Tool-Assisted Specification and Verification of the JavaCard Platform

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New generation smartcards

- Flexibility
  - High-level language for developing applets
  - Multi-application and post-issuance
- New Security Threats
  - Confidentiality
  - Integrity
  - Availability

Formal verification for smartcards

- Motivations
  - Complex software with high demands on securit[y]
  - Common Criteria require formal methods at leve[l] EAL5-EAL7

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  - Complex software with high demands on security
  - Common Criteria require formal methods at levels EAL5-EAL7
- Focus
  - Platform vs. program verification
  - Bytecode vs. source level

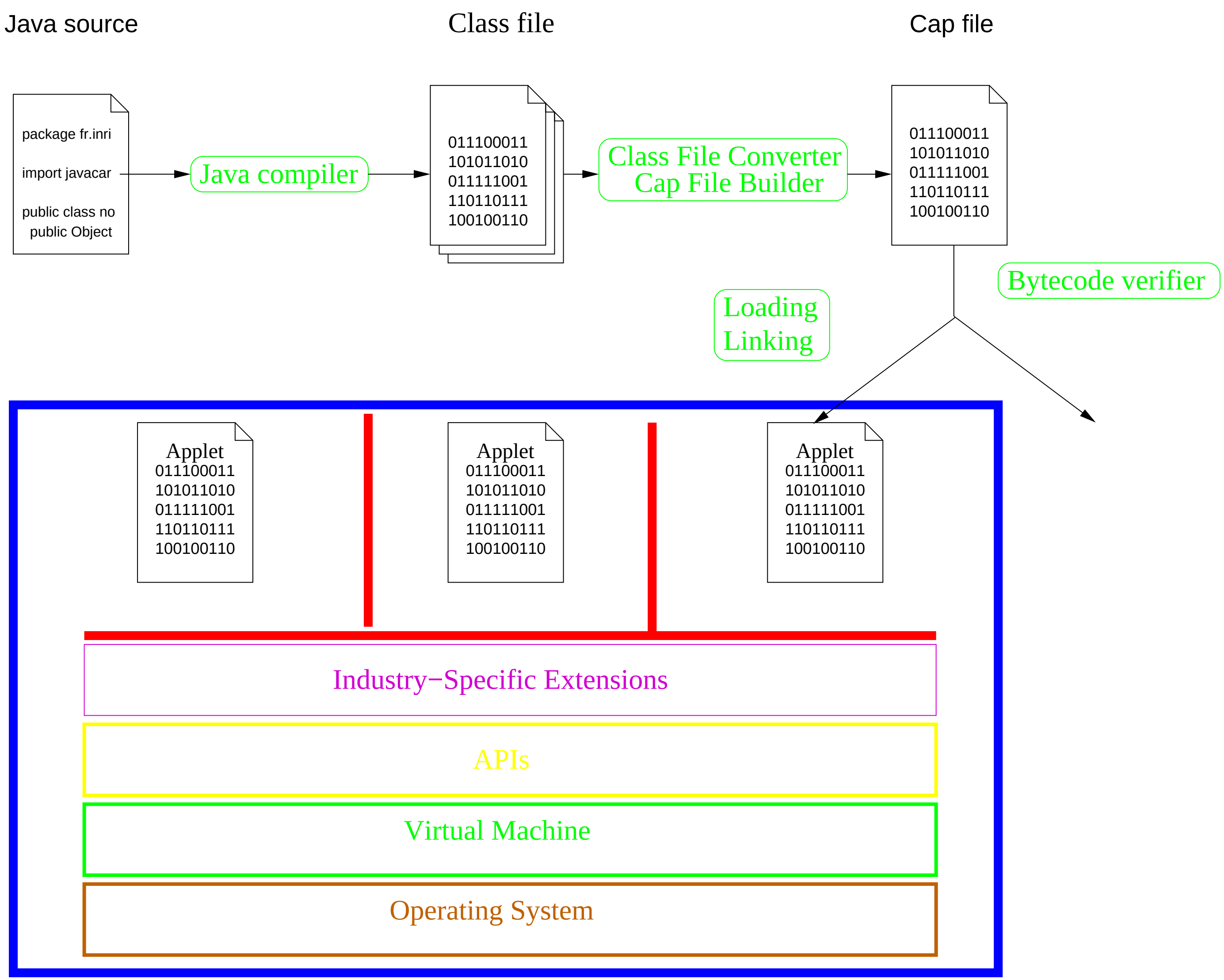
Overview

- JavaCard
- CertiCartes: verification of the JavaCard platform
- Jakarta: tool support for specification and verificatio of virtual machines

