JavaOne℠

Step-by-Step development of an Application for the Java Card 3.0™ platform

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About the speakers

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Session objectives

- Learn the basic principles of Java Card 3.0
  - Based on a small realistic application
    - Step-by-step building of a first version
  - Including typical smart card issues
    - Security, performance, deployment
- Discover the development tools
  - Building a project
  - Using the Reference Implementation

The Session at a Glance

- An introduction to Java Card 3.0
- Writing a first application
- Building and running the application
- Making your application realistic
- Further options
- Deploying your application

Smart Card Characteristics

- Smart cards are small
  - Best in class have 32k RAM, 1M Flash
- Smart cards are cheap
  - A single chip, embedded in plastic
- Smart cards are secure
  - They are often used to manage sensitive assets
- Smart cards are manageable
  - Powerful remote app management tools

Why a Specific Platform?

- Limited resources
    - RAM is very scarce; object use is limited
    - Flash memory is hard to access
    - Computing power is limited
- Specific requirements
    - High level of security
    - Several applications share the same VM
    - Persistence is achieved through objects

Java Card 3.0 in One Slide

- VM and core API based on CLDC
  - Minus floating-point numbers and a few details
  - Plus persistent objects
  - Plus a firewall between applications
  - Plus detailed permissions

- A servlet application model
  - Plus a legacy smart card application model

The First Application

- A basic password manager
  - Stores triplets made of
    - An identifier (URL or simple string)
    - A user name
    - A password
- Available through a Web interface
  - Main application is a servlet

A Password Record

```
package com.vetilles.passwords;

public class PasswordEntry ;

  private String userName;
  private String password;

  public PasswordEntry(String userName, String password) {
    this.userName = userName;
    this.password = password;
  }

  public String getUserName() {
    return userName ;
  }

  public void setUserName(String userName) {
    this.userName = userName;
  }
  ...
```

A Password Manager

```
package com.vetilles.passwords;

import java.util.Hashtable;
import java.util.Enumeration;
import javacardx.framework.TransactionType;
import javacardx.framework.TransactionTypeValue;

public class PasswordManager ;

  private Hashtable<String,PasswordEntry> entries;

  public PasswordManager() {
    entries = new Hashtable();
  }

  ...
```

A Password Manager

```
...

@TransactionType(TransactionTypeValue.REQUIRED)
public boolean addPasswordEntry
        (String id, String userName, String password) {
  if (entries.containsKey(id)) return false ;

  entries.put(id, new PasswordEntry(userName, password);
  return true ;
}

public PasswordEntry retrievePasswordEntry(String id)
{
  return entries.get(id) ;
}

...
```

A Password Manager

```
      ...

      @TransactionType(TransactionTypeValue.REQUIRED)
      public boolean deletePasswordEntry(String id) {
        return entries.remove(id) != null ;
      }

      public Enumeration<String> listIdentifiers()
      {
        return entries.keys() ;
      }

    }
```

Persistence basics

- Persistence by reachability
  - Reachability by a root of persistence
    - Static field, servlet context, applet object
  - All persistent objects stored in persistent memory
- Guarantees on persistent objects
  - Individual write operations are atomic
  - All writes in a transaction are atomic

Transaction basics

- Inspired from Java EE persistence
  - With some specific details
  - A smart card is not a database
- Three basic principles
  - The scope of the transaction is a method
  - Commit occurs on normal return
  - Abort occurs on exception exit

Transaction types

- SUPPORTS
  - By default, transaction optional
- REQUIRED
  - When a transaction is needed
- REQUIRES_NEW
  - For a separate transaction
- MANDATORY, NEVER, NOT_SUPPORTED:
  - For special cases

A Password Servlet

```
package com.vetilles.passwords;

import java.io.IOException;
import java.io.PrintWriter;

import java.util.Enumeration;
import javax.servlet.http.HttpServlet;
import javax.servlet.http.HttpServletRequest;
import javax.servlet.http.HttpServletResponse;

/** A Simple Hello Servlet */
public class PassServlet extends HttpServlet {

  private static PasswordManager manager =
            new PasswordManager();

...
```

A Password Servlet

```
@Override
public void doGet( HttpServletRequest request,
                   HttpServletResponse response)
                      throws IOException
{
  // First interprets the command
  String command = request.getServletPath();

  // Matches the possible incoming commands
  if (command.equals("/addentry"))
    addEntry(request, response);
  else if (command.equals("/retrieveentry"))
    retrieveEntry(request, response);
  else if (command.equals("/deleteentry"))
    deleteEntry(request, response);
  else if (command.equals("/listidentifiers"))
    listIdentifiers(request, response);
}
```

