Security of JavaCard smart card applets

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SMART CARDS

Nice cryptography , but

- Where do I keep my private keys ?
- Who do I trust to do my en/decryption ?

For traditional authentication - face/voice recognition - this is not a problem !

Smart Cards

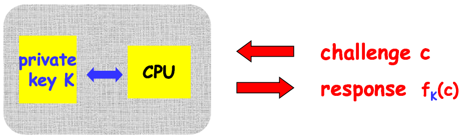
Card with microprocessor capable of

- storing information
- processing information: en/decyption

  This is what makes a smart card smart; stupid cards cannot do this

Eg. bank card, mobile phone SIM

Why use smart cards ?



private key K

CPU

challenge c

response $f_K(c)$

- Private key K never leaves the card
- Card issuer does not have to trust card holder, terminal, or network

Why use smart cards ?

- send password unencrypted over net (eg. rlogin)
  but can we trust the network ?
- send password encrypted over net (eg. slogin)
  but can we trust the terminal ?
- idem, but user, not terminal, does encryption
  but can we trust the user ?
- use smart card
  trust no-one

NB smart card security is not perfect

Card can be physically attacked:

- Reading or writing of the chip (memory, bus)
- Analysing timing or power consumption (DPA)

NEW GENERATION SMART CARDS

Eg: Mondex,
Java Card,
Windows for Smart Cards

Old vs new smart cards

- one program (applet)
- written in chip-specific machine code
- burnt into ROM

- Applet written in high-level language
- compiled into bytecode
- stored in EEPROM
- interpreted on card

- multi-application: several applets on one card
- post-issuance: adding or deleting applets on card

Multi-application

Several applets on one card, possibly interacting

Eg
- credit card + loyalty program
- access to buildings + computer networks
- frequent flyer card + electronic check-in
- all of the above

Post-issuance

Additional applets downloaded onto card after it has been issued, to add or upgrade services
- eg. removing chipper and adding chipknip
- cf. downloading applets in web-browser

Post-issuance download tightly controlled: only trusted - digitally signed - applets are downloaded (using VISA Open Platform), or none at all.

Java Card

A subset of Java

- no threads, doubles, strings, gc optional

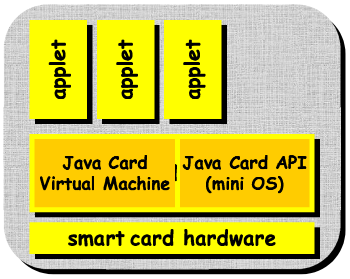
with some extras

- persistent and transient objects
- transaction mechanism

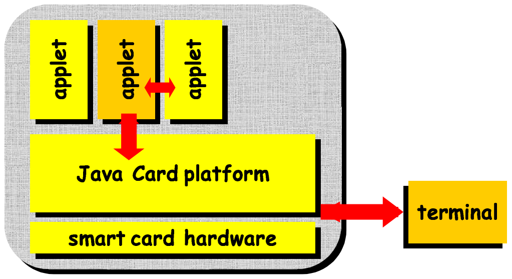
and increased language-level security

- standard sandbox (cf. web-browsers)
- plus firewall between applets

Java Card smart card



Java Card smart card



Advantages of new generation

- easier development of applications
  - faster and cheaper
  - high-level language
  - independent of underlying hardware
- more flexibility
  - multi-application
  - post-issuance download ?

Disadvantage: Security

- incorrect or malicious applet may interfere with other applets or platform
  - Eg a virus on a credit card or mobile phone
- platform can provide basic security against illegal operations
- applet should take care to provide any additional security it requires

Platform level security (platform = VM+OS)

- language level security

  byte code verification
- OS security

  firewall

Applet security

- anything beyond this

APPLET SECURITY

Context of this work

Verification of JML-annotated Java code,eg

```
public int squareRoot(int i);
 //@ pre:  i >= 0;
 //@ modifiable: nothing;
 //@ post: \result^2 <= i && i < (\result+1)^2;
```

using the LOOP tool as front-end for the PVS theorem prover.

What can we do for applets with this approach ?

Towards applet security

How to specify "applet security" ?

1. Applet correctness
   method does what it should do
2. Applet security policy: access control
   method/data only accessed when allowed
3. Secure information flow
   method does not leak information

......

1. Applet correctness

ie. verify that applet

- satisfies pre-/postconditions
- preserves invariants, eg.

```
//@ invariant: 0 <= balance && balance <= MAX;
```

- preserves constraints, eg.

```
//@ constraint: balance <= \old(balance);
```

1. Applet correctness

But: correctness ⇒ security?

