Analyzing Android Applications with Abstract Interpretation

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Motivation

We aim to use abstract interpretation to provide a static analysis for verifying fine-grained application permissions on the Android platform.

The current Android permission model offers coarse, per-application specifications. This enables an app's sub-programs to abuse all the permissions available to the greater host application:

- An advertisement library could access location APIs in a GPS App.
- A malicious user-plugin interpreter embedded in an application could allow arbitrary API usage at run-time.

Method

1. Build a concrete CESK interpreter for Dalvik bytecode.
2. Turn concrete into abstract by removing infinite structures

   Abstract Domains: abstract value spaces as finite lattices. We use a flat domains: 'string, 'number, etc.

   Addresses: restrict address allocation to be finite, make the store map addresses to sets of values, and use joins in place of strong updates.

   Frame Pointer & Time: let time be the last k statements and use the current time for frame pointer allocation.
3. Compute a sound approximation of visited states using this abstracted CESK interpreter. Perform a reachability analysis on the set of visited states.

Background

Dalvik bytecode is a register-based variant of the Java bytecode used by the Android platform.

(new-instance v0 java/lang/StringBuilder)
(invoke-virtual {v0 v1} java/lang/StringBuilder/append [object java/lang/String])

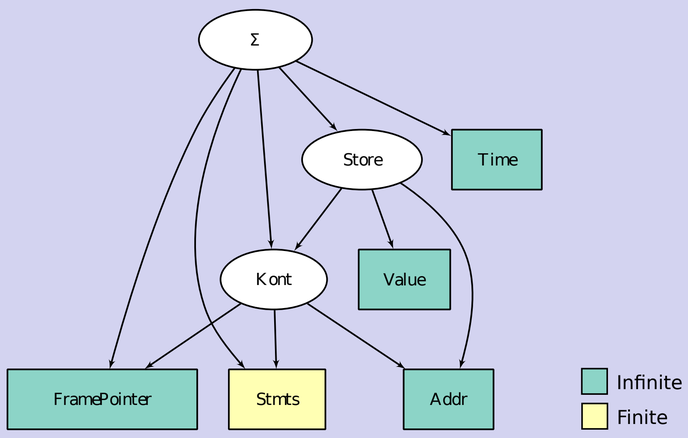
Abstract interpretation is a sound, terminating approximation of a program's concrete interpretation.

CESK machine is an abstract state machine consisting of Control, Environment, Store and Kontinuation components.

$\varsigma \in \Sigma = Stmts \times FramePointer \times Store \times Kont \times Time$
$fp \in FramePointer$ an infinte set
$\sigma \in Store = Addr \rightharpoonup_{fin} Value$
$\kappa \in Kont = \mathbf{fnk}(Stmts,\ fp,\ a_\kappa) \mid \mathbf{halt}$
$a \in Addr = RegAddr \mid HeapAddr \mid KontAddr$
$a_r \in RegAddr = (fp,\ register)$
a_h, a_κ are elements in an infinte set
$t \in Time$ an infinite set