JavaCard

- A superset of a subset of Java:
  - A subset: no large datatypes, security manager, dynamic class loading, (garbage collection). . .
  - A superset: firewall, entry points, shareable interfaces, transactions, etc.
- JavaCard programs use the JavaCard APIs

The JavaCard Platform



CertiCartes

Formal specification/verification of:

- JCVMs: small-step semantics

```
exec: state -> returned_state
```

  - written in Coq but use a neutral style
  - executable with the JCVM Tools
- BCV: executable in Caml
- part of the JCRE

Program model

```
Record jcprogram : Set := { interfaces : (list Interfac
                             classes    : (list Class);
                             methods    : (list Method)
Record Method : Set := {
 is_static      : bool;
 signature      : ((list type)*type);
 local          : nat;                    (* Number of local
 handler_list   : (list handler_type); (* Exception hand
 bytecode       : (list Instruction);  (* instructions to
 method_id      : method_idx;             (* Index of the me
  owner          : class_idx              (* Index of the ov
```

Memory model

- Stack as a list of frames

```
Record frame : Set := {
   locvars          : (list valu);        (* Local Vari
   opstack          : (list valu);        (* Operand st
   p_count          : bytecode_idx;       (* Program co
   method_loc       : method_idx;         (* Location o
   context_ref      : package;            (* Context In
```

- State

```
Definition state := static_heap*heap*stack.
```

Instruction

```
Definition NEW := [idx:cap_class_idx][state:jcvm_state]
Cases (stack_f state) of
(cons h lf) =>
  (* Extract the owner class from thew cap_file *)
  Cases (Nth_elt (classes cap) idx) of
  (* then a new instance is created and pushed into the heap *)
  (Some cl) => let new_obj = ... in
      (Normal
         (Build_jcvm_state
            (sheap_f state)
              (app (heap_f state) new_obj)
 (* the reference of the created object is pushed  into the opstack *)
 (cons
   (update_opstack (cons (vRef (vRef_instance idx (S (length (heap_f state)
           lf))) |
    None => (AbortCode class_membership_error state)
  end |
_ => (AbortCode state_error state)
```

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- Abstract JCVM used in bytecode verification:
  - Manipulates types as values
  - Operates on a method-per-method basis

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Best viewed as some form of correctness of abstract interpretations

Offensive vs. Defensive

- Abstraction function: $\alpha_{do} : (t, z) \mapsto z$

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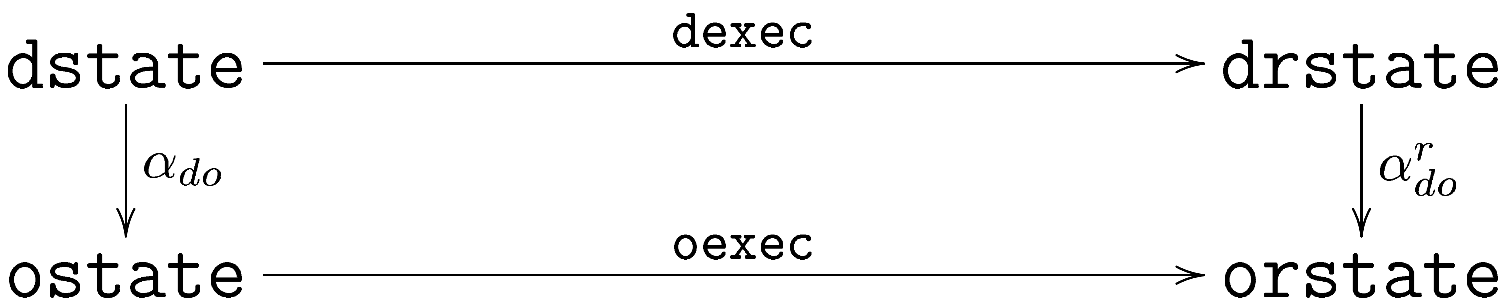
- Diagram commutes



