# X.org security

## Recap, vulnerabilities, attacks and discussions on the graphic stack's security

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# Disclaimer

- We are not Linux **graphics** stack developers (yet?);
- We are interested in (desktop/mobile) UI security;
- This presentation is based on our study and is (likely) incomplete (mostly focused on Linux);
- Feel free to interrupt us.

# Summary

1. Expected security properties & X-server
2. About Wayland/Weston
3. Hardware/Driver security

# Confidentiality

## Use cases 0 & 1

- The user is shopping online ;
- He/she keys in the credit card number;
- A keylogger was installed on the computer
  or
  A program takes periodical screenshots;
- His/her credit card number got stolen!

# Confidentiality & the X-server

## User's expectation towards confidentiality

- Applications should never be able to access other applications' input events or output buffers (allow only copy/paste);
- ⇒ Apps should not be able to eavesdrop other apps' input events (keyloggers) nor their output buffers;
- ⟼ This would make e-shopping safer on the system-side.

## X11 & X-server

- Grants full-access to whoever can read the magic cookie;
- **Security model**: Applications run by a user should be trusted. Isolation between users only;
- **Problem**: applications cannot be trusted anymore and some apps can be launched behind the user's back;
- ⇒ This busts confidentiality!

# Integrity

## Use case

- The user is visiting his bank's website;
- He/she checks the website address (https + right domain);
- He/she is unaware that he/she is visiting a fake website and that Firefox's address bar has been redrawn by a malware;
- His/her bank information got stolen!

# Integrity & the X-server

## User's expectation towards integrity

- What is displayed is what the application drew;
- The events sent to the application are never tampered with;
- ⇒ Applications should never be able to alter other applications' output buffers or input events;
- ⟼ Help blocking Phishing-like attacks.

## X11 & X-server

- Apps can inject input events (virtual keyboards);
- Apps with DRI 1 can render outside their "window";
- ⇒ This busts integrity!

# Availability & the X-server

## User's expectation towards availability

- Users think their computers do multitasking;
- Thus, one app shouldn't be able to bring the system down;
- ⇒ Applications should never be able to deny access to other applications.

## X11 & X-server

- Apps can act as screen lockers;
- Virtual keyboards may kill applications they want using XF86ClearGrab (the famous security hole of xserver 1.11);
- ⇒ This busts availability!

# Current mitigation techniques

## XACE ↦ X11 hardened

- Provides a finer-grained access control in X11;
- Mostly per-feature access control with some clipboard control;
- XSELinux: Deactivated by default in Fedora/RHEL/CentOS as users are unconfined.
- Use of sandbox services (Xephyr) recommended instead;
- ⇒ Still too coarse-grained to be fully useful.

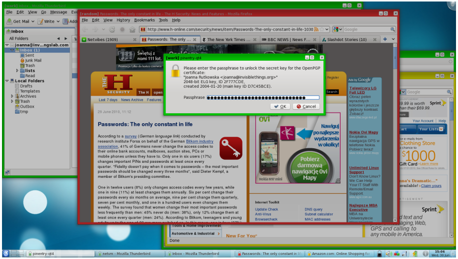
## Isolate groups of applications into domains

- QubesOS : Isolation using virtual machines;
- PIGA-OS : Isolation using SELinux + XSELinux + PIGA-SYSTRANS;
- ⇒ Force applications to communicate via a controlled system.

# QubesOS

## QubesOS

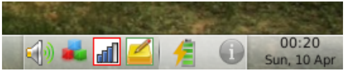
- Allows the user to group applications into domains;
- Each domain requires a new Xen Virtual Machine (VM);
- Applications from the VM integrate with the original desktop but are outlined with a specific colour;
- A daemon in dom0 provides a mean of communication between the VMs and does Mandatory Access Control (MAC).


[work] pinentry-qt4

Please enter the passphrase to unlock the secret key for the OpenPGP certificate:
"Joanna Rutkowska <joanna@invisiblethings.org>"
2048-bit ELG key, ID 2F777CDE,
created 2004-01-20 (main key ID D7C45BCE).

Passphrase ●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●

OK
Cancel
http://www.h-online.com/security/news/item/Passwords-The-only-constant-in-life-1030
Passwords: The only ...
The New York Times ...
BBC NEWS | News F...
Slashdot Stories (10)
Passwords: The only constant in life



# QubesOS

## Pros

- Allows defining activities and keep files separated (Taxes, e-shopping, private mails. . . );
- ⇒ A compromised domain cannot interfere with other VMs;
- Uses Xen but could also use cgroup/LXC;
- Provides a nicely-integrated GUI to ease setup.

