Lightweight verification of customizable policies for mobile devices through program slicing

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1. Introduction
2. Overview of approaches to mobile code security
3. Model Generation
4. Further Work

Importance of mobile code security

- Applications today may run anywhere, with data and code moving freely between servers, PC's and portable devices.
- Since mobile code gets executed with the privileges of the user who downloaded the code the risk of damage due to malicious or faulty mobile code is very high.
- Many of the techniques currently deployed in computer security are not effective when it comes to mobile code.

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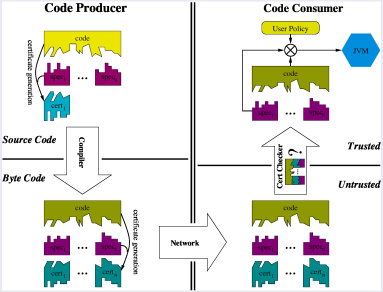
Approaches to Mobile Code Security

The ongoing use of mobile devices has motivated intensive research focused on deploying techniques suitable for ensuring security of mobile code:

- Sandboxing
- Proof Carrying Code [2, G.Necula, 1997]
- Model Carrying Code [4, Sekar et al, 2001]
- **Sound** Model Carrying Code

Proof Carrying Code

Overview



Description

- Code producer establishes security properties.
- Code producer performs a mathematical proof (certificate) stating that the code satisfies the property.
- Code consumer receives code and certificate and mechanically checks that the certificate is valid.

Caveats

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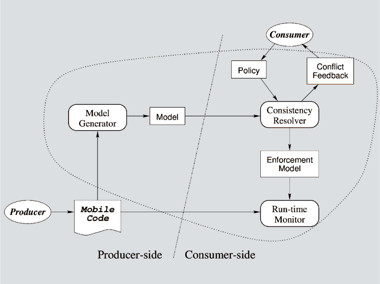
- Certificate is not reusable. If the policy changes a new certificate must be constructed.

Model Carrying Code

Overview



Description

- Producer generates mobile code and program model.
- Consumer receives mobile code and model.
- Consumer mechanically checks wether the model conforms the policy.
- Based on the outcome, consumer may refine its security policy.

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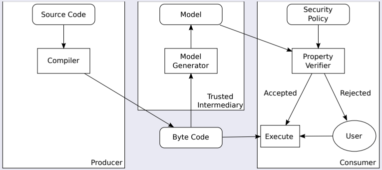
- The generated models in this work are unsound. Therefore, the fact that the model satisfies the security policy does not guarantee that the actual program does.
- An enforcement model, with the consequent computational overhead, is instrumented even when the model satisfies the security policy.

Sound Model Carrying Code

Overview



Sound Model Carrying Code

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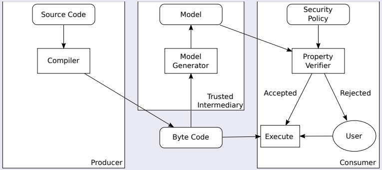

Description

- Producer writes source code and compiles it.
- Trusted intermediary generates model and digitally signs bytecode and model.
- Consumer mechanically checks wether the model conforms its policy.
- If the property is verified, program is authorized to be executed, otherwise, user may choose wether to execute it.

Contributions

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- allows model reuse.
- does not put any additional burden on code producer side.
- allows code consumer to customize the security policies.

Key Issues

How do we generate *sound* models?

We use program slicing[1, Hatcliff et al,1999]. When stating slicing correctness one proves:

$$P \equiv_C P_S$$

This notion of equivalence needs to entail soundness:

$$\Phi(P_S) \Rightarrow \Phi(P)$$

where Φ is a property.

Key Issues

Which language is suitable for expressing *high level* security properties?

We use a fragment of LTL. The idea is that the user will be able to specify properties such as:

- bounds on resource usage, e.g. this program will not send more than 3 SMS. (Safety property).
- protocol enforcement, e.g. every time a file is opened it should be eventually closed. (Liveness property).

Key Issues

How do we check wether a model conforms a security policy?

- We transform the model to obtain a finite state space model and then we perform exhaustive verification.
- This transformation is made based on the assumption that we have lower and upper bounds on the amount of iterations of every loop.
- This can be obtained either by forcing the programmer to insert annotations on loop headers or by performing conservative static analysis.
- So far we can treat loops with linear updates, and linear loop bounds

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This will be the focus of the rest of the talk.

