Wireless Application Programming with Java

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You will learn:

- What is the J2ME platform?
- How does it differ from J2SE?
- KVM (Kilo Virtual Machine)
- Configurations and Profiles
  - CLDC and MIDP
  - CDC, Foundation, Personal, RMI
- How to get started developing wireless applications using the J2ME platform

Outline

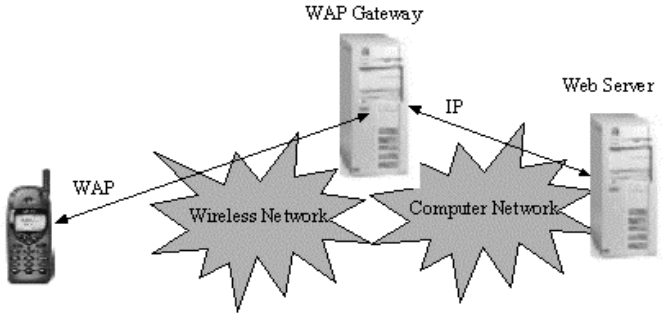
- Web Content for Mobile Devices
- WAP Programming Model
- J2ME Platform
- KVM (Kilo Virtual Machine)
- Configurations and Profiles
  - CLDC (Connected Limited Device Configuration)
  - MIDP (Mobile Information Device Profile)
- Examples
- Availability and Resources

Web Content for Mobile Devices

- Markup languages to deliver Web content to device browsers:
  - HDML
    - Phone.com (now Openwave)
  - Compact HTML (cHTML)
    - NTT DoCoMo's i-mode network
  - WAP Forum's WML
    - An emerging standard for content delivered to mobile devices

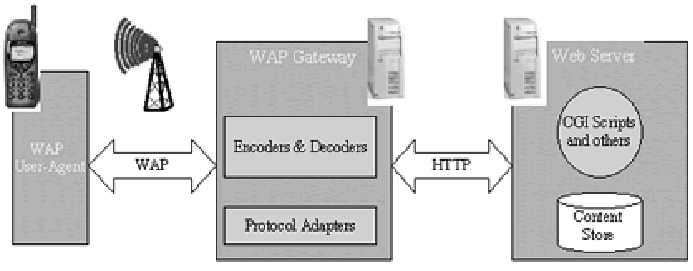
WAP Network Structure

- The WAP Gateway plays an important role



WAP Programming Model

- Similar to the Web programming model with extensions for the wireless environment



WML Example

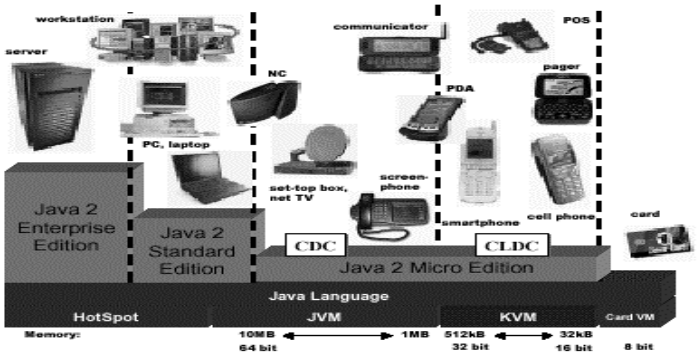
```
<?xml version="1.0"?>
  <!DOCTYPE wml PUBLIC "-//WAPFORUM//DTD WML
  1.1//EN" "http://www.wapforum.org/DTD/wml_1.1.xml">
  <wml>
   <card id="MyFirstCard" title="First Card">
    <p align="center">
     My First WML Example
    </p>
   </card>
  </wml>
```

Transcoding Proxies

- Transcoding proxies are becoming more capable and widely used
- HTML, cHTML, and WML are converging towards XHTML
- XHTML is the re-writing of HTML as an XML-based markup language

Java 2 Platform

- Virtual Machines and horizontal and vertical APIs specified in *configurations* and *Profiles*



Configurations

- A configuration defines the minimum APIs and VM capabilities for a family of devices:
  - Similar requirements of memory size and processing capabilities
- The minimum APIs that an application developer can expect to be available on implementing devices

Configurations

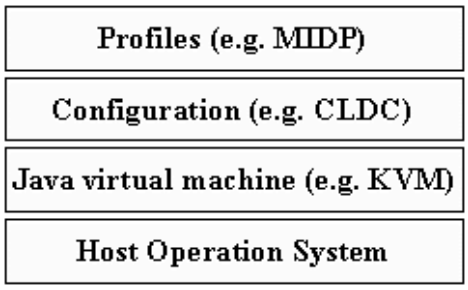
- May not contain any optional features
- Defined through the Java Community Process (JCP)
  - *http://java.sun.com/jcp* (www.jcp.org)
- Subject to compatibility tests

Profiles

- A profile is a collection of APIs that supplement a configuration to provide capabilities for a specific vertical market
- Defined through Java Community Process initiative (www.jcp.org)
- Subject to compatibility tests

How do they fit together?