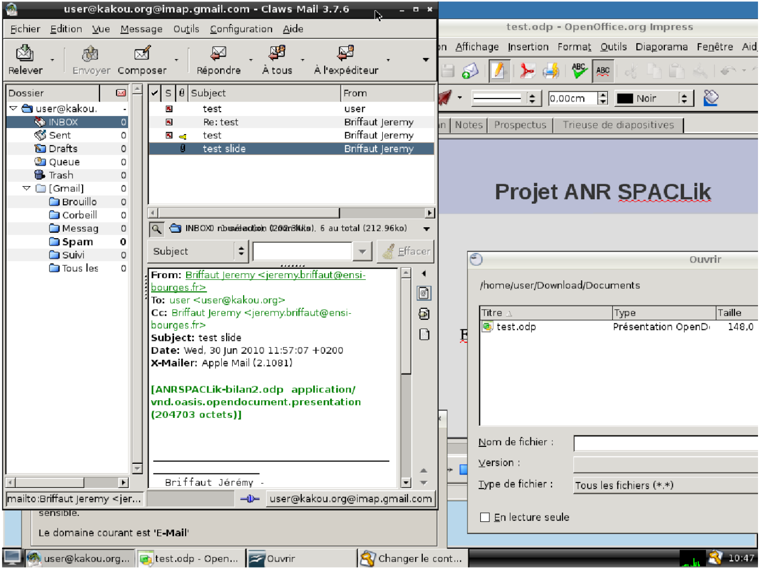
## Cons

- Slow and resource heavy;
- Hardware graphic acceleration limited to the number of GPU (with PCI passthrough which requires an IOMMU);
- Limited power management;
- Is Xen able to securely isolate VMs?

# PIGA-OS

- Each applications is put inside a SELinux domain (Type);
- Files, processes, sockets are tagged with a SELinux label;
- A SELinux policy is set for every application and every activity;
- XSELinux is also used to restrict permissions inside the Xserver;
- A daemon (PIGA-SYSTRANS) grants rights as needed and prompts the user if he would like to enter a new domain depending on his/her activity.

# PIGA-OS : Example domain Email


user@kakou.org@imap.gmail.com - Claws Mail 3.7.6
Fichier Edition Vue Message Outils Configuration Aide
Relever
Envoyer
Composer
Répondre
À tous
À l'expéditeur
test.odp - OpenOffice.org Impress
n Affichage Insertion Format Outils Diaporama Fenêtre Aid
0,00cm
Noir
n Notes Prospectus Trieuse de diapositives
Projet ANR SPACLik
Ouvrir
Effacer
user@kakou.org... test.odp - Open... Ouvrir Changer le cont... 10:47

| Dossier | |
|---|---|
| user@kakou. | - |
| INBOX | 0 |
| Sent | 0 |
| Drafts | 0 |
| Queue | 0 |
| Trash | 0 |
| [Gmail] | 0 |
| Brouillo | 0 |
| Corbeill | 0 |
| Messag | 0 |
| Spam | 0 |
| Suivi | 0 |
| Tous les | 0 |

| Subject | From |
|---|---|
| test | user |
| Re: test | Briffaut Jeremy |
| test | Briffaut Jeremy |
| test slide | Briffaut Jeremy |

INBOX0 nouveau(x) (202.3ko), 6 au total (212.96ko)

Subject

**From:** Briffaut Jeremy <jeremy.briffaut@ensi-bourges.fr>
**To:** user <user@kakou.org>
**Cc:** Briffaut Jeremy <jeremy.briffaut@ensi-bourges.fr>
**Subject:** test slide
**Date:** Wed, 30 Jun 2010 11:57:07 +0200
**X-Mailer:** Apple Mail (2.1081)