$alloc : \Sigma \to FramePointer$
$tick : \Sigma \to Time$

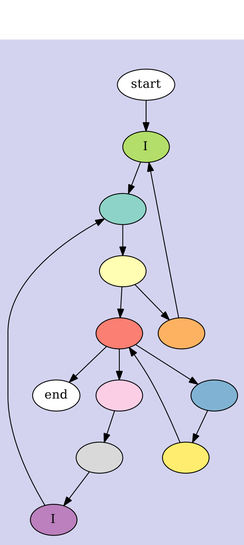
Time-stamped CESK* machine state space



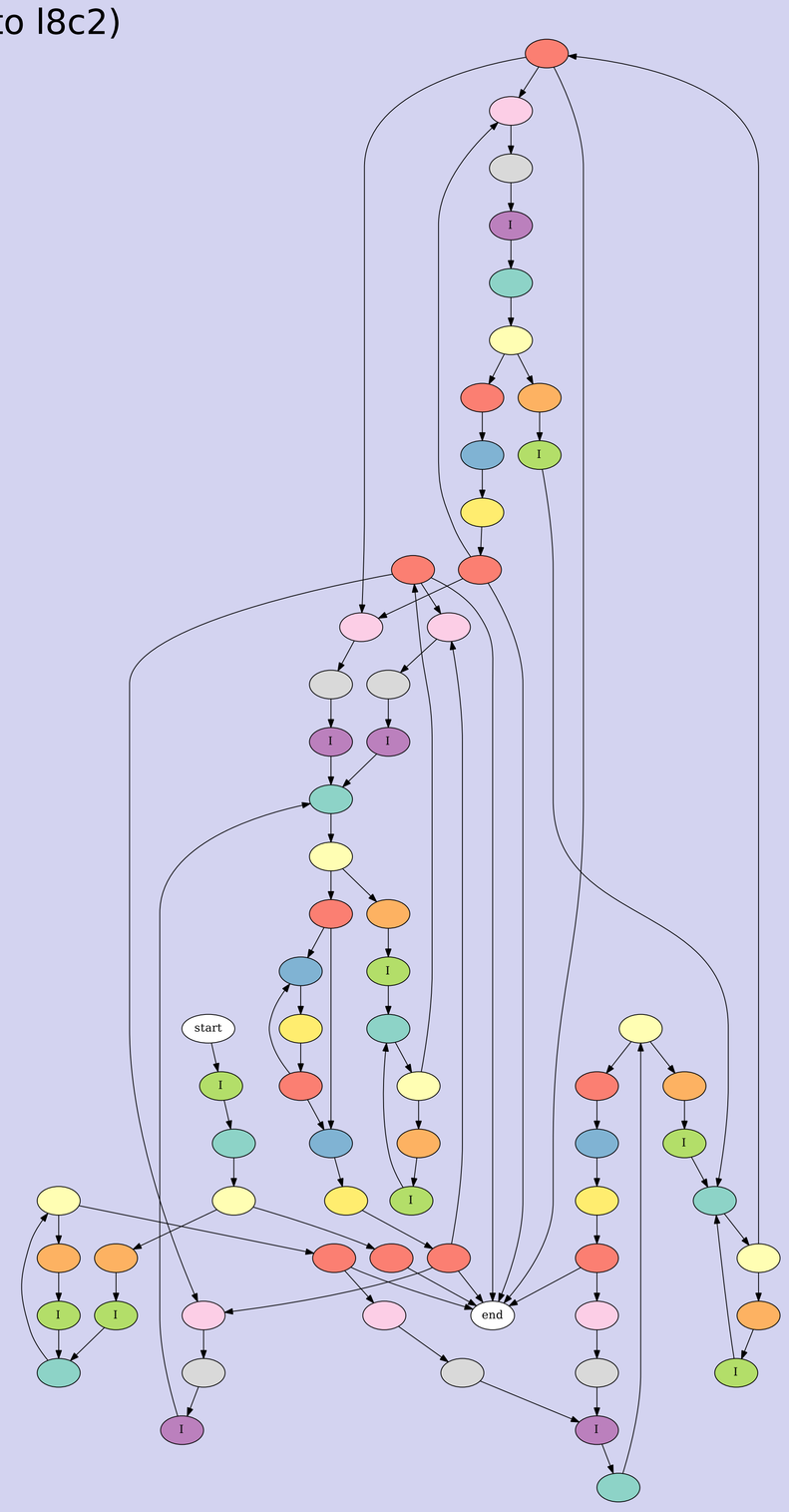
Time-stamped CESK* state space dependency graph

Results

```
(method (attrs public static) fib(int)int
  ; parameter[0] : v2 (int)
  (const/4 v0 1)
  (if-gt v2 v0 l8c4)
  (label l8c2)
  (return v2)
  (label l8c4)
  (add-int/lit8 v0 v2 255)
  (invoke-static {v0} org/ucombinator/FibonacciApp/fib int)
  (move-result v0)
  (add-int/lit8 v1 v2 254)
  (invoke-static {v1} org/ucombinator/FibonacciApp/fib int)
  (move-result v1)
  (add-int v2 v0 v1)
  (goto l8c2)
)
```



Control flow graph of Fibonacci



Abstract 1-CFA visited states graph of Fibonacci