Capsicum: Practical capabilities for UNIX

Anna Kornfeld Simpson & Venkatesh Srinivas
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And a little bit about Confused Deputies too...

Anna Kornfeld Simpson & Venkatesh Srinivas
A Tale of Woe

Evil Solitaire
A Tale of Woe, pt.2

“I was just trying to share a photo!”
Problem, pt. 1

UNIX (& friends) treat the user as a principal

Any process of a user can do anything that user can do.
Confused Deputy

Tricking a compiler
The Problem

Abelson: “Name gives you Power over object”

In UNIX & friends, a process can pronounce names that it might not have power over.

The names convey no authority or reference
The Problem

The amount of Ambient Authority is ....
(Orthogonal problem)

- We don’t trust other users on our machine
- Existing access control systems specify which other users can do what to each file (using techniques such as chmod() in Linux or ACLs in Windows, or sharing online)
- If the user has permission to access the file, any program run by that user can access
What are capabilities?

An unforgeable reference.

The reference itself conveys authority.
What are capabilities?

“Protection”, Lampson 1971

Access Control Matrix

<table>
<thead>
<tr>
<th></th>
<th>Object 1</th>
<th>Object 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>R,W,X</td>
<td></td>
</tr>
<tr>
<td>P2</td>
<td>R</td>
<td>R</td>
</tr>
</tbody>
</table>
What are capabilities?

An elegant idea from a more civilized time
What are capabilities?

An elegant idea from a more civilized time

But actually…

GNOSIS ‘Great New Operating System In the Sky’ (1979)
KeyKOS (1985)
EROS (1999)
E language (2006)
Cap’n Proto / Sandstorm (coming to an Internet near you any day now!)
… many, many others.
A Pure Capability System

No ambient authority

All object access for a process via explicit caps a process holds.
And now we change gears...
Sandboxing Programs

Modern applications are large and should have their pieces sandboxed. Ex. the rendering engine in the browser is the location of most vulnerabilities.

From: Barth et. al. Security Architecture of Chromium Browser, 2008
Sandboxing Programs

- Sandboxed processes shouldn’t have ability to see filesystem etc.
- Capabilities allow us to do sandboxing very neatly!

From: Cambridge slide deck
Delegation

- Want to be able to pass capabilities to other programs (example: photo gallery shares image with Dropbox)
- Share only the specific capabilities
- Programs delegate specific capabilities by sharing the file descriptors
Imagine
What if …?
Capsicum

New UNIX interface (developed for FreeBSD), ~2010.

Merged for FreeBSD-9.
Capsicum

Modal interface -- a process may enter ‘cap’ mode

Gives up old interfaces when it does so.
Capsicum
cap_enter

Enter capability mode.

Irrevocable for a process and its descendants
Capability mode

No ambient authority.

No global filesystem namespace. (sys_open no more)

All file descriptors preserved on entry.
cap_new

Generates a ‘weakened’ copy of a file descriptor

Ex: you can hold a read/write fd to a file. And generate a weakened one to send to some other process
PIDs as file descriptors?!

fork() / wait() / kill() rely on a global namespace (PID)

fork() is disallowed in capability mode.
pdfork() replaces it -- same semantics, but returns a file descriptor.
fexecve

execve() doesn’t work in capability mode (relies on a string path)

fexecve() should be easy, right?

Surprise global namespace! (RTLD)
Sandboxing is easy now!

- “immediate benefits” in tcpdump: 10 lines
  - Acquire resources up front, packet-process in capability mode
  - On-demand initialization
- gzip is surprisingly complicated
  - Need usermode library for pipeline mode
  - 400 lines, mostly in RPCs
Figure 13: Capsicum system call performance compared to standard UNIX calls.
Performance is fine
Now available in a store near you!

Shipping since FreeBSD 9

Ported to DragonFly BSD
Discussion

- Does this go far enough in sandboxing?
  - kernel/user implementation question?
- Is this worth all the re-writing that is necessary?
- How would you sandbox Evil Solitaire or Dropbox without capabilities?