**[ANRSPACLik-bilan2.odp application/vnd.oasis.opendocument.presentation (204703 octets)]**

Briffaut Jérémy -

mailto:Briffaut Jeremy <jer...   user@kakou.org@imap.gmail.com

/home/user/Download/Documents

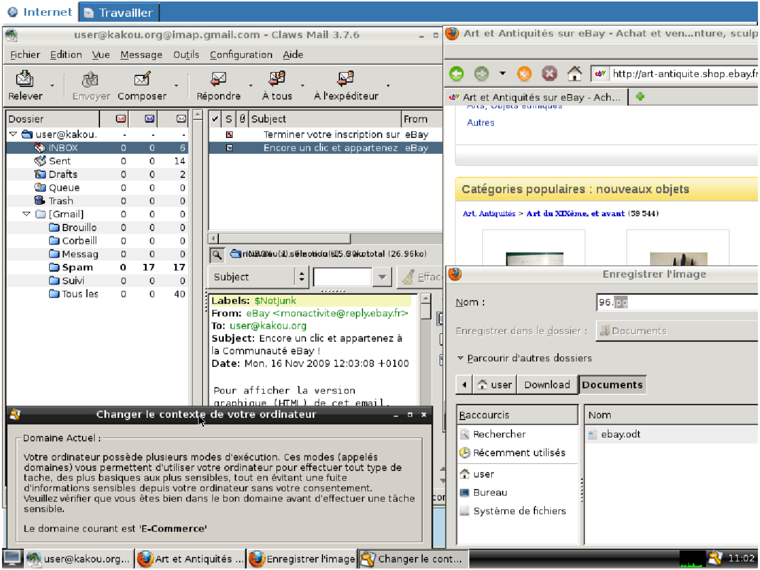
| Titre | Type | Taille |
|---|---|---|
| test.odp | Présentation OpenD | 148,0 |

Nom de fichier :
Version :
Type de fichier : Tous les fichiers (*.*)
☐ En lecture seule

sensible.

Le domaine courant est '**E-Mail**'

# PIGA-OS : Example domain E-Shopping


Internet
Travailler
user@kakou.org@imap.gmail.com - Claws Mail 3.7.6
Fichier Edition Vue Message Outils Configuration Aide
Relever
Envoyer
Composer
Répondre
À tous
À l'expéditeur
Art et Antiquités sur eBay - Achat et ven...nture, sculp
http://art-antiquite.shop.ebay.fr
Art et Antiquités sur eBay - Ach...
Autres
Catégories populaires : nouveaux objets
Art, Antiquités > Art du XIXème, et avant (59 544)

| Dossier | | | |
|---|---|---|---|
| user@kakou. | - | - | - |
| INBOX | 0 | 0 | 6 |
| Sent | 0 | 0 | 14 |
| Drafts | 0 | 0 | 2 |
| Queue | 0 | 0 | 0 |
| Trash | 0 | 0 | 0 |
| [Gmail] | 0 | 0 | 0 |
| Brouillo | 0 | 0 | 0 |
| Corbeill | 0 | 0 | 0 |
| Messag | 0 | 0 | 0 |
| Spam | 0 | 17 | 17 |
| Suivi | 0 | 0 | 0 |
| Tous les | 0 | 0 | 40 |

| Subject | From |
|---|---|
| Terminer votre inscription sur | eBay |
| Encore un clic et appartenez | eBay |

**Labels:** $NotJunk
**From:** eBay <monactivite@reply.ebay.fr>
**To:** user@kakou.org
**Subject:** Encore un clic et appartenez à la Communauté eBay !
**Date:** Mon, 16 Nov 2009 12:03:08 +0100

Pour afficher la version graphique (HTML) de cet email.

**Changer le contexte de votre ordinateur**

Domaine Actuel :

Votre ordinateur possède plusieurs modes d'exécution. Ces modes (appelés domaines) vous permettent d'utiliser votre ordinateur pour effectuer tout type de tache, des plus basiques aux plus sensibles, tout en évitant une fuite d'informations sensibles depuis votre ordinateur sans votre consentement. Veuillez vérifier que vous êtes bien dans le bon domaine avant d'effectuer une tâche sensible.

Le domaine courant est '**E-Commerce**'

**Enregistrer l'image**

Nom : 96.jpg

Enregistrer dans le dossier : Documents

# PIGA-OS

## Pros

- No need for a virtual machine;
- We can use graphic acceleration for all apps!
- Dynamically adjusts applications' permissions according to the user's activity (if the user agrees with it);
- The model can be re-used if new confinement means appear;
- Power management available.

## Cons

- Requires SELinux and a SELinux policy;
- Finer-grained so harder to configure;
- No declassification method provided (yet?).

## Summary

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2 About Wayland/Weston

3 Hardware/Driver security

# Input security & Wayland/Weston

## Input confidentiality

- Weston knows where applications are on the screen;
- It decides which applications receive input events (currently selected, under the cursor. . . ) ⇒ no broadcasting;
- ⇒ This defeats keyloggers.

## Input integrity

- Weston does not receive input events from applications;
- Input events can not be forged (access to /dev/(u)input restricted to the root user);
- ⇒ Virtual keyboards will be discussed later.

# Output security & Wayland/Weston

## Output buffers confidentiality & integrity

- Weston shares output buffers with applications using the GEM interface to limit buffer copy;
- The GEM handle is a 32bit integer;
  ⇒ This can be guessed or easily bruteforced!
- Applications output buffers can be eavesdroped and modified.

## Possible solutions

- Add access control to GEM (turn it into GEM2)?
- DMA-BUF for userspace? Access control in DMA-BUF?

# Availability & Wayland/Weston

## Requirements

- Applications shouldn't crash the compositor;
- Applications shouldn't deny access to other applications.