A Password Servlet

```
private void addEntry(
          HttpServletRequest request,
          HttpServletResponse response)
             throws IOException
{
  boolean status = manager.addPasswordEntry(
          request.getParameter("id"),
          request.getParameter("name"),
          request.getParameter("pass")) ;

  PrintWriter out = startResponse(response);
  if (status)
    out.println(HTML_ADD_ENTRY_SUCCESS);
  else
    out.println(HTML_ADD_ENTRY_FAILED);
  finishResponse(response);
}
```

A Password Servlet

```
private static final String HTML_ADD_ENTRY_SUCCESS =
  "<p align=\"center\">"
+   "Password entry added successfully"
+ "</p><br>";

private static final String HTML_ADD_ENTRY_FAILED =
  "<p align=\"center\">"
+   "Password entry addition failed."
+ "</p>"
+ "<p align=\"center\">"
+   "Identifier already in use."
+ "</p><br>";
```

A Password Servlet

```
private PrintWriter startResponse(
        HttpServletRequest request,
        HttpServletResponse response)
             throws IOException, ServletException {
  // Set content type first
  response.setContentType("text/html");

  // Uses RequestDispatcher to write the header
  RequestDispatcher dispatcher =
      request.getRequestDispatcher("/WEB-INF/header.i");
  dispatcher.include(request, response);

  // Get PrintWriter object to create response
  return response.getWriter();
}
```

A Password Servlet

```
private void finishResponse(
        HttpServletRequest request)
        HttpServletResponse response)
    throws IOException
{
  // Uses RequestDispatcher to write the footer
  RequestDispatcher dispatcher =
      request.getRequestDispatcher("/WEB-INF/footer.i");

  dispatcher.include(request, response);
}
```

HTML file: header.i

```
<html>
  <head><title>Password Manager</title></head>
  <body>
    <table><tr>
      <h1 align="center">Password Manager</h1><br>
      <td><a href="/pass/add.html">Add entry</a></td>
      <td><a href="/pass/retrieve.html">
        Retrieve entry
      </a></td>
      <td><a href="/pass/delete.html">
        Delete entry
      </a></td>
      <td><a href="/pass/listidentifiers">
        List identifiers
      </a></td>
    </tr></table>
    <br><br>
```

HTML file: footer.i

```
  </body>
</html>
```

Access Control

- No access control
  - The user must be authenticated
- Container-managed authentication is possible
  - BASIC authentication for simplicity
  - FORM-based for more flexibility
- Role-based security is available
  - Access rights orthogonal to authentication

So ?

- For Java Card 2.x developers
  - Java Card 3.0 is a major breakthrough
  - The servlet model is entirely new
- For other Java developers
  - Java Card 3.0 is more traditional
  - Well integrated into standard tool chain
    - NetBeans, debugger, *etc*.

Demo

What is Wrong with this Application?

- Security
  - Content is not well protected
  - No protection against Web attacks

- Performance
  - Too much content going back and forth
  - Card-specific optimizations

Why Protect the Content?

- No separation in *n* tiers
  - Data is stored by the presentation application
- Smart cards are subject to attacks
  - They are a Web server in the attacker's hands
  - Attacks on the hardware are possible
    - Observation and fault induction attacks
- Content is sensitive

Secure Storage of Passwords

- Issue 1: Upon deletion, passwords must be wiped
  - How do you wipe a String?
  - Persistent storage must be in a byte array
- Issue 2: Passwords should be stored encrypted
  - Once again, byte arrays are required
- The **`PasswordEntry`** class needs some work
  - Storage of passwords in encrypted byte arrays

Secure Storage of Passwords

```
package com.vetilles.passwords;

import javacard.security.DESKey ;
import javacard.security.KeyBuilder ;
import javacardx.crypto.Cipher ;
import javacardx.crypto.RandomData ;

public class PasswordEntry {

  private String userName;
  private byte[] password;
  private static DESKey theKey ;
  private static Cipher cipher ;

  public PasswordEntry(String userName, String password) {
    if (theKey == null)
      initCrypto() ;

    this.userName = userName;
    setPassword(password);
  }
```

Secure Storage of Passwords

```
private static void initCrypto()
{
  // Allocates the objects
  theKey = (DESKey)KeyBuilder.buildKey(
              "DES",KeyBuilder.LENGTH_DES3_2KEY, false);
  cipher = Cipher.getInstance("DES_CBC_ISO9797_M2", true);

  // Generates a random key value
  RandomData rnd = RandomData.getInstance("SECURE_RANDOM");
  byte[] value = new byte[16] ;
  rnd.generateData(value, (short)0, (short)16);
  theKey.setKey(value);

  // Clears the key value before to return
  rnd.generateData(value, (short)0, (short)16);
}
```

