NICTA

seL4 Enforces Integrity

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Australian Government
Department of Broadband, Communications and the Digital Economy
Australian Research Council

NICTA Funding and Supporting Members and Partners

Introduction

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- Proving integrity holds in seL4 is a good exercise in frustration.

Overview

Talk overview:

1. Integrity overview
2. Previous work: Composability and Comparability
3. Integrity for seL4
4. Proof of integrity

Integrity

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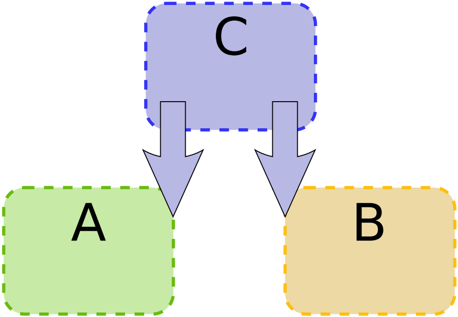

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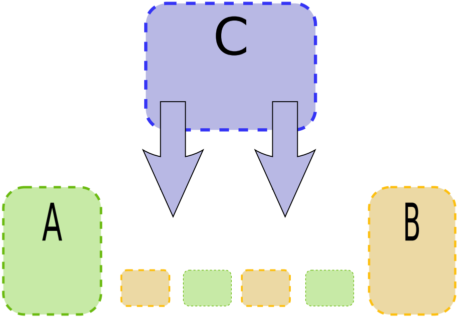

Previous Work: L4.verified

Previous work on seL4 includes the L4.verified project, which proved its functional correctness.

Harvey Tuch, Gerwin Klein and Gernot Heiser. **OS Verification - Now!** In Proceedings, 10th HotOS 2005.

Gerwin Klein, Kevin Elphinstone, Gernot Heiser, June Andronick, David Cock, Philip Derrin, Dhammika Elkaduwe, Kai Engelhardt, Michael Norrish, Rafal Kolanski, Thomas Sewell, Harvey Tuch and Simon Winwood. **seL4: Formal verification of an OS Kernel.** In Proceedings, 22nd SOSP 2009.

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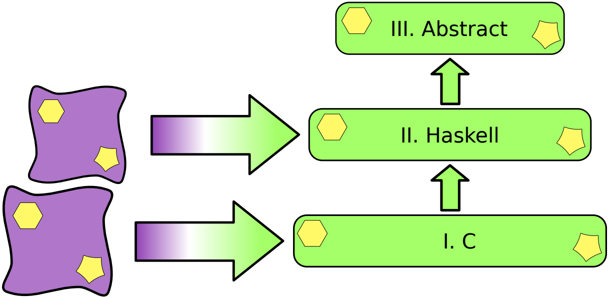

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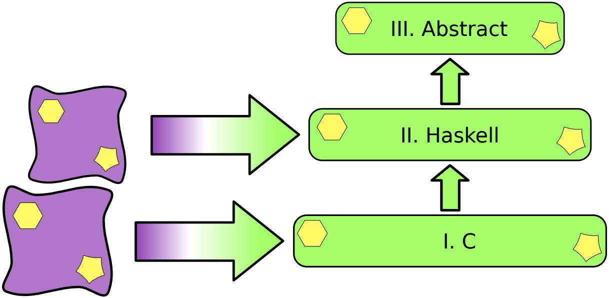

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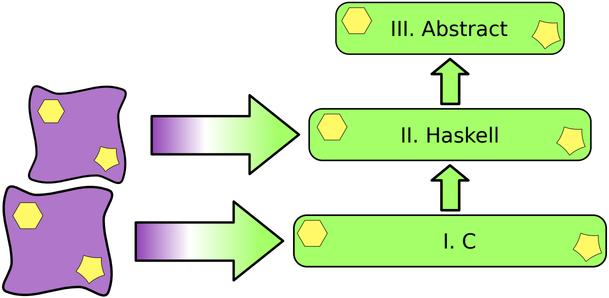

Hoare triples $\{P\}$ f $\{Q\}$ compose down these refinement proofs modulo the abstraction/refinement relation.

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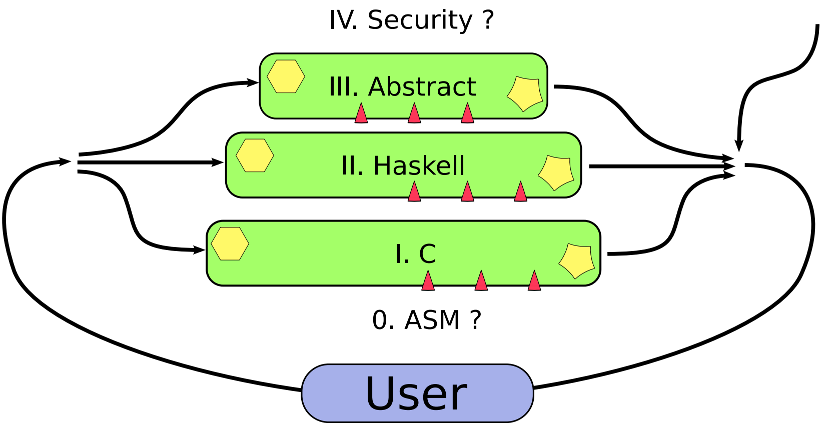