if defensive VM does not raise typing errors

Abstract vs. Defensive

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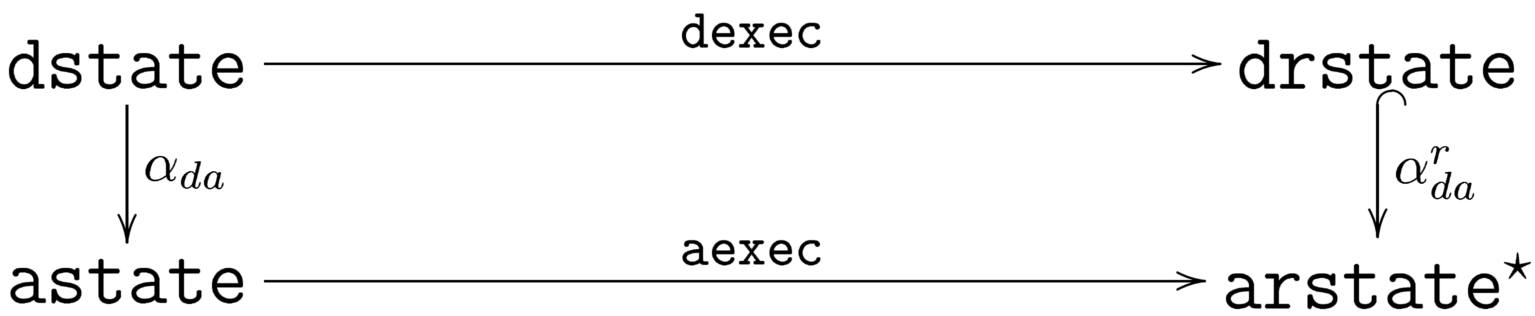

if “execution keeps in the same frame”

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- Defensive and offensive machines coincide on programs that pass bytecode verification
- Proof builds upon commuting diagrams, correctness of DFA, methodwise verification, and monotonicity of abstract VM

Assessment

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- The methodology works well and could be used for other analyses
- High-level of automation is possible
- Specifications use a restricted language and proofs use well-understood techniques

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- Designed to support:
  - executable specifications
  - abstractions (and refinement) of specifications
  - automation of correctness proofs

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  - the abstract virtual machine is monotone

Jakarta Specification Language

- JSL types are first-order polymorphic types
- JSL expressions are first-order algebraic terms

$$\mathcal{E} := \mathcal{V} \mid \mathcal{E} == \mathcal{E} \mid c\,\vec{\mathcal{E}} \mid f\,\vec{\mathcal{E}}$$

- Functions defined by conditional rewrite rules

$$l_1 \twoheadrightarrow r_1, \ \ldots\ , l_n \twoheadrightarrow r_n \Rightarrow g \rightarrow d$$

where r_i are patterns with fresh variables

Compiling JSL Specifications

- Specifications are executed by rewriting engines
- Deterministic specifications are compiled into case-expressions then CAML, Coq, Isabelle, PVS
- Non-deterministic specifications $f : \sigma \to \tau$ are translated into $f^\star : \sigma \to \tau^\star$
- Partial specifications $f : \sigma \to \tau$ are translated into $f_\perp : \sigma \to \tau_\perp$

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- Not a legal rule: substitution and cleaning steps declared in abstraction scripts
- Generated offensive and abstract JCVMs

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- Built tactics that reduce $\forall \vec{x}.\ \phi(\vec{x}, f\ \vec{x})$ to

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- Exploiting abstraction scripts seems promising

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- Cross-validation of the VMs for 2/3 of bytecodes
- Now applying Spike to prove the monotonicity of abstract VM

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- For further information www.inria.fr/lemme/verificar[d]