Secure Storage of Passwords

```
public void setPassword(String pass)
{
  byte[] bytes = pass.bytes();
  password = new byte[bytes.length+9];

  cipher.init(theKey,Cipher.MODE_ENCRYPT);
  password[0] = (byte)cipher.doFinal(
    bytes, (short)0, (short)bytes.length, password, (short)1 );
}

public String getPassword()
{
  byte[] bytes = new byte[password.length];

  cipher.init(theKey,Cipher.MODE_DECRYPT);
  short len = cipher.doFinal(
          password, (short)1, password[0], bytes, (short)0 );

  return new String(bytes,(short)0,len);
}
```

Secure Communication

- Several issues are present
  - All data is transmitted in clear
  - Master password is transmitted in clear
- One simple solution: SSL
  - Supported at the container level
  - Not a single line of code
  - Only constraint: manage the certificates

Web Security

- Web applications have many security issues
- See OWASP for a starting point
  - In particular the “Top 10 Vulnerabilities”
- Some countermeasures are required
  - Input filtering
  - Output canonicalization
  - Proper session management

Validating Input

```
private void addEntry(
          HttpServletRequest request,
          HttpServletResponse response)
             throws IOException
{
  boolean status ;
  try {
    status = manager.addPasswordEntry(
          validateId(request.getParameter("id")),
          validateId(request.getParameter("name")),
          request.getParameter("pass")) ;
  } catch(Exception e) {
    sendError(response,e.getMessage());
    return;
  }
  ...
}
```

Validating Input

```
private static final String otherChars = "-_@." ;

private String validateId(String id) throws IOException
 {
   char[] chars = id.toCharArray() ;

   for(char c:chars)
   {
     if (Character.isDigit(c)) continue;
     if (Character.isLowerCase(c)) continue;
     if (Character.isUpperCase(c)) continue;
     if (otherChars.indexOf(c)!=-1) continue;
     throw new IOException("Invalid identifier string");
   }
   // If we get here, all characters are acceptable
   return id ;
 }
```

Canonicalizing Output

- The idea is to make the output innocuous
  - Make sure that characters are not interpreted
  - The following only works on ASCII characters

```
private String encodeUnverifiedString(String str)
 {
   StringBuffer s = new StringBuffer();
   char[] chars = str.toCharArray() ;

   for(char c:chars)
   {
     s.append("<span>#&" + Integer.toString(c) + ";</span>");
   }
   return s.toString();
 }
```

Communication Performance

- Card communication remains slow
  - Content production also has limits
- Similar to other elements of the “Web of Things”
  - Servers are less powerful than clients
  - The work must be delegated to clients
- Ajax can be used
  - Limits the amount of communication
  - Limits HTML overhead on the server side

Ajax on a Smart Card?

- Ajax is an interesting technique
  - It is entirely managed on the card
  - It uses the client's resources
- Aren't there security issues ?
  - No, not really
  - The browser must be trusted anyway

Performance Optimization
Persistent memory

```
private static void initCrypto()
{
  // Allocates the objects
  theKey = (DESKey)KeyBuilder.buildKey(
              "DES",KeyBuilder.LENGTH_DES3_2KEY, false);
  cipher = Cipher.getInstance("DES_CBC_ISO9797_M2", true);

  // Generates a random key value
  RandomData rnd = RandomData.getInstance("SECURE_RANDOM");
  byte[] value = new byte[16] ;
  rnd.generateData(value, (short)0, (short)16);
  theKey.setKey(value);

  // Clears the key value before to return
  rnd.generateData(value, (short)0, (short)16);
}
```

Performance Optimization

Persistent memory

```
    private static void initCrypto()
    {
      // Allocates the objects
      DESKey newKey = (DESKey)KeyBuilder.buildKey(
                    "DES",KeyBuilder.LENGTH_DES3_2KEY, false);
      cipher = Cipher.getInstance("DES_CBC_ISO9797_M2", true);

      // Generates a random key value
      RandomData rnd = RandomData.getInstance("SECURE_RANDOM");
      byte[] value = new byte[16] ;
      rnd.generateData(value, (short)0, (short)16);
      newKey.setKey(value);

      // Clears the key value before to return
      rnd.generateData(value, (short)0, (short)16);

      // Promotes the key to persistent memory
      theKey = newKey ;
    }
```

What more could we do ?