- Profiles are built on top of configurations



CLDC

- Targeted at devices with:
  - 160 to 512 KB of total memory available for Java technology
  - Limited power (e.g. battery)
  - Limited connectivity to a network (wireless)
  - Constrained User Interface (small screen)
- It is available for free download
- Reference implementation built using KVM

MIDP

- Targets mobile two-way communication devices implementing the CLDC
- It addresses:
  - Display toolkit (user input)
  - Persistent data storage
  - HTTP based networking using CLDC generic connection framework
- Available for free download

KVM

- Stands for Kilo Virtual Machine
- Originated from a research project called **Spotless** at Sun Research Labs
- Implements the classes defined in the CLDC specification + some additional UI classes
- Note: the UI classes are not part of the CLDC and can be removed at any time

KVM...

- A complete runtime environment for small devices
- Built from the ground up in C
- Small footprint (40 – 80 KB)
- Class file verification takes place off-device
- Supports multi-threading
- Supports garbage collection

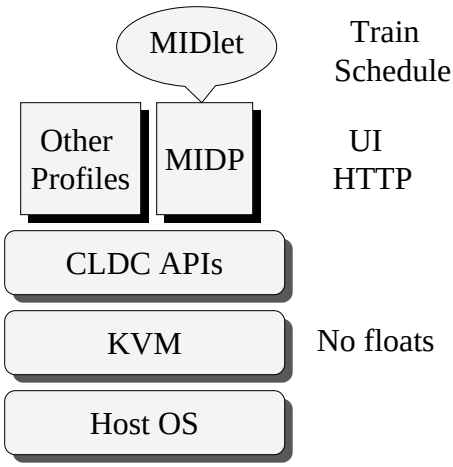
KVM Security

- VM level security
  - Off-device pre-verification
  - Small in-device verification
- Application level security
  - No Security Manager
  - Sandbox security model:
    - Applications run in a closed environment
    - Applications can call classes supported by the device

KVM

- It runs on Solaris, Win32, and PalmOS
- To install on Palm devices (KVM.prc, KVMutil.prc)

Wireless Device Stack



CLDC Internals

- The CLDC specification specifies VM features required by a CLDC implementation
- Specifies requirements and APIs for
  - Input/Output
  - Networking

Beyond the CLDC scope

- Profiles implemented on top of CLDC specify APIs for:
  - User Interface support
  - Event handling
  - Persistent support
  - High-level application model
- An example profile is the Mobile Information Device Profile (MIDP)

Language & VM Compatibility

- Goal:
  - Full java language and VM specification compatibility
- Language-level exception:
  - No floating point support in CLDC 1.0
    - No hardware floating point support
    - Manufacturers and developers can include their own floating point

CLDC vs. J2SE JVM

- Limitations in CLDC supporting JVM:
  - No floating point support
  - No finalization
  - Limited error handling
  - No Java Native Interface (JNI)
  - No support for reflection
  - No thread groups or daemon threads
  - No weak references

CLDC APIs

- Classes inherited from J2SE v1.3 are in packages:
  - java.lang
  - java.io
  - java.util
- New classes introduced by the CLDC are in package:
  - javax.microedition

CLDC Libraries: java.lang.*

- Boolean
- Byte
- Character
- Class
- Integer
- Long
- Math
- Object
- Runnable
- Runtime
- Short
- String
- StringBuffer
- System
- Thread
- Throwable

CLDC Libraries: java.io.*

- ByteArrayInputStream
- ByteArrayOutputStream
- DataInput
- DataOutput
- DataInputStream
- DataOutputStream
- InputStream
- OutputStream
- InputStreamReader
- OutputStreamWriter
- PrintStream
- Reader
- Writer

CLDC Libraries: java.util.*

- Calendar
- Date
- Enumeration
- Hashtable
- Random
- Stack
- TimeZone
- Vector

MIDP internals

- Goal:
  - MIDP implementation must fit in small footprint (128KB ROM)
  - Must run with limited heap size (32-200KB RAM)
- To be implemented by device manufacturers, operators, or developers

