A Type System for Checking Applet Isolation in Java Card

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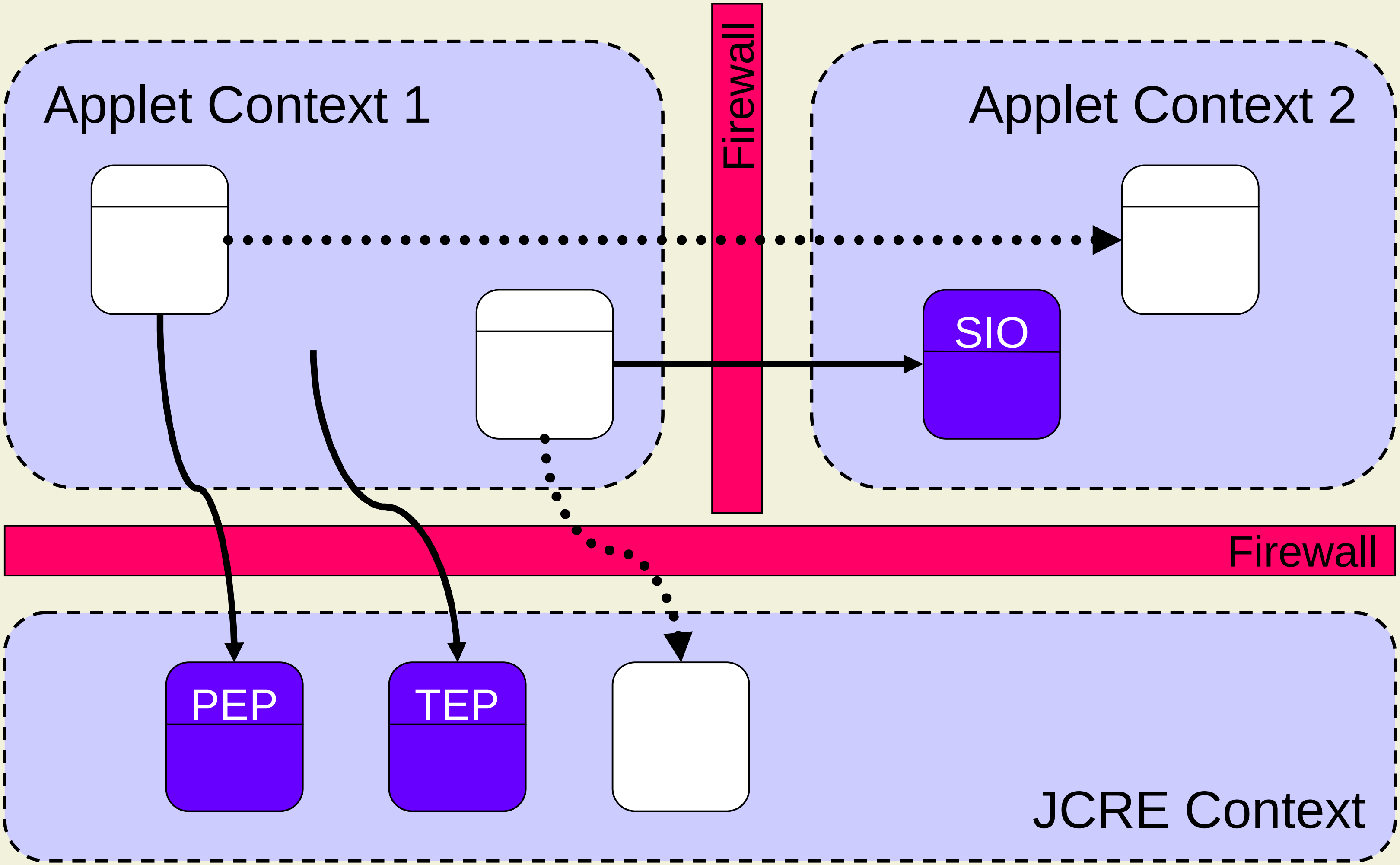
Applet Isolation



Example

```
class Status {
  …
  boolean isSuccess( ) { … }
}
```

```
interface Service extends Shareable {
  Status doService( );
}
```

