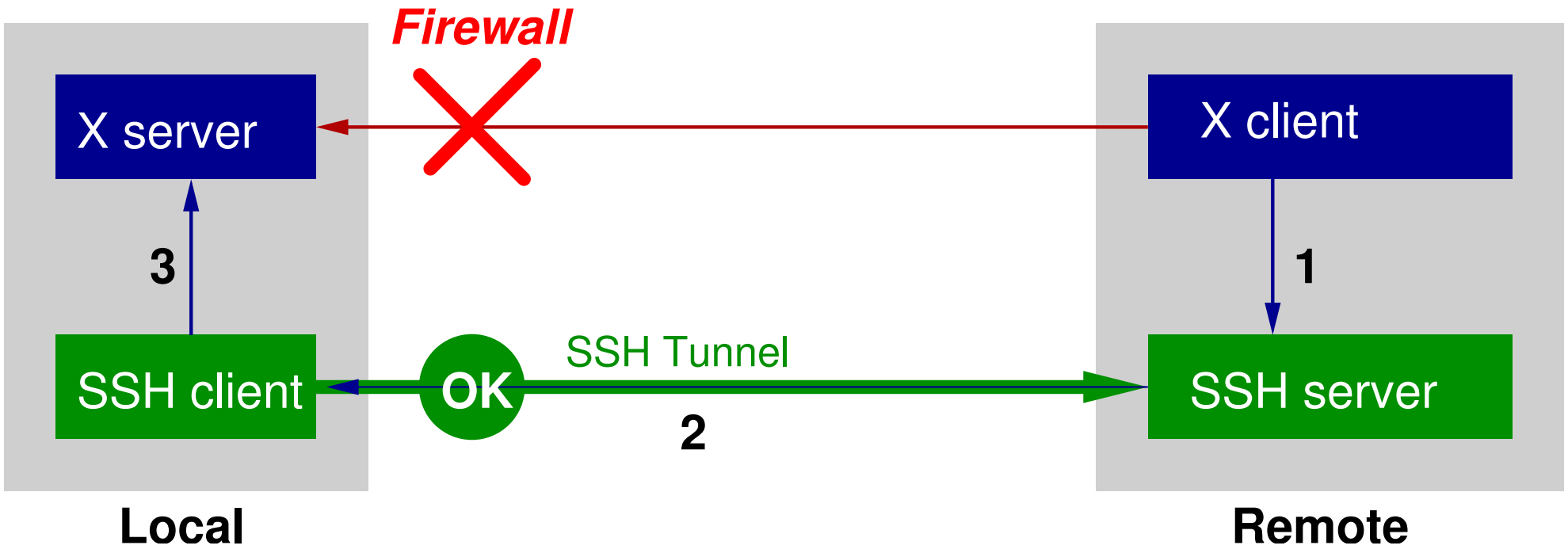
Based on secure-RPC credentials. A valid secure-RPC credential is needed to connect to the X server.

`xhost` is used to add authorized principals
(example: `xhost +nis:unix.3715@xfree86.org`)

MIT-KERBEROS-1

Based on kerberos tickets.

Secure Shell tunnels



Note: the cookie is stored on the remote system
$\rightarrow$ one needs to trust the remote admin
(he can gain access to the local X server).

The X Security extension

Aimed to control access from clients to X server resources.

Policy based (`/etc/X11/xserver/SecurityPolicy`).

Almost ignored in practice.

Chapter 3

Server side security

Threats

The X server is traditionally run as root.

Lots of non-trusted data are handled by the X server:

- X requests
- Fonts
- Driver modules (but only root can install them)
- Configuration file (but only root can set the pathname)

In addition to spawning a root shell one could potentially:

- decrement system security level
- load a user-land driver for a device that's not configured
- Brutal DoS: toast the machine (stop fans, re-flash BIOS, etc...)

Unix domain sockets

Created in `/tmp/.X11-unix/`

Several processes owned by different users need to be able to create sockets here.

Difficult to handle socket creation correctly

Solution: (ab)use of server privileges to create the sockets.

System	X server implementation	privilege used
Solaris	Xsun	setgid root
Linux, *BSD, etc.	XFree86	setuid root

Causes problems to 3rd party servers (ICE, xfs, etc.) that need to be installed with the same privileges.

One solution: only use TCP connections (example: SSH X11 forwarding).

MIT-SHM extension - CAN-2002-0164

An extension designed to share pixmaps between a client and the X server for faster image display.