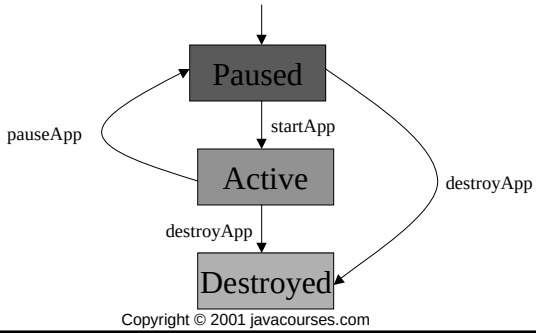
MIDlets

- A MIDlet consists of a class that extends the `MIDlet` class and other classes as needed
- To handle events it must implement the `CommandListener` interface

```
public class MyMIDlet extends MIDlet implements
   CommandListener{
}
```

MIDP Application Lifecycle

- MIDlets move from state to state in the lifecycle:
  - **Start**: acquire resources and start executing
  - **Pause**: release resources and wait
  - **Destroyed**: release all resources and end all activities



MIDlet Packaging

- Two or mode MIDlets form a MIDlet suite
- One or more MIDlets may be packaged in a single JAR file that includes:
  - A manifest describing the contents
  - Java classes for the MIDlet(s)
  - Resource file(s) used by the MIDlet(s)
- Each jar file is accompanied by a Java Application Descriptor (JAD) file

MIDlet Packaging

- Java Application Descriptor (JAD) file provides info:
  - Configuration properties
  - Pre-download properties
    - Size, version, storage requirements

Example MIDlet

```
import javax.microedition.midlet.MIDlet;
import javax.microedition.lcdui.*;

public class FirstMIDlet extends MIDlet {
   Display display = null;
   TextBox tb = null;
   public FirstMIDlet() {
     display = Display.getDisplay(this);
   }
```

Example MIDlet ...

```
public void startApp() {
     tb = new TextBox("FirstMIDlet", "Welcome to
                          MIDP Programming", 40, 0);
    display.setCurrent(tb);
  }
  public void pauseApp() { }
  public void destroyApp(boolean unconditional) { }
  }
}
```


Example MIDlet...

- Compile (javac)
- Preverify (off device preverification)
- Create a JAR file: first.jar
- Create a JAD file: first.jad
  - MIDlet-Name: MyFirst
  - MIDlet-Version: 1.0.0
  - MIDlet-Vendor: Sun Microsystems, Inc.
  - MIDlet-Description: My First MIDlet
  - MIDlet-Info-URL: http://java.sun.com/j2me/
  - MIDlet-Jar-URL: first.jar
  - MIDlet-Jar-Size: 1063
  - MicroEdition-Profile: MIDP-1.0
  - MicroEdition-Configuration: CLDC-1.0
  - MIDlet-1: MyFirst,, FirstMIDlet

Example MIDlet: Testing

- midp –descriptor first.jad

MIDlet Example: Deploy

- To deploy a MIDlet on a web server, you need to add a new MIME type:

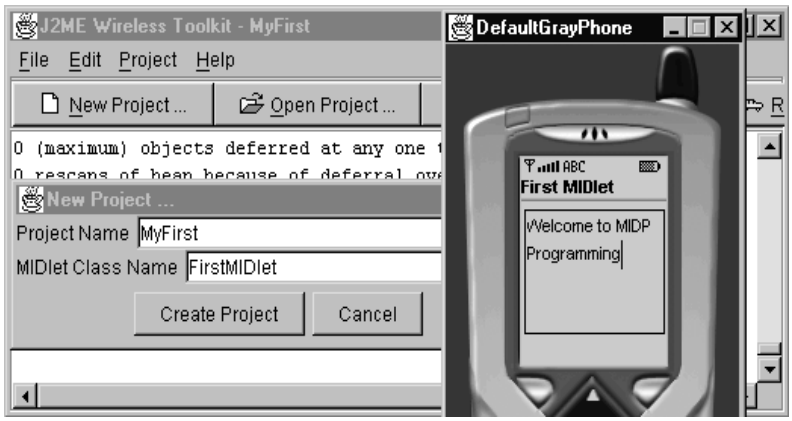
  text/vnd.sun.j2me.app-descriptor jad

- Use the following command to run:

  midp -transient http://hostname/path/first.jad

Simplifying the Development Effort

- Sun's Wireless Toolkit



MIDP APIs

- The MIDP specifies APIs for:
  - User Interface
  - Networking (based on CLDC)
  - Persistent Storage
  - Timers

MIDP User Interface

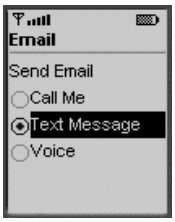
- Not a subset of AWT or Swing because:
  - AWT is designed for desktop computers
  - Assumes certain user interaction models (pointing device such as a mouse)
  - Window management (resizing overlapping windows). This is impractical for cell phones
- Consists of high-level and low-level APIs

