Research Report: Mitigating LangSec Problems With Capabilities
Or: How Sandstorm Taught Me to Stop Worrying and Love the Web

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One-Slide Elevator Pitch

Actually two, related, pitches:

- Sandstorm’s capability-based design enables *very fine-grained sandboxing* of application software, which largely (sometimes completely!) *mitigates* the majority of LangSec bugs seen in practice.

- Capability systems offer the potential to turn difficult authorization decisions into LangSec’s bread and butter: syntactic constraints on requests; *every well-formed request which can be stated is authorized.*
Traditional Web Application Hosting
The Sad Story

Consider a standard LAMP-esque stack.

- Many co-hosted applications at different paths.
  - Maybe have separate kernel UIDs when executing?
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  - Even SSO systems typically require application buy-in.
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- Client authn, authz up to *each* hosted application.
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- Web’s failings left to apps: XSRF, XSS, SRI, ...
Traditional Web Application Hosting
The Impact of LangSec Bugs

In this environment, what do LangSec bugs buy an attacker?

- Outright authn/authz confusion:
  - Authn/authz cookie leak & replay
  - XSRF & XSS

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- Code injection:
  - Probe file system, loopback network
  - Make remote network connections
  - Probe local *kernel* for vulnerabilities

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Sandstorm Application Hosting
What a mess! Alternative design?

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- Replace web server with application supervisor.
  - *Not* “Web Application Firewall”
  - No dynamic inspection of application display content!
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  - Applications enumerate possible “rights”.
  - Supervisor computes agent’s rights; tells application.
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  - Applications enumerate possible “rights”.
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- Sandbox server-side resources very tightly.
  - Each document in its own container is possible!
  - Granularity up to application author and user.
  - Possible due to centralized management of sharing.
Sandstorm Application Hosting
What a mess! Alternative design?

Old world:

- As admin, install application to web server (or find host)
- Users register with *each* application (or be anonymous)
- Application juggles many documents / objects / . . .
- User rights managed within *each* application
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New world:
- As admin, install sandstorm server (or . . .)
- Users register once with sandstorm installation (or . . .)
- *Users* install *arbitrary* applications as desired!
- Users *instantiate* applications as “grains.”
  - Each user may have zero or more grains of any app.
  - Grains begin *private to creator.*
- Users share (and revoke) appropriate access to grains.
Sandstorm Application Hosting
User’s Perspective
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User’s Perspective

ShareLaTeX

Version: 2015.11.16 (0.1.4+)
Last Updated: 2015 Nov 16
Signed by: David Renshaw

Create new document

LangSec Sandstorm

4:55:37 AM My grain
Sandstorm Application Hosting
User’s Perspective

https://main.sandstorm.acm.jhu.edu/shared/pruMzgByO3ReRVV9tT5uQQyhwXJulmoMCSNSFutPjXJ
Sandstorm Application Hosting
Supervisor’s Perspective

Supervisor tracks *capabilities* conveying *rights* to grains:

- Each application specifies a collection of rights.
  - ShareLaTeX: “read”, “write”
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  - When grain is created, owner gets *all* rights.
  - *Nobody else gets any rights*
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- Users *delegate* access to grains:
  - Creates a new capability object held by designated user(s) or within a sharing link.
  - Delegated access is a *subset* of delegator’s access.
  - Sandstorm tracks *provenance* of rights & adjusts.
Sandstorm Application Hosting

Supervisor’s Perspective

Supervisor juggles sessions: user’s live connection to a grain.

- Grains started and stopped by supervisor as needed.
Sandstorm Application Hosting
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- Grains started and stopped by supervisor as needed.
- At session startup, the grain is told what rights the initiator has to the grain.
  - Each request by a user will be part of a session. *Application just needs to check that request is permitted by session’s rights.*
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- At session startup, the grain is told what rights the initiator has to the grain.
  - Each request by a user will be part of a session. *Application just needs to check that request is permitted by session’s rights.*
- Web sessions on *random hostnames* (anti-XSRF, -XSS).
  - Not as good as if application didn’t have bugs, but ups ante to require that attacker can see client traffic.
**Sandstorm Application Hosting**

**Application’s Perspective**

Grain subject to extremely fine sandboxing:

- Filesystem (private mount namespace) contains *only*:
  - grain’s application mounted read-only
  - grain’s data mounted read-write
  - Minimal collection of “device” nodes
- Native network access limited to “dummy” interface.
- Many syscalls are disabled via seccomp-bpf.
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Sandstorm Application Hosting
Application’s Perspective

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- Outbound network requests overseen by supervisor!
- Inbound requests, naturally, too.
- Uses “Cap’n Proto” capability-based RPC.
Sandstorm project claims

95% of (application) security issues automatically mitigated, before they were discovered.

That is borne out by the data:

- 20 CVEs in sampled applications (some restrictions apply)
  - Only one, an XSS exploit, was not fully mitigated.
  - All path traversal bugs (4) mooted.
  - Most code injection bugs (2 of 3) required write access to the grain to execute; 3rd in typically unshared grains.
  - Authn (3) & authz (2) bugs eliminated: supervisor’s job!
- Additionally: 27 (of 224) Linux kernel CVEs considered; only 3 pose threat to Sandstorm hosts.
However, capabilities and sandboxing are not a panacea!

- Still possible to have bad authz checks in applications.
- May be difficult to draw sandbox boundaries neatly in all cases; authz, path traversal, and/or code injection bugs here could still lead to unintentional information disclosure.
The hope is that this approach...

- *rules out or confines damage from certain classes of bugs*
- *makes it easier to write secure multi-user applications*
- Provides new slogan and grounds for LangSec: “*Every well-formed request is authorized*” means that *parsers* become the place for authn checks.
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Questions?