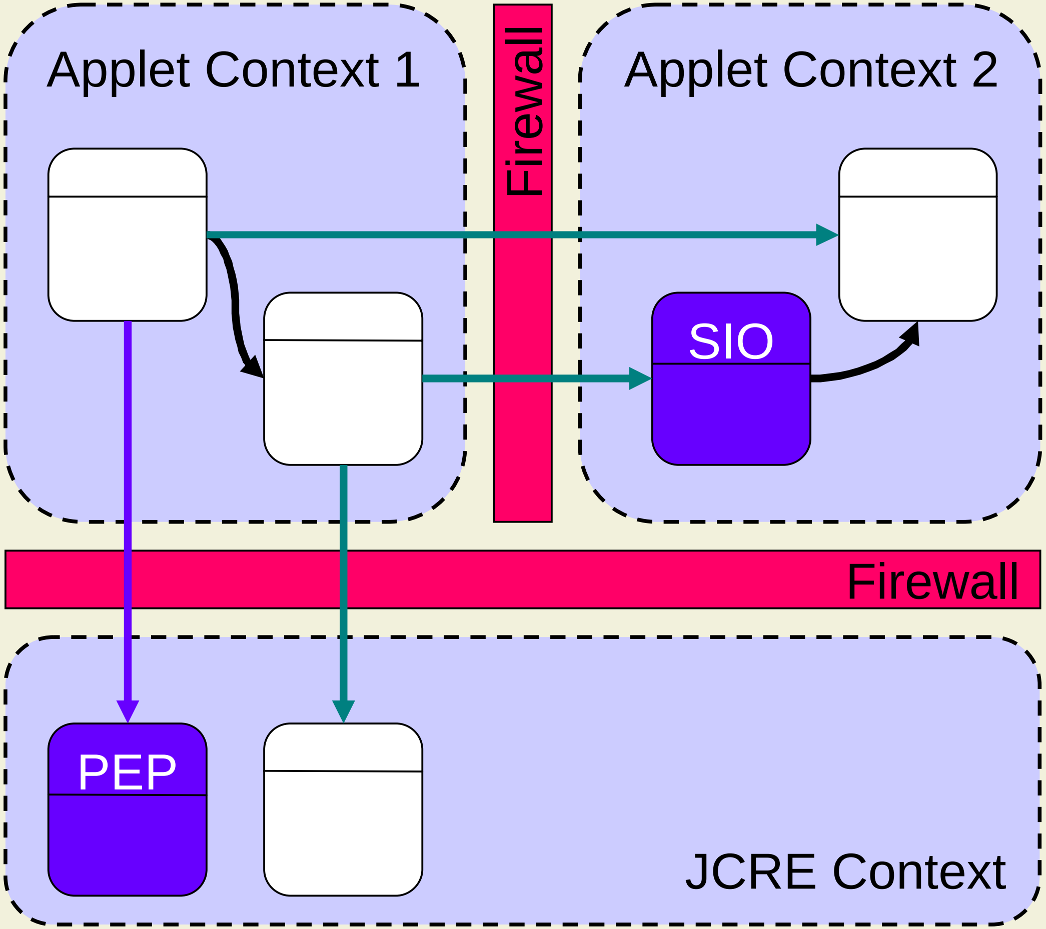
```
class Client extends Applet {
  …
  void process( APDU apdu ) {
    AID          server = …;
    Shareable    s =
          JCSystem.getAppletShareableInterfaceObject( server, (byte) 0 );
    Service      service = ( Service ) s;
    Status       status = service.doService( );
    if ( status.isSuccess( ) ) { … }    // SecurityException raised
} }
```

Motivation

- Formal program verification
  - **Prove absence of SecurityExceptions** for many kinds of expressions
  - Firewall property causes **significant overhead** for specifications and proofs
- Objective
  - **Check** applet isolation **statically**
  - Develop a solution for **source programs**
  - Build on experience with **ownership** and the Universe Type System

Approach

- Use **type system** to classify references to
  - Objects in the same context
  - Objects in any contexts
  - Entry points
- Perform **static checks** to enforce applet isolation

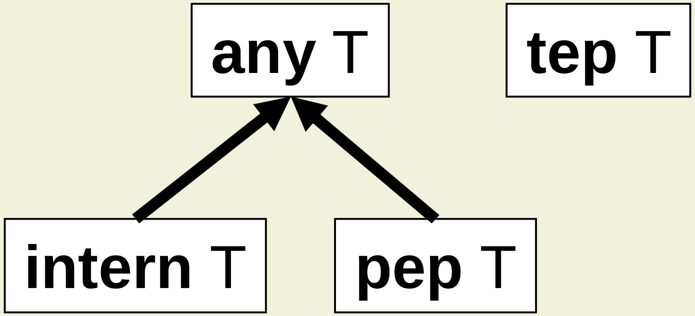


Tagged Types

- Tags
  - **intern**: References within a context
  - **any**: References to any context
  - **pep**: References to permanent entry points
  - **tep**: References to temporary entry points and global arrays
- Tagged types **specify the context** a reference may point into
  - Tagged types are tuples: Tag × Type, e.g., **intern** T