MIDP UI APIs

- High-level API
  - Applications should be runnable and usable in all MIDP devices
  - No direct access to native device features
- Low-level API
  - Provide access to native drawing primitives, device key events, native input devices
  - Allows developers to choose to compromise portability for user experience

MIDP UI Programming Model

- The central abstraction is a **screen**
- Only one screen may be visible at a time
- Three types of screens:
  - Predefined screens with complex UI components (`List`, `TextBox`)
  - Generic screens (`Form` where you can add text, images, etc)
  - Screens used with low-level API (`Canvas`)



MIDP UI and Display

- The `Display` class is the display manager
- It is instantiated for each active MIDlet
- Provides methods to retrieve information about the device's display capabilities
- A screen is made visible by calling:

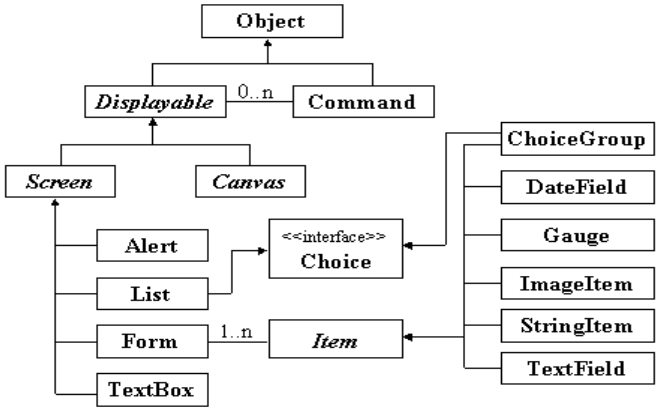
```
Display's setCurrent(screen);
```

MIDP UI Classes

- `javax.microedition.lcdui` classes:
  Alert, AlertType, Canvas, ChoiceGroup, Command, DateField, Display, Displayable, Font, Form, Gauge, Graphics, Image, ImageItem, Item, List, Screen, StringItem, TextBox, TextField, Ticker
- `javax.microedition.lcdui` interfaces:
  Choice, CommandListener, ItemStateListener

MIDP UI Class Diagram

- Major classes and interfaces:



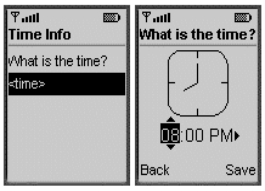
High-Level API Examples

- List:

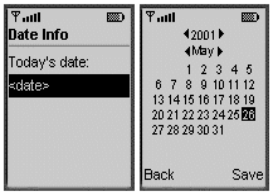
```
Display display = Display.getDisplay(this);
List menu = new List("Method of payment", Choice.EXCLUSIVE);
menu.append("Visa");
menu.append("MasterCard");
menu.append("Amex");
display.setCurrent(menu);
```

High-Level API Examples...

- Form (Date/Time info):




```
DateField date = new DateField("Today's
date", DateField.TIME);
Form form = new Form("Date Info");
form.append(date);
display.setCurrent(form);
```



High-Level Examples…

- Form (Sign in screen):

```
Display display = Display.getDisplay(this);
TextField userName = new TextField("LoginID:", "", 10,
   TextField.ANY);
TextField password = new TextField("Password:", "", 10,
   TextField.PASSWORD);
Form form = new Form("Sign in");
form.append(userName);
form.append(password);
display.setCurrent(form);
```

Low-level Example

- Canvas:

```
public class MyCanvas extends Canvas {
  public void paint(Graphics g) {
    g.setColor(255, 0, 0);
    g.fillRect(0, 0, getWidth(), getHeight());
    g.setColor(255, 255, 255);
    g.drawString("Hello World!", 0, 0, g.TOP | g.LEFT);
  }
}
```

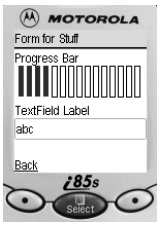
Low-level Example...