IV. Security ?

III. Abstract

II. Haskell

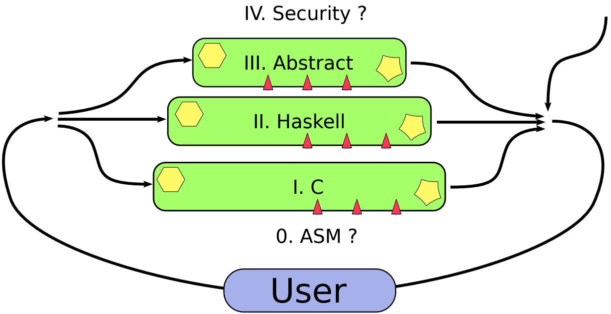
I. C

0. ASM ?

User

Previous Work: Verisoft

The Verisoft project addressed all the hardware-related issues by designing the hardware.



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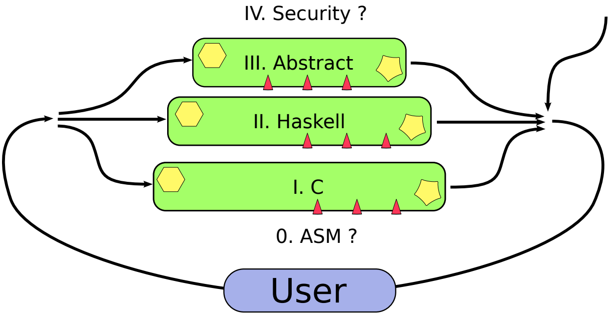

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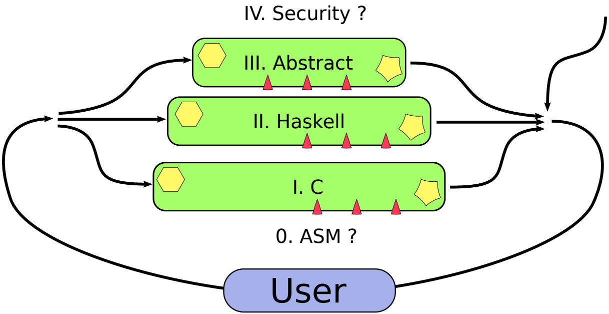

Verisoft also had defining property for their kernel: simulating multiple machines. This is a **policy**.

The seL4 Permission Model

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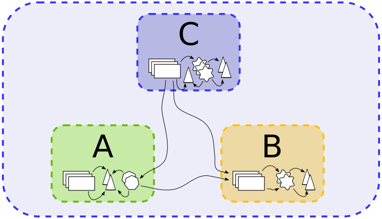
Capabilities can be created, moved, sent through communcation channels and shared between threads.

Integrity Property



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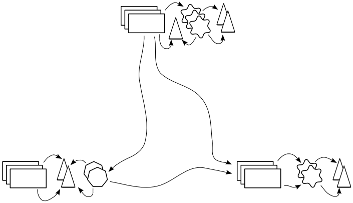

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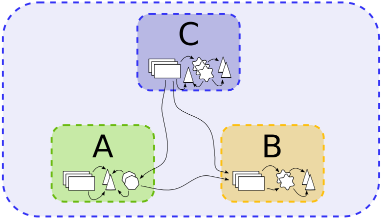

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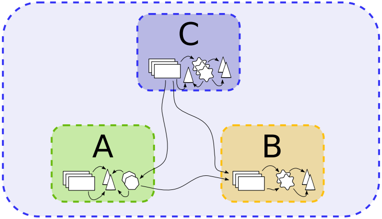
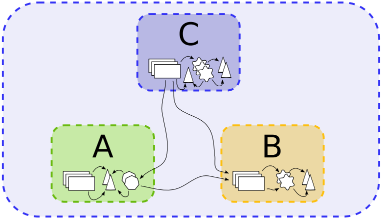


abstraction :: obj-ref ⇒ α

policy :: $(\alpha \times \text{auth} \times \alpha)$ set

Integrity Property: Requirements

The kernel comes with **no explicit policy** about the way untrusting components may interact.