Flaw: The X server needs to be able to read the shared memory segment (and sometimes to write it). The client needs to create it mode 644 (or even 777).

$\rightarrow$ the data is exposed to the world.

Solution: this extension needs to be redesigned from scratch.

XFree86 internals

XFree86 needs direct access to the graphics card hardware (DMA, registers, etc.) for:

- legacy ISA (+ VLB) device probes
- hardware accelerated 2D rendering

On most systems this requires one or several of these:

- **root privileges**
- low kernel security level
- a special `ioperm` syscall

Kernel security levels

An *BSD feature.

if `securelevel` = 1 some operations are prohibited:

- lowering securelevel
- accessing physical memory through `/dev/mem`
- other file system operations, out of scope here

XFree86 needs `/dev/mem` access on i386 and alpha → cannot run with securelevel=1

→ The "aperture" driver is a special `/dev/mem` driver that restricts accesses to the memory above the physical memory, and to the BIOS and interrupt vectors.

PCI only architectures can provide a better access control through a vga_pci driver.

Lowering the privileges

Most of the operations that need root privileges are done during startup.

- move all privileged operation as early as possible in the startup sequence
- switch to a non privileged id once done

The XFree86 version shipped with OpenBSD 3.2 was using this technique.

Problems:
- reopening the mouse device after a VT switch
- correct synchronization for startx

Privilege separation

Technique developed by Niels Provos for the SSH server.

Can be used in the X server for privileged operations that need to be done any time (VT switches)

While the main process is running privileged, fork a child that will keep the privileges.

Then change uid in the main process (lower privileges).

Use a pipe to send requests / get data back from the privileged child.

The child makes strict controls on what it accepts to do.

The child's code is kept small and simple -¿ easy auditing

Privilege separation for XFree86

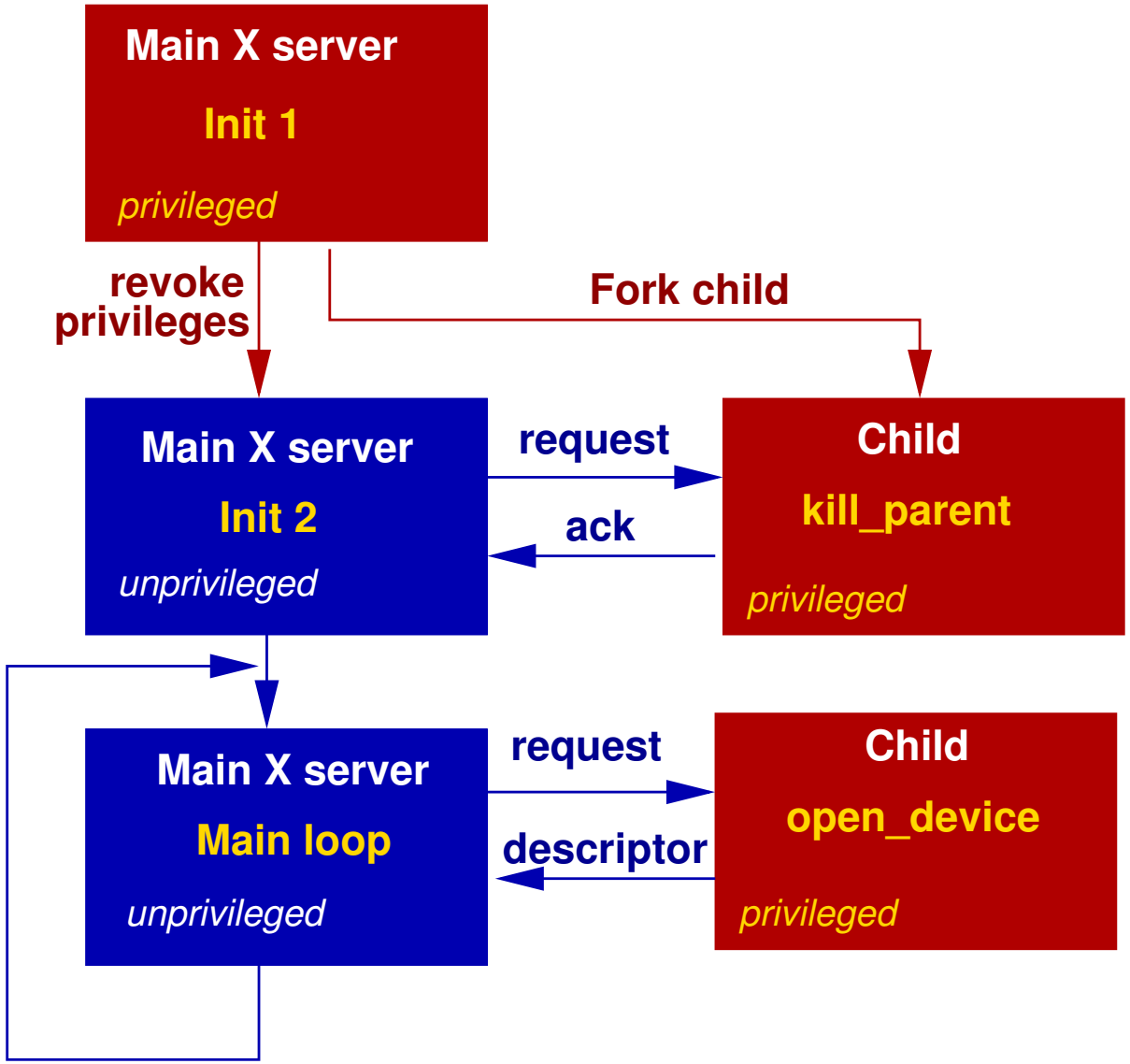
As shown above, most privileged operations can be done early