- Instantiate and display MyCanvas

```
public class MyMidlet extends MIDlet {
  public MyMidlet() { // constructor
  }
  public void startApp() {
    Canvas canvas = new MyCanvas();
    Display display = Display.getDisplay(this);
    display.setCurrent(canvas);
  }
  // pauseApp() and destroyApp()
}
```

Input Handling

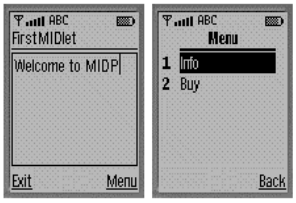
- High-Level API input is handled using abstract commands
  - No direct access to soft buttons
  - Commands are mapped to appropriate soft buttons or menu items



Input Handling: Example

- TextBox screen with commands:

```
Display display = Display.getDisplay(this);
TextBox tb = new TextBox("MIDP", "Welcome to MIDP
    Programming", 40, TextField.ANY);
Command exit = new Command("Exit", Command.SCREEN, 1);
Command info = new Command("Info", Command.SCREEN, 2);
Command buy = new Command("Buy", Command.SCREEN, 2);
tb.addCommand(exit);
tb.addComment(info);
tb.addCommand(buy);
display.setCurrent(tb);
```



Event Handling: High-level

- High-level Events:
  - Based on a listener model
  - Screen objects can have listeners for commands
  - For an object to be a listener, it must implement the `CommandListener` interface
  - This interface has one method: `commandAction`

Event Handling: Example

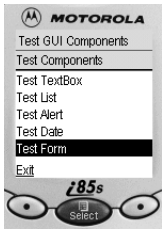
- MIDlet implements CommandListener

```
public class MyMIDlet extends MIDlet implements
    CommandListener {
      Command exitCommand = new Command(…);
      // other stmts
    public void commandAction(Command c, Displayable s) {
      if (c == exitCommand) {
        destroyApp(false);
        notifyDestroyed();
      }
   }
}
```


Event Handling: Example

- Handling List events:

```
public void commandAction(Command c, Displayable d) {
  if (c == exitCommand) { ..
  } else {
   List down = (List)display.getCurrent();
   switch(down.getSelectedIndex()) {
     case 0: testTextBox();break;
     case 1: testList();break;
     case 2: testAlert();break;
     case 3: testDate();break;
     case 4: testForm();break;
   }
```



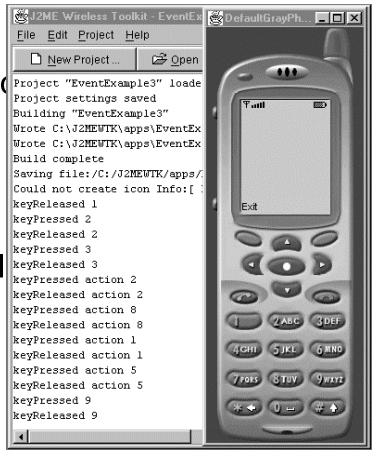
Event Handling: Low-level

- Low-level Events:
  - Low-level API gives developers access to key press events
  - Key events are reported with respect to key codes
  - MIDP defines key codes: KEY_NUM0 .. KEY_NUM9, KEY_STAR, KEY_POUND

Handling Events: example

- Low-level events

```
protected void keyPressed(int keyC
  if (keyCode > 0) {
    System.out.println("keyPressed
  } else {
    System.out.println("keyPressed
  +getGameAction(keyCode));
  }
}
```



MIDP UI Design Principles

- Make the UI simple and easy to use
- Use the high-level API (portability)
- If you need to use low-level API, keep to the platform-independent part
- MIDlets should not depend on any specific screen size
- Entering data is tedious, so provide a list of choices to select from

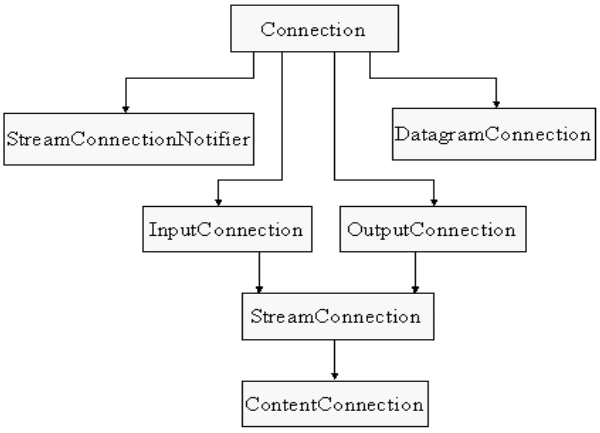
Networking

- J2SE and J2EE networking APIs are not suitable for handheld devices
  - Require several megabytes of memory to run
  - Device manufacturers who work with circuit-switched networks require TCP support
  - Device manufacturers who work with packet-switched networks require UDP support
  - Other devices have specific mechanisms for communications

CLDC Generic Connections

- A set of related abstractions at the programming level
- No abstractions for different forms of communications
- All connections are created using the `Connector.open()`
- If successful, it returns an object that implements one of the generic connection interfaces

