JFlow*

CS 6301-002: Language-based Security

Kevin W. Hamlen

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Information Flow Control

- Goal: Write software that avoids divulging secrets
- Information flow policies
  - programmer labels secret sources (input parameters, input channels, variables)
  - everything else is assumed attacker-viewable
  - enforcement detects/blocks flows from secret to public
- Traditional approach: taint tracking
  - label all values with runtime confidentiality level
  - detect policy-violating flows at runtime
  - disadvantage: very high runtime overhead (space & time)
  - disadvantage: few pre-deployment guarantees
Language-based Information Flow Control

- **Additional Goals**
  - detect as many flow violations as possible at compile-time ("mostly static")
  - support large, versatile policies (distributed label model)
  - use a normal(ish) programming language (Java)
  - support common language features (objects, subclassing, dynamic typing, exceptions, ...)
  - support controlled declassification

- **Approach:** Encode classifications and flow tracking as types!
  - type-checker detects most policy violations
  - compiler inserts dynamic tests for remaining flows
  - type-checker proves integrity of dynamic tests (!)
Decentralized Label Model

- **Principal** – an entity with a security interest
  - Examples: customer, shipping department, billing department
  - each principal “owns” certain data
- **Principals** specify may-read policies for owned data.

\[
\text{int}\{o_1: r_1, r_2\} \ x; \ // \ o_1 \text{ says only } r_1 \text{ and } r_2 \ (\text{and } o_1) \text{ may read } x
\]
\[
\text{int}\{o_2: r_2, r_3\} \ y; \ // \ o_2 \text{ says only } r_2 \text{ and } r_3 \ (\text{and } o_2) \text{ may read } y
\]

- **Binary operations** *join* (\(\sqcup\)) operand policies

\[
z = x+y; \ // \text{ now } z \text{ has policy } \{o_1: r_1, r_2; \ o_2: r_2, r_3\}
\]

- **Effective reader set** – intersection of permitted readers
  - Only \(r_2\) may read \(z\)
Label Comparisons

- \( L_1 \sqsubseteq L_2 \)
  - \( L_1 \) is “less restrictive than (or equivalent to)” \( L_2 \)
  - \( L_1 \) is constrained by a subset of the restrictions upon \( L_2 \)

- Examples
  - \( \{o_1 : r_1, r_2\} \sqsubseteq \{o_1 : r_1\} \)
  - \( \{o_1 : r_1\} \sqsubseteq \{o_1 : r_1; o_2 : r_2\} \)

- defines lattice of security labels (\( \sqsubseteq \) is a partial order)
  - reflexive, anti-symmetric, transitive

- basis for defining \( \sqcup \): \( L_1 \sqcup L_2 = \min_{\sqsubseteq}\{L | L_1 \sqsubseteq L, L_2 \sqsubseteq L\} \)

- label-checking and inference based on linear constraint solving

- relative labels: \( \text{int}\{y\} x \)
  - \( x \) is at least as confidential as \( y \)
  - \( \text{label}(y) \sqsubseteq \text{label}(x) \)

- sub-classing / sub-typing
  - can safely up-cast “\((L) x\)” if \( \text{label}(x) \sqsubseteq L \)
  - downcasts must be guarded by runtime type-checks
int{} x;

boolean{o_1 : r_1} b;

x = 0;

if (b) {
    x = 1;
}

Implicit Flow Protection

```java
int{} x;
boolean{o_1 : r_1} b;

:\n
x = 0;
if (b) {    // label(pc) ← label(pc) ▽ label(b)
    x = 1;    // compile-time type-error: label(pc) □ label(x)
}
```
class Account {
    final principal customer;
    final label {customer:} customer_policy;
    float {∗customer_policy} balance;
}

- Principals and labels are first-class.
  - Statically tracked as type variables (α)
  - Dynamically tracked as values (L)
- Static is conservative: \( L \subseteq α \)
  - Programmer must insert dynamic type-checks to avoid compilation errors.
Dynamic Type-checks

```java
void print(principal user, String{user:} s) { ... }

void show_balance(principal user, Account a){
    switch label(a.balance){
        case(Float{user:} z) print(user, z.toString());
        else print(user, “Permission denied”);
    }
}
```
class passwdFile authority(root){
    private String[] names;
    private String{root:}[] pwds;

    public boolean check(String user, String pwd) where authority(root) {
        boolean match = false;
        try {
            for(int i = 0; i < names.length; i++) {
                if(names[i] == user && pwds[i] == pwd) {
                    match = true;
                    break;
                }
            }
        }

        catch(NullPointerException e){}
        catch(IndexOutOfBoundsException e){}
        return declassify(match, {user; pwd});
    }
}
Limitations

- **Threads**: confidentiality not guaranteed for multi-threaded code
  - **Finalizers** are threaded in Java, so excluded from JFlow.
- **Timing channels**: not protected
- **hashCode**: default Java implementation divulges info (how?)
  - Every JFlow class must override hashCode.
- **Static vars**: order of initialization can divulge info
  - No dynamic checks possible in static initializers!
  - Static vars illegal in JFlow
- **Resource exhaustion**: uncatchable in JFlow (1 bit of info divulged)
- **Unchecked exceptions**: excluded from JFlow (rare in Java)
- **Dynamic type discrimination**: only in parameterless classes
Discussion Questions

- Introduced in ’99 (actually earlier). Still not standard. Why?
- Can we verify declassification points?
- What about confidentiality for binary legacy code?
- What about covert channels (power, timing, etc.)?