Two remaining operations:

- (re)opening input device after a VT switch
- sending a signal to the process that started the X server to notify that it's ready to accept connections.

Shipped in OpenBSD 3.3, being ported to XFree86-current on systems that provide file-descriptor passing.

Privilege separation for XFree86



Using systrace to control XFree86 privileges

systrace is another tool by Niels Provos.

Allows to define a policy that allows/denies system calls

Makes it possible to do controlled privilege elevation.

Available on Linux, NetBSD, OpenBSD, Mac OS X.

Used with a standard XFree86 server

Much finer grain.

Still some issues.

An experimental systrace policy for the X server

```
root# systrace -a -c 35:35 XFree86
```

(Only privilege elevation lines are shown)

```
Policy: /usr/X11R6/bin/XFree86, Emulation: native
  native-rename: filename eq "/var/log/XFree86.0.log" and filename[1] \
      eq "/var/log/XFree86.0.log.old" then permit as root
  native-fswrite: filename eq "/var/log/XFree86.0.log" then permit as root
  native-fswrite: filename eq "/tmp/.tX0-lock" then permit as root
  native-fsread: filename eq "/tmp/.X0-lock" then permit as root
  native-fswrite: filename eq "/tmp/.X0-lock" then permit as root
  native-open: filename match "/dev/tty*" then permit as root
  native-fswrite: filename eq "/dev/mem" then permit as root
  native-fswrite: filename eq "/dev/xf86" then permit as root
  native-sysarch: true then permit as root
  native-kill: true then permit as root
  native-open: filename match "/dev/*mouse*" then permit as root
```