Connection Interfaces



Example Connections

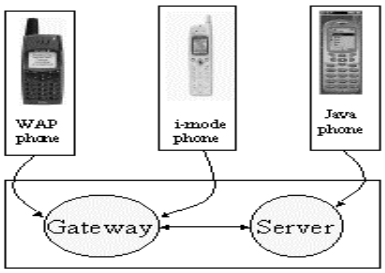
- HTTP: Connector.open("http://www.host.com");
- Socket: Connector.open("socket://host.com:80");
- Datagram: Connector.open("datagram://address:port");
- File: Connector.open("file:/myfile.txt");

Advantages of CLDC Generic Connections

- Isolate the differences between the setup of one protocol and another
- Most of the application code remains the same regardless of the protocol you use
- Note: CLDC itself does not provide any protocol implementation

MIDP Connectivity

- It provides support for HTTP (`HttpConnection`)
- Why? HTTP can be implemented using IP protocols or non-IP protocols



HttpConnection

- Part of the `javax.microedition.io`
- Defines the necessary methods and constants for an HTTP connection

```
HttpConnection c = (HttpConnection)
   Connector.open("http://quotes.yahoo.com");
C.setRequestMethod(HttpConnection.POST);
C.setRequestProperty("Content-Language", "en-CA");
```

Invoking Remote Applications

- A MIDlet may invoke remote applications:
  - Fetching a page
  - Invoking a CGI script (GET or POST method)
  - Invoking a Servlet

Example: Invoke a CGI Script

- GET Method:

```
String url = "http://host/cgi-bin/getgrade?idnum=182061";
c = (HttpConnection) Connector.open(url);
c.setRequestMethod(HttpConnection.GET);
// set some request properties: c.setRequestPropert(" ", " ");
is = c.openDataInputStream();
while((ch = is.read()) != -1) {
  b.append((char)ch);
}
```

Example...

- If you want to send data to a remote application:

```
String s = "stuffToSend";
byte postmsg[] = s.getBytes();
for(int i=0;i<postmsg.length;i++) {
  os.writeBytes(postmsg[i]);
}
// OR
os.write(s.getBytes());
```


Databases

- A persistent storage: a place to store the state of objects
- Facilities provided in J2SE and J2EE are not suitable for handheld devices
- MIDP provides a record-oriented database mechanism to persistently store data and retrieve it later

MIDP's RMS

- Lightweight record-oriented database
  - Device independent API
  - Unique recordID for each record within the store
  - A record is an array of bytes
  - Shared within MIDlet suite
  - Support for enumeration, sorting, and filtering
- `javax.microedition.rms`

MIDP RMS Methods

- Record Store

  openRecordStore, closeRecordStore, listRecordStore, deleteRecordStore, getRecordSize, getNumRecords
- Record Data

  addRecord, deleteRecord, getRecord, setRecord, getRecordSize
- Record Selection

  RecordEnumeration, RecordFilter, RecordComparator

RMS: Record Stores

- To open a record store:
  - RecordStore db = RecordStore.openRecordStore("myDB", true);
- To close a record store:
  - db.closeRecordStore();

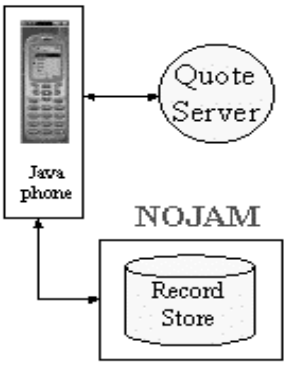
Create/Add a new record

- To create a new record:

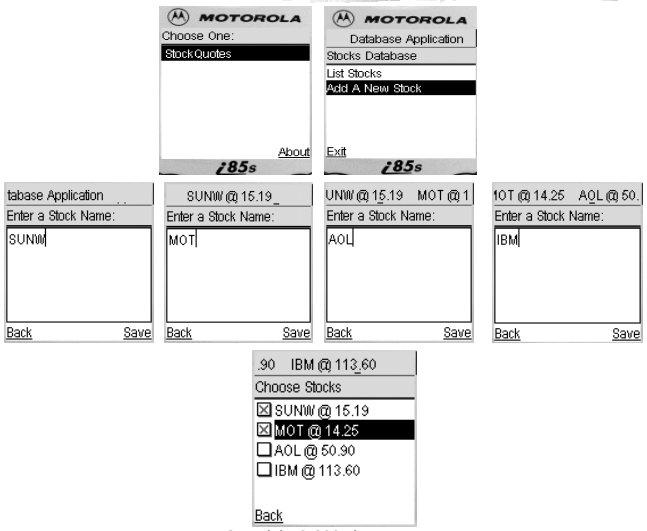
```
ByteArrayOutputStream baos = new
   ByteArrayOutputStream()
DataOutputStream dos = new
   DataOutputStream(baos);
dos.writeUTF(record);
Byte b[] = baos.toByteArray();
db.addRecord(b, 0, b.length);
```

Building a Stock Database

- See appendix for source code:
  - Stock.java
  - StockDB.java
  - QuotesMIDlet.java



StockQuotes MIDlet



MIDP Timers

- Handle queuing and delivery
- Timer task:
  - Multiple tasks per timer
  - Periodic
  - Fixed interval
  - One-time execution

Tasks

- To define a task, create a subclass of TimerTask:

```
import java.util.*;
public class MyTask extends TimerTask {
  public void run() {
    System.out.println("Run Task");
  }
}
```

Tasks...