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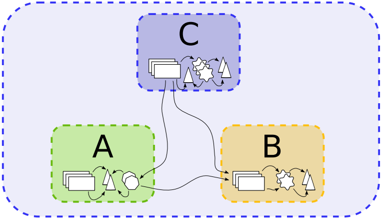

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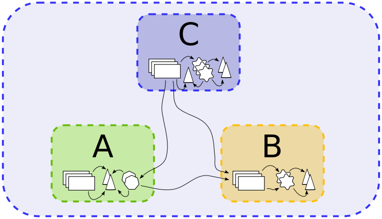
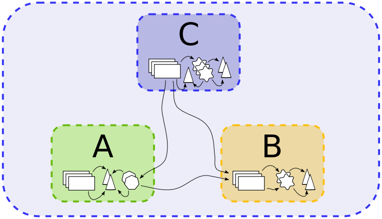
There are also Grant and Reset constructors. See the paper.

Integrity Policy: Controllers



A & B	Integrity & Authority Confinement
C	??

Integrity Policy: Controllers



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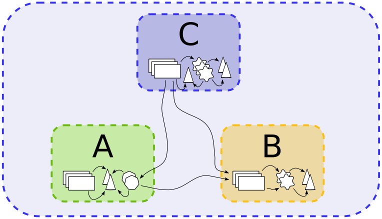

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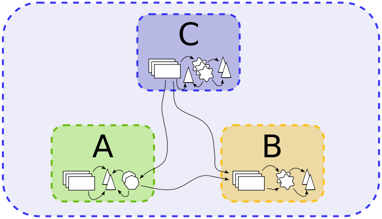

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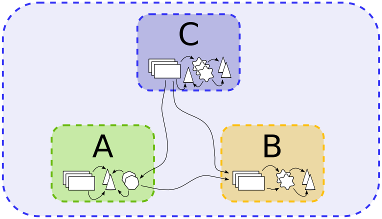

A & B	Integrity & Authority Confinement
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Fine grained analyses like Take-Grant deal poorly with this case.

We can handle some dynamic cases this way.

Integrity Property: PAS

We define the PAS record:

$$\begin{array}{lrcl} \text{record } \alpha \text{ PAS } = & \text{pasPolicy} & :: & (\alpha \times \text{auth} \times \alpha) \text{ set} \\ & \text{pasAbs} & :: & \text{obj-ref} \Rightarrow \alpha \\ & \text{pasSubject} & :: & \alpha \end{array}$$

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The PAS record is a **constant** parameter to all analysis.

Integrity Property: Definition 1

Definition

pas-wellformed *pas* $\equiv$
$\forall\, y.\ (\text{pasSubject } pas, \text{Control}, y) \in \text{pasPolicy } pas$
$\longrightarrow y = \text{pasSubject } pas$

The current subject cannot have Control authority over any other.

Integrity Property: Definition 2

Definition

pas-refined *pas* *s* $\equiv$
    $\forall$ (x, *auth*, y) $\in$ system-auth *s*
        $\rightarrow$ (pasAbs *pas* x, *auth*, pasAbs *pas* y) $\in$ pasPolicy *pas*

All authority in the system must be permitted in the policy.

Integrity Property: Definition 3

Definition

integrity *pas s s'* $\equiv \ldots$

The subject is allowed to cause this transition. Describes what is allowed by Read, Write, Send, Receive and Control.

More details are in the paper.

Integrity Property: Hypothesis

We set out to prove two Hoare triples.

Integrity:

$\forall \mathit{pas}\ s\ e.$ pas-wellformed $\mathit{pas} \rightarrow$ pas-refined $\mathit{pas}\ s \rightarrow$

$\quad \{s\}$ call-kernel e $\{s'.$ integrity $\mathit{pas}\ s\ s'\}$

Confinement:

$\forall \mathit{pas}\ e.$ $\{s.$ pas-wellformed $\mathit{pas} \wedge$ pas-refined $\mathit{pas}\ s\}$

$\quad$ call-kernel e $\{s.$ pas-refined $\mathit{pas}\ s\}$

Proofs

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Lemma receive-async-ipc-pas-refined:

∀ *pas cap*. {*s*. pas-refined *pas s* ∧
(∀ *aepptr* ∈ obj-refs *cap*. pasAbs *pas t*, Receive, pasAbs *pas aepptr*)
∈ pasPolicy *pas*)}
receive-async-ipc *t cap*
{*s*. pas-refined *pas s*}

Lemma receive-async-ipc-integrity:

∀ *pas cap st*. {*s*. integrity *pas st s* ∧ pas-refined *pas s* ∧ valid-objs *s*
∧ pasAbs *pas t* = pasSubject *pas* ∧ (∀ *aepptr* ∈ obj-refs *cap*. pasAbs
pas t, Receive, pasAbs *pas aepptr*) ∈ pasPolicy *pas*)}
receive-async-ipc *t cap*
{*s*. integrity *pas st s*}

Proofs: History

We've done this before.

David Cock, Gerwin Klein and Thomas Sewell. **Secure Microkernels, State Monads and Scalable Refinement.** In Proceedings TPHOLs 2008.

Conclusions

- Defined Integrity for seL4, and not the textbook way.
- Proven that seL4 Enforces Integrity.