The Language: Syntax

The abstract syntax of the instructions is the following:

$$\begin{array}{lcl} i & ::= & nop \mid x := e \mid goto\ l \mid ifeq\ e\ l \mid call\ f(e \ldots e) \\ e & ::= & e \oplus e \mid x \mid v \end{array}$$

where

- x ranges over *Var* (variable names)
- l over *Loc* (locations)
- v over integers
- f over *Func* (function names)
- $\oplus$ represents common binary operations

The programs are abstracted as functions betwen locations *Loc* and instructions i.

The Language: Semantics

We define the structural operational semantics of the language in terms of the following:

- The state of the variables of the computation will be abstracted by
  $\Sigma = Var \rightarrow \mathbb{Z}$
- The set of non-terminal states of the program is captured by:
  $\Gamma_{NT} = Loc \times \Sigma$
- The set of terminal states of the program is captured by:
  $\Gamma_{T} = \Sigma$
- We assume the existence of a semantic function for expressions:
  $[\![\_]\!]_{Exp} : Exp \rightarrow \Sigma \rightarrow \mathbb{Z}$

The Language: Semantics (cont.)

We define the transition relation $\rightsquigarrow \subseteq \Gamma_{NT} \times \Gamma_T$ as the least relation satisfying the following rules:

$$\frac{P\ l = x := e \qquad [\![e]\!]_{Exp}\sigma \ = v}{(l,\sigma) \rightsquigarrow (succ(l), [\sigma \mid x : v])}$$

$$\frac{P\ l = goto\ l'}{(l,\sigma) \rightsquigarrow (l',\sigma)}$$

$$\frac{P\ l = ifeq\ e\ l' \qquad [\![e]\!]_{Exp}\sigma \ = 0}{(l,\sigma) \rightsquigarrow (succ(l),\sigma)}$$

$$\frac{P\ l = nop}{(l,\sigma) \rightsquigarrow (succ(l),\sigma)}$$

$$\frac{P\ l = call\ f(e_1 \ldots e_n)}{(l,\sigma) \rightsquigarrow (succ(l),\sigma)}$$

$$\frac{P\ l = return}{(l,\sigma) \rightsquigarrow \sigma}$$

$$\frac{P\ l = ifeq\ e\ l' \qquad [\![e]\!]_{Exp}\sigma \ \neq 0}{(l,\sigma) \rightsquigarrow (l',\sigma)}$$

The Language: Control Flow Graph

A control flow graph $G = (N, E, n_0, e)$ is a labeled directed graph in which:

- N is the set of nodes that represent the statements in the program.
- E is the set of labeled edges that represents the control flow between graph nodes.
- n_0 is the start node.
- e is the end node.
- We assume the programs satisfy the *unique end node property*.
- We assume the programs yield *reducible graphs*.

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  3. We transform the instructions of the program depending on wether the node corresponding to them appears in S_c.

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The slice set is then defined as:

$$S_C \quad = \quad \{m : m\underbrace{(\overset{dd}{\rightarrow} \cup \overset{cd}{\rightarrow} \cup \overset{\Omega d}{\rightarrow})^*}_{d} n, n \in C\}$$

Slicing Transformation

Given program p the residual program p_s has the same nodes as p but its codemap is modified as follows:

1. forall $n \in S_C, code_2(n) = code_1(n)$.
2. forall $n \notin S_C$ we have the following cases:
   1. If $code_1(n) = goto\ m$ then $code_2(n) = goto\ m$
   2. If $code_1(n) = ifeq\ e\ m$ then $code_2(n) = goto\ k$ where k is the nearest postdominator of nodes $n + 1$ and m.
   3. If $code_1(n) = return$ then $code_2(n) = return$
   4. Else $code_2(n) = nop$

Correctness

Correct slice

Now, p_s is a correct slice of p w.r.t. C if for any initial store σ, the initial states are C-bisimilar [3, Ranganath et al,2007].

We have shown that:

- the slicing transformation defined previously produces correct slices w.r.t. to the last definition.
- the notion of correct slice entails soundness, that is, if a property is valid on the slice then is also valid on the original program.

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Further work

- Extend the model conformance checking techniques: beyond linear updates in loops.
- Extend these ideas other language constructions: data types, abstraction, etc.
- More examples.
- Identify a class of properties for which this approach is also complete.
- Implementation.

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