- Schedule it for execution by creating a `Timer` object and invoking `schedule()`

```
Timer timer = new Timer();
TimerTask task = new MyTask();
// wait five seconds before executing
timer.schedule(task, 5000);
// wait two seconds before executing then
// execute every five seconds
timer.schedule(task, 2000, 5000);
```


MIDP Next Generation

- MIDP NG will:
  - Maintain backward compatibility with MIDP 1.0
  - Continue focus on wireless phones
  - Maintain small footprint (limit API growth)
  - Fine tune MIDP 1.0 APIs
  - Enable mobile commerce

MIDP Next Generation

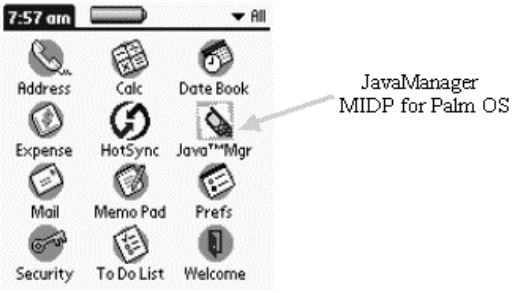
- Areas to investigate:
  - HTTPS and secure networking (SSL)
  - Network connectivity via sockets and diagrams
  - Formal inclusion of Over The Air Provisioning
  - Inclusion of a small XML Parser
  - Sound API

MIDP for Palm OS >= 3.5

- A J2ME application runtime environment based on CLDC 1.0 and MIDP 1.0
- It is targeted at handheld devices (such as Palm Pilot, Handspring Visor) running Palm OS 3.5 or higher.
- Java Manager: MIDP.PRC

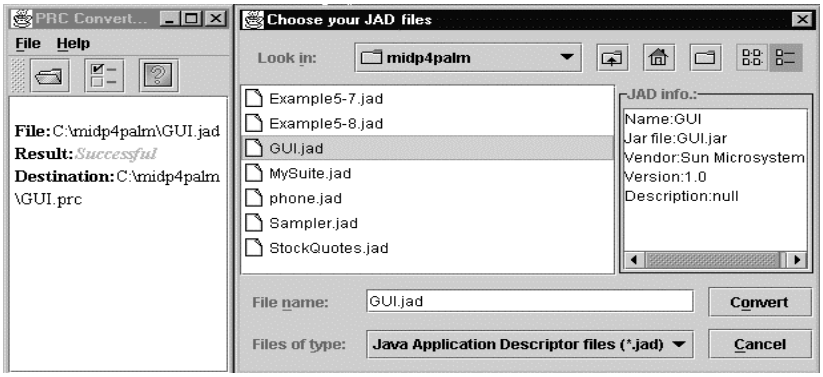
MIDP for Palm OS

- To install:
  - Place palm device in the craddle
  - Use Palm Desktop Software to install MIDP.PRC