## Vulnerabilities

- Screenlocking;
- Any idea?

# Screenlocking

## Goals

- Unbypassable screen;
- Ask for a user secret or device to login;
- Enable users to switch or start new sessions.

## Recomendations

- Control which applications are able to lock the screen;
- Make sure it uses PAM so we can extend loggin methods.

# How do we allow exceptions?

## Visual keyboards

- They need to send input events to the compositor;
- Could be included into the compositor.

## Screenshot applications

- They need access to the global buffer;
- They can easily break confidentiality.

## Global shortcuts

- Media players use global shortcuts to interact with the user;
- They should register key combos to the compositor in order to receive those events;
- Where is the limit (keyloggers, user configured shortcuts)?

# Proposal: a MAC framework

## Mandatory Access Control

- Control enforced by the system (mostly the kernel);
- Based on a policy (no unprivileged user control).

## Suggestions

- Should be implemented as a library to unify access control on every wayland compositors;
- Should define which applications are allowed to take screenshots/act as virtual keyboards/copy & paste/drag & drop/register global shortcuts. . .
- Generic model, could look like or be polkit;
- Integrating SELinux to use policy mecanisms.

# Rootless Weston ?

## Incentives

- Compositors have access to everything;
- They will only get bigger as the feature list grows;
- They will have vulnerabilities.

## What's blocking us?

- Input management;
- Output buffer management.

## Possible solution

- Separate the privileged code from the functional one;
- Use UNIX sockets to forward file descriptors (drm + input).

# Summary

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# Why should we care about the driver/hardware security?

## Requirements

A driver/hw should not allow privilege escalation and should isolate GPU users:

- User ID;
- Confidentiality: read access to other buffers;
- Integrity: write access to other buffers.

## Current status

- Good access control to the RAM and VRAM from the CPU;
- The GPU may provide read-write-access to the whole VRAM/Host RAM range to UNIX users through the use of Shaders/GPGPU/copy-engines (TEGRA 2);
- The nVidia driver allows users to access the GPU's registers.

# Driver/Hardware security : Current solutions

## Expose a secure API to the userland

Goal: Users shouldn't be able to interfere with other GPU users

- The kernel should expose a sane API that isolate GPU users;
- This API should be the only way for a user to access the GPU;
- ↦ no regs should be accessible from the userspace!

## Restrict GPU's RAM access rights

Goal: Deny access to the GPU to the kernel's internal structures or other programs' data.

- VGA window: The GPU can access the first 1.5MB of RAM;
- AGP aperture: Allow GPU access to a fixed part of the RAM;
- IOMMU: Programmable MMU for devices to grant RAM access as needeed where needed.

# Driver/Hardware security : Current solutions

## Isolate users in a separate VM

Goal: Restrict a GPU user to its own data by abstraction the memory address space

- Most secure solution;
- Increase context-switching delay (problem with DRI2 and Qt5)
- Currently used by: Nouveau (geforce 8+);
- Could also be used by: AMD (Southern Island+), Intel (Sandy Bridge+), . . .

# Driver/Hardware security : Current solutions

## Isolate users through Command Submission validation

Goal: Restrict a GPU user to its own data by checking the commands issued by the user

- Lower context-switching delay;
- Higher CPU usage in kernel space;
- Currently used by: Radeon, Intel;
- Can be used by: any driver on any card.

# Driver/Hardware security : Possible solutions

## Zero buffer content at allocation time

Goal: Restrict a GPU user to its own data by zeroing buffers at allocation time

- Increase confidentiality;
- Prettier output;
- High-performance hit on memory-intensive applications;
- Solution: Zero un-used buffers when idle?

# Limits to per-GPU-user isolation

- Driver/Hardware can provide isolation between GPU users;
- Compositors have access to applications' output buffers;
- ↦ The compositor and its plugins should also be secured.

## Compositor ↔ plugins Interface

- Plugins shouldn't have access to buffers (when possible);
- Plugins shouldn't have access to inputs (when possible);
- We should make it hard for plugins to access output buffers;
- Buffers should be located at random addresses:
  Address-Space Layout Randomization (ASLR) in the driver?
- Applications generating a pagefault should be killed.

# Conclusion

## Goals

- Make it possible to implement activities and provide secure isolation between them (like QubesOS/PIGA-OS);
- Allow the user to decide what he wants (per-application isolation vs performance?);
- Be ready for GPGPU shared clusters and the soon-to-come WebGL applications.

## Current state

- No confidentiality/integrity between applications run by the same user:
  ↦The Linux graphics stack make it possible to spy on users.

## Needed work

- Increase isolation between GPU users.

# Thank you for listening!

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