XFree86 policy - other rules

```
native-fsread: filename eq "/var/run/ld.so.hints" then permit
native-fsread: filename match "/usr/lib" then permit
native-fsread: filename match "/usr/lib/lib*.so.*" then permit
native-fsread: filename eq "/usr/X11R6/lib" then permit
native-fsread: filename match "/usr/X11R6/lib/lib*.so.*" then permit
native-fsread: filename eq "/etc/X11/XF86Config" then permit
native-fsread: filename eq "/etc/X11/XF86Config-4" then permit
native-fsread: filename eq "/etc/malloc.conf" then permit
native-link: filename eq "/tmp/.tX0-lock" and filename[1] eq "/tmp/.X0-lock" then permit
native-fsread: filename eq "/var/log/XFree86.0.log" then permit
native-fswrite: filename eq "/tmp/.X11-unix" then permit
native-fsread: filename eq "/tmp/.X11-unix" then permit
native-fswrite: filename eq "/tmp/.X11-unix/X0" then permit
native-bind: sockaddr eq "/tmp/.X11-unix/X0" then permit
native-fsread: filename eq "/etc/X0.hosts" then permit
native-fsread: filename match "/usr/share/zoneinfo/*" then permit
native-fsread: filename match "/usr/X11R6/lib/X11/fonts/*" then permit
native-fsread: filename match "/usr/local/lib/X11/fonts/*" then permit
native-fsread: filename match "/usr/X11R6/lib/X11/locale/*" then permit
native-fswrite: filename eq "/dev/tty" then permit
native-fswrite: filename match "/dev/ttyC*" then permit
native-fsread: filename eq "/dev/apm" then permit
native-fsread: filename eq "/usr/X11R6/lib/X11/rgb.txt" then permit
native-fsread: filename eq "/usr/X11R6/lib/X11/XKeysymDB" then permit
native-fsread: filename match "/usr/X11R6/lib/modules" then permit
native-fsread: filename match "/usr/X11R6/lib/modules/*" then permit
native-fsread: filename eq "/etc/X11/xserver/SecurityPolicy" then permit
```

```
native-fsread: filename eq "/etc/X11/xkb/X0-config.keyboard" then permit
native-fsread: filename match "/etc/X11/xkb/*" then permit
native-fsread: filename eq "/var/tmp/server-0.xkm" then permit
native-fswrite: filename eq "/var/tmp/server-0.xkm" then permit
native-fsread: filename match "/<non-existent filename>: *" then permit
native-fsread: filename eq "/usr/share/nls/C/libc.cat" then
native-chdir: filename eq "/etc/X11/xkb" then permit permit


native-issetugid: permit
native-mprotect: permit
native-mmap: permit
native-__sysctl: permit
native-fstat: permit
native-close: permit
native-read: permit
native-mquery: permit
native-sigprocmask: permit
native-break: permit
native-geteuid: permit
native-getuid: permit
native-getrlimit: permit
native-write: permit
native-getpgrp: permit
native-getpid: permit
native-sigaction: permit
native-setitimer: permit
native-umask: permit
native-getppid: permit
native-gettimeofday: permit
native-setpgid: permit
native-kqueue: permit
native-kevent: permit
```

```
native-munmap: permit
native-nanosleep: permit
native-shmget: permit
native-shmctl: permit
native-pipe: permit
native-fork: permit
native-wait4: permit
native-getgid: permit
native-setgid: gid eq "35" then permit
native-setuid: uid eq "35" and uname eq "_x11" then permit
native-dup2: permit
native-execve: permit
native-select: permit
native-sigreturn: permit
native-exit: permit
native-ioctl: permit
native-fcntl: permit
native-fstatfs: permit
native-getdirentries: permit
native-lseek: permit
native-sigsuspend: permit
native-getrusage: permit
native-fchmod: fd eq "0" and mode eq "444" then permit
native-socket: sockdom eq "AF_INET" and socktype eq "SOCK_STREAM" then permit
native-socket: sockdom eq "AF_UNIX" and socktype eq "SOCK_STREAM" then permit
native-setsockopt: permit
native-bind: sockaddr eq "inet-[0.0.0.0]:6000" then permit
native-listen: permit
native-getsockname: permit
```

Chapter 4

Miscellaneous issues

The font server

Used to be run as root.

Need to trust font data.

TrueType font renderers have a byte-code interpreter. Is it safe?

XDMCP

The protocol used to manage X terminals

Issues too

Write xor eXecute

Technique developed in OpenBSD and other systems:
one page is either writeable or executable but not both at the same time.

Makes exploit almost impossible to write

The XFree86 module loader is not compatible with W^X on i386. :-(

Thanks

Theo de Raadt has suggested some of the idea that were implemented to lower the X privileges.

Niels Provos and Marc Espie have provided some of the code that is used in the X privilege separation code.

Todd Fries and many OpenBSD developers for testing and finding bugs in the code.

Bibliography

1. Unix manual page, section 7. *Xsecurity - X display access control*.
2. L. Mui and E. Pearce. *X Window System Administrator's Guide*, volume 8 of *The Definitive Guides to the X Window System*. O'Reilly, October 1992.
3. D. P. Wiggins. Security extension specification. Technical Report Version 7.1, X Consortium, Inc., November 1996.
4. D. J. Barret and R. Silverman. *SSH, The Secure Shell: The Definitive Guide*. O'Reilly, January 2001.
5. Niels Provos. Preventing privilege escalation. In *12th USENIX Security Symposium*, Washington, DC, August 2003. http://www.citi.umich.edu/techreports/reports/citi-tr-02-2.pdf.
6. Niels Provos. Improving host security with system call policies. In *12th USENIX Security Symposium*, Washington, DC, August 2003. http://www.citi.umich.edu/techreports/reports/citi-tr-02-3.pdf.

Conclusion

- Some issues with XFree86 security have been shown
- Solutions exist
- More work is needed
- Don't be afraid to run X on your machine

Questions ?