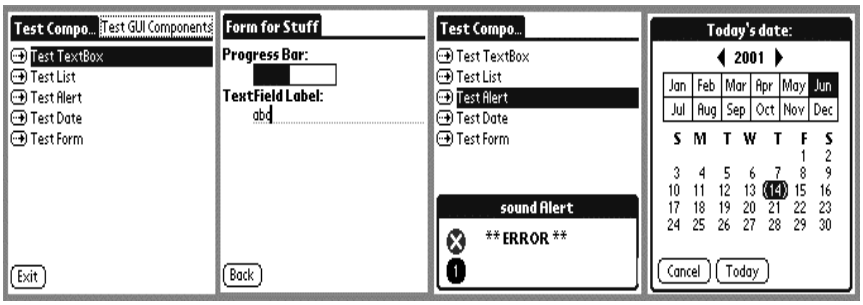
MIDP for Palm OS

- Comes with a PRC converter tool
  - C:\midp4palm\java –jar Converter.jar



MIDP for Palm OS

- Install GUI.PRC

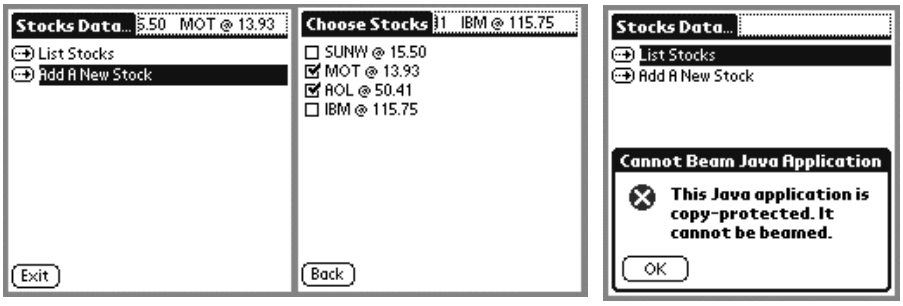


MIDP for Palm OS

- To have more control, use command line tool:
- Converting a single MIDlet JAR to PRC file
  - java –jar MakeMIDPApp.jar –nobeam –o Stocks.prc –JARtoPRC StockQuotes.jar StockMIDlet
- Converting a MIDlet suite to PRC file
  - java –jar MakeMIDPApp.jar –jad MySuite.jad –o MySuite.prc –JARtoPRC MySuite.jar MySuite

MIDP for Palm OS

- Networking and Databases



Other Configurations/Profiles

- PDA Profile (CLDC-based)
- Connected Device Configuration (CDC)
  - CVM
  - Supports full Java library
- Foundation Profile
- Personal Profile
- RMI Profile

PDA Profile

- www.jcp.org/jsr/detail/75.jsp
- Based on the CLDC 1.0
- Will provide user interface and data storage APIs for handheld devices
- The UI API is expected to be a subset of the AWT
- No reference implementation yet

CDC/Foundation

- CDC targets the next generation of wireless, handheld consumer devices
- The Foundation Profile is meant to serve as a foundation for other profiles
- It extends the CDC by adding most of the missing J2SE core libraries, except those related to UI
- APIs for beans, rmi, sql are not part of CDC/Foundation
- Reference Implementations are available for Linux and VxWorks

CLDC vs. CDC

- CLDC implements a subset of Java features and APIs
- KVM
- For limited devices
- 16 or 32-bit processors
- Targets devices with 160-512 KB of memory

- CDC is a full Java implementation
- CVM
- For more powerful devices
- 32-bit processors
- Targets devices with at least 2 MB of memory

Personal Profile

- PersonalJava is being redefined as the Personal Profile
- It extends the Foundation Profile
- Provides GUI capable of running Java web applets
- Backward compatible with 1.1 and 1.2 PersonalJava applications
- No reference implementation yet

RMI Profile

- Extends the CDC and Foundation to provide Remote Method Invocation for devices
- Therefore, it is meant to be used with the CDC/Foundation and not CLDC/MIDP
- Requires TCP/IP network connectivity
- Compatible with J2SE RMI API 1.2.x or higher
- No reference implementation yet

Availability and Resources

- Sun's CLDC implementation supports development using Solaris, Win32, PalmOS
- NTT DoCoMo started Java-based cell phone service in January/01
- Motorola announced a Java-enabled GSM phone (Accompli A008).
- Motorola & Nextel (i50sx, i85s)
- Nokia, Ericsson, and others support J2ME

J2ME SDKs

- Sun's Wireless Toolkit: java.sun.com/j2mewtoolkit
- Motorola's J2ME implementation: www.motorola.com/java
- RIM's BlackBerry JDE: developers.rim.net/handhelds
- Metrowerks CodeWarrior for Java: www.metrowerks.com/desktop/java
- Zucotto' WHITEborad SDK

  www.zucotto.com

J2ME Resources

- J2ME:
  http://java.sun.com/j2me
- CLDC and KVM:
  http://java.sun.com/products/cldc
- MIDP:
  http://java.sun.com/products/midp
- Wireless Toolkit:
  http://java.sun.com/products/j2mewtoolkit

Additional Resources

- KVM Interest Archive:
  archives.java.sun.com/archives/kvm-interst.html
- Device Programming Forum @ ITWorld.com
  forums.itworld.com
- J2ME Archive:
  www.billday.com/j2me
- WirelessDevNet Developer Portal:
  www.wirelessdevnet.com

Thank you

Q&A

Copyright Info

Speaker Bio

Qusay H. Mahmoud provides Java consulting and training services. He has published dozens of articles on the Java programming language, including the MIDP and Palm programming articles for Sun Microsystems Java Developer Connection. Qusay is the author of Distributed Programming with Java (Manning Publications Co., 1999) **http://www.manning.com/Mahmoud**, and the upcoming *J2ME in a Nutshell* book from O'Reilly.

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