Type Rules

- **intern** and **pep** types are subtypes of the corresponding **any** types



- Type rules for tagged types follow Java’s type rules

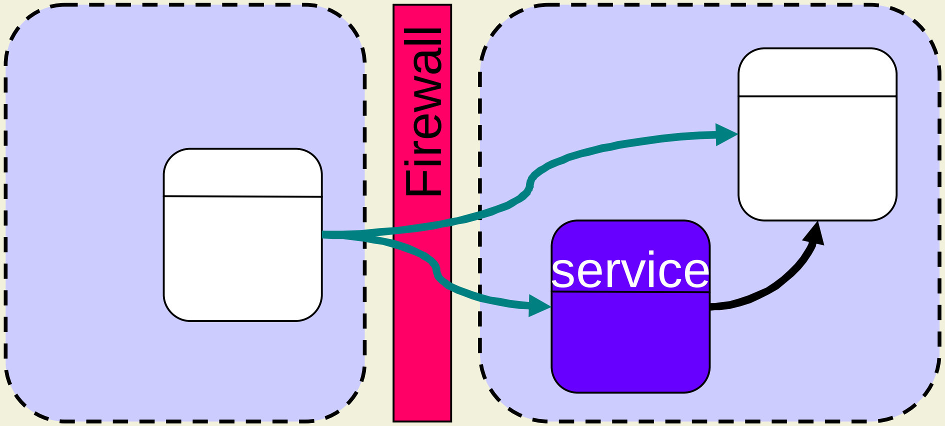
```
void process( tep APDU apdu ) {
 intern AID        server = …;
 any Shareable  s =
     JCSystem.getAppletShareableInterfaceObject( server, (byte) 0 );
 any Service       service = ( any Service ) s;
 ??   Status        status = service.doService( );
 if ( status.isSuccess( ) ) { … }                                              }
```

Method Invocations

- Tag intern specifies context **relatively** to the current context
- For method invocations, parameter and result types have to be interpreted **relatively** to the tag of the target

```
interface Service extends Shareable {
  intern Status doService( );
}
```

```
any Service service = …;
any Status   status = service.doService( );
```



Type Combinations

- Type combinator *

$$(H,T)*(G,S) = \begin{cases} (\textbf{any},S) & \text{if } H \neq \textbf{intern} \text{ and } G = \textbf{intern} \\ (G,S) & \text{otherwise} \end{cases}$$

- Type rule for method invocations

$$\frac{\vdash e1 :: (H,T)\ ,\ \vdash e2 :: (G,S)\ ,\ (H,T)*(G,S) <: (F_P,T_P)}{\vdash e1.m(\ e2\ ) :: (H,T)*(F_R,T_R)}$$

Dynamic Type Checks

- Casts
  - Downcasts from **any** types to corresponding **intern** and **pep** types require dynamic checks
  - In practice only necessary for static fields (no **intern** tag)
  - Casts may throw SecurityException

- Covariant arrays
  - **intern** T[ ] and **pep** T[ ] are **not subtypes** of **any** T[ ]
  - **Avoid dynamic check** for assignments to array slots

Static Firewall Checks

- Method invocation e.m(…)
  - (H,T) is the static tagged type of e
  - If H is **any**, T has to be an interface that extends Shareable

- Field access e1.f = e2
  - Static type of e1 must have tag **intern**
  - Static type of e2 must not have tag **tep**

Example Revisited

```
class Status {
  …
  boolean isSuccess( ) { … }
}
```

```
interface Service extends Shareable {
 intern Status doService( );
}
```

```
class Client extends Applet {
  …
  void process( tep APDU apdu ) {
    intern AID         server = …;
    any Shareable      s =
           JCSystem.getAppletShareableInterfaceObject( server, (byte) 0 );
    any Service        service = ( any Service ) s;
    any Status         status = service.doService( );
    if ( status.isSuccess( ) ) { … }      // Static type error
} }
```

Results

- Type Safety
  - All references are **correctly tagged**
  - Proof by rule induction based on operational semantics
- Applet Isolation
  - Lemma: Each Java Card program with tagged types that passes the static checks behaves like the corresponding program with dynamic checks
  - Every Java Card program that can be correctly tagged **does not throw SecurityExceptions** (except for casts)
  - Proof by rule induction with two operational semantics (with and without dynamic checks)

Conclusions

- Presented approach supports program verification
  - **Absence of SecurityException** does not have to be shown during verification (except for some casts)
  - Static checking is **modular**

- Security requires
  - Type system on bytecode level
  - Adapted VM / Bytecode verifier
  - Forbidding downcasts from **any** to **intern** or **pep**

Future Work

- Extension of presented work
  - Support for missing language features (exceptions)
  - Annotation of Java Card API
- Formal verification
  - Integration of type system with Universe Type System
  - Implementation in JIVE (Java Interactive Verification Environment)