- Manage the data in a separate application
  - Use sharing to communicate
- Add an APDU interface
  - Work with legacy smart card applications
- Manage our own authenticators
  - Rather than use the platform's default ones
- Backup our passwords
  - Open a connection to a backup server

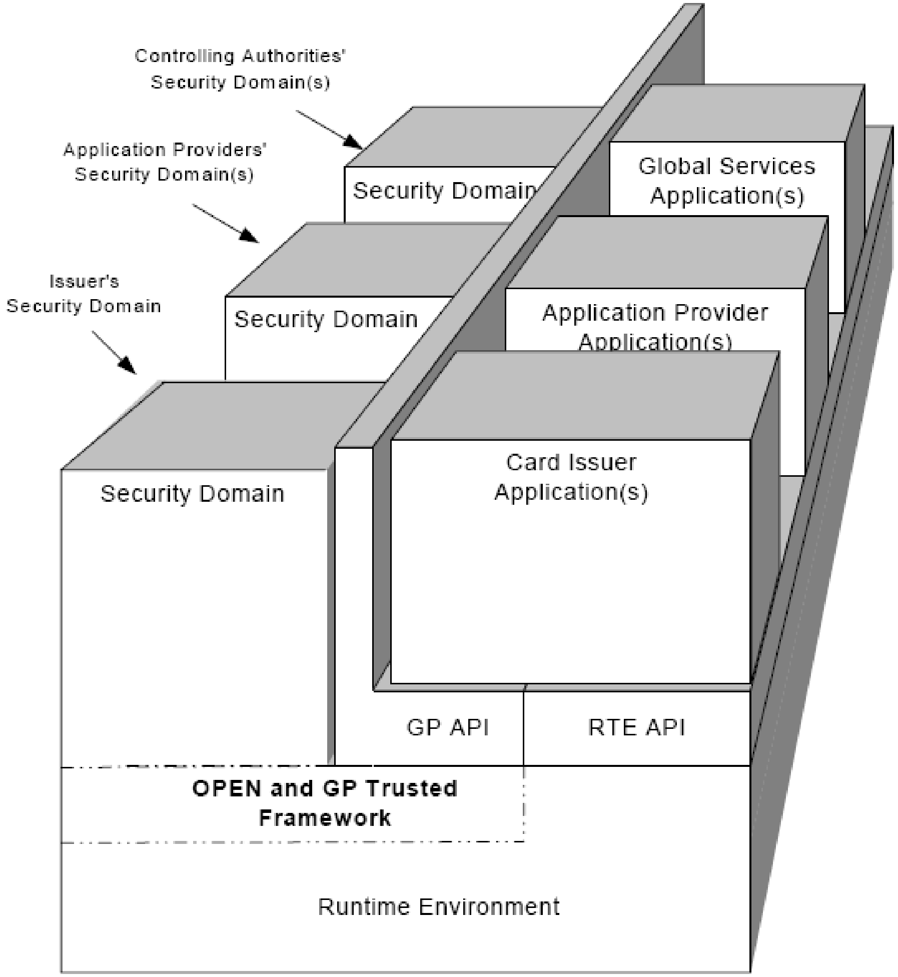
What about Deployment?

- Many instances
  - Not a single server
  - Instead, millions of cards/objects
- A mutualized server
  - Several providers represented on the server
  - Usually, one single issuer (the owner)
  - Some resource allocation to manage

GlobalPlatform

- Card management technology since 1999
  - Standards to deploy/manage applications
  - Standards to manage relationships
    - Between card issuers and application providers
    - Including trusted third parties when needed
- Currently being adapted to a Web model
  - Update of application management
  - Addition of new resources to be managed

GlobalPlatform Architecture


Controlling Authorities' Security Domain(s)
Application Providers' Security Domain(s)
Issuer's Security Domain
Security Domain
Global Services Application(s)
Security Domain
Application Provider Application(s)
Security Domain
Card Issuer Application(s)
GP API
RTE API
OPEN and GP Trusted Framework
Runtime Environment

From GlobalPlatform Card Spec v2.2, 2006

Issuer-Centric Deployment

- Current model for smart cards
  - The issuer owns the card
- Many deployment options
  - The issuer manages all applications
    - Simple and practical
  - A third party needs to sign all applications
    - Practical to enforce issuer policies
  - Management can be delegated
    - All operations may still be explicitly authorized

Alternative Deployment Scenarios

- White card schemes
  - Very similar to an issuer-centric scheme
  - But the “issuer” is an association/public entity
- Cardholder-owned cards
  - Not the tendency for traditional cards
  - Likely trend with smart objects
- ...

GlobalPlatform Networked Framework

- Adapts the existing model to the Web
  - HTTP and SSL as transport
  - ASN.1 as encoding
- Supports specific Web application features
  - Management of URIs
    - Who can use the http://localhost:8019/google ?
  - Management of realms and authenticators
    - Who can use the “Visa” authentication realm?

Recap

- Java Card 3.0 brings Web servers everywhere
  - On cards and on other devices
  - Using a very classical model
- Of course, there is a catch
  - Resources are severely limited
  - Deployment needs to be carefully planned
  - Applications and devices may be linked

Getting More Information

- Spec and Development Kit
  - java.sun.com/products/javacard
    - Look at the samples ...
- Blogs
  - javacard.vetilles.com
- Other sessions at JavaOne

JavaOne Thank You

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