- Limits to the expressivity of specification language
- At least: ¬correct ⇒ ¬secure

In any case: no assumptions on incoming data!

No assumptions on incoming data:

Not

```
public int squareRoot(int i);
//@ pre:  i >= 0;
//@ post: \result^2 <= i && i < (\result+1)^2;
```

but

```
public int squareRoot(int i);
//@ pre:  true;
//@ post: ...  ;
//@ signals: (SomeException) i < 0;
```

2. Applet security policy

Access control for methods

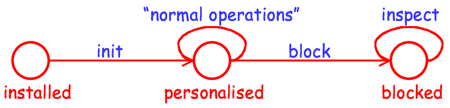
- who may invoke which method when in the smartcard/applet life cycle

and for data

- confidentiality: who may access data
- integrity: who may modify data - modification by authorised party with uncorrupted (digitally signed) data

2. Method access control

Distinguish states in smartcard/applet life cycle.
Specify who may do what in which state



This can be specified in JML, eg

```
//@ pre: state == blocked && user == admin;
```

2. Method access control

- Method access control
  method invoked when allowed
  complements correctness
  method does what it should do

- Maybe temporal logic specifications better for expressing (il)legal access control ?

2. Data access control

Annotate any data access with checks

```
...
//@ assert: state == admin;
PIN = newPIN;
...
```

verify that these conditions are met

Data access conditions already show up in the preconditions of methods ?

3. Secure information flow

No sensitive information may be leaked

Traditional approach to information flow:

- distinguish **high** and **low security level** variables
- forbid **assignments** of high to low cq. **dependencies** of low on high level
- check this by
  - static analysis/type checking, or
  - model checking

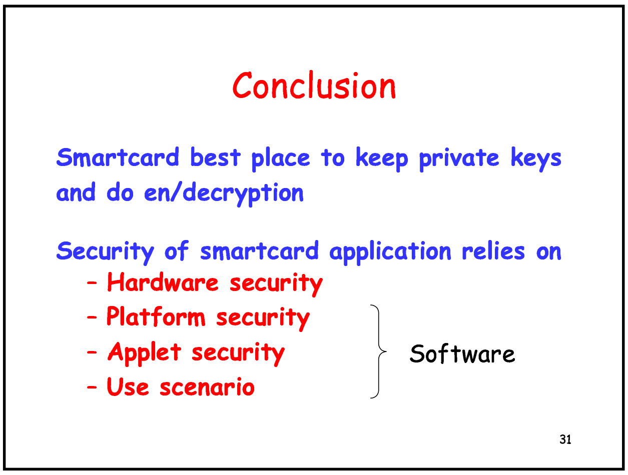
3. Secure information flow

Information flow using pre/postconditions:

```
public int m(int i);
//@ post:  \result == f(i,low level variables);
//@ signals: (Exception) P(i,low level vars);
```

for some `f` and `P` means that no high security level values are leaked.

Practical in real examples ?



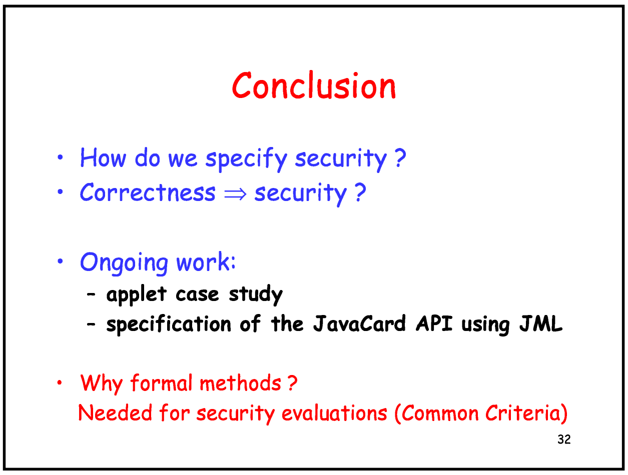
Conclusion

Smartcard best place to keep private keys and do en/decryption

Security of smartcard application relies on

- **Hardware security**
- **Platform security**
- **Applet security**
- **Use scenario**

} Software



Conclusion

- How do we specify security ?
- Correctness ⇒ security ?

- Ongoing work:
  - **applet case study**
  - **specification of the JavaCard API using JML**

- Why formal methods ?

  Needed for security evaluations (Common Criteria)