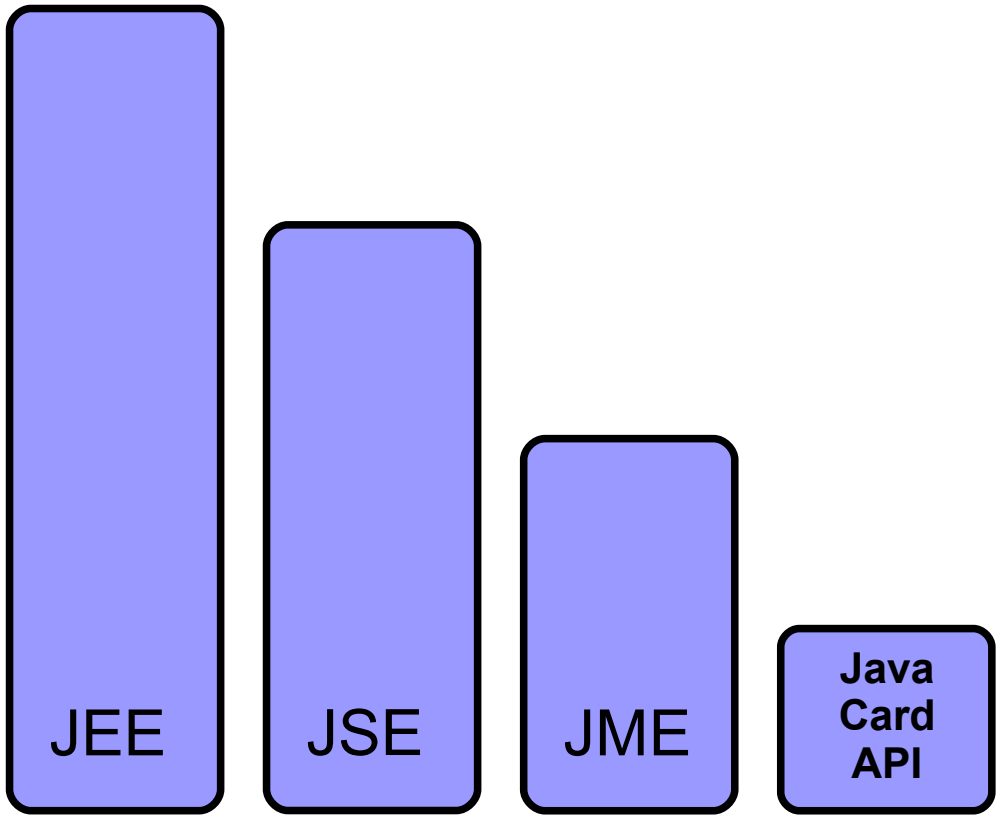
Java Micro Edition

Overview

- predecessors
  - Personal Java (1997)
  - Embedded Java (1998)
- JME definition – via JCP
  - JCP – Java Community Process
- JME is not a single SW package
  - a set of technologies and specifications
  - defines
    - *configuration*
    - *profiles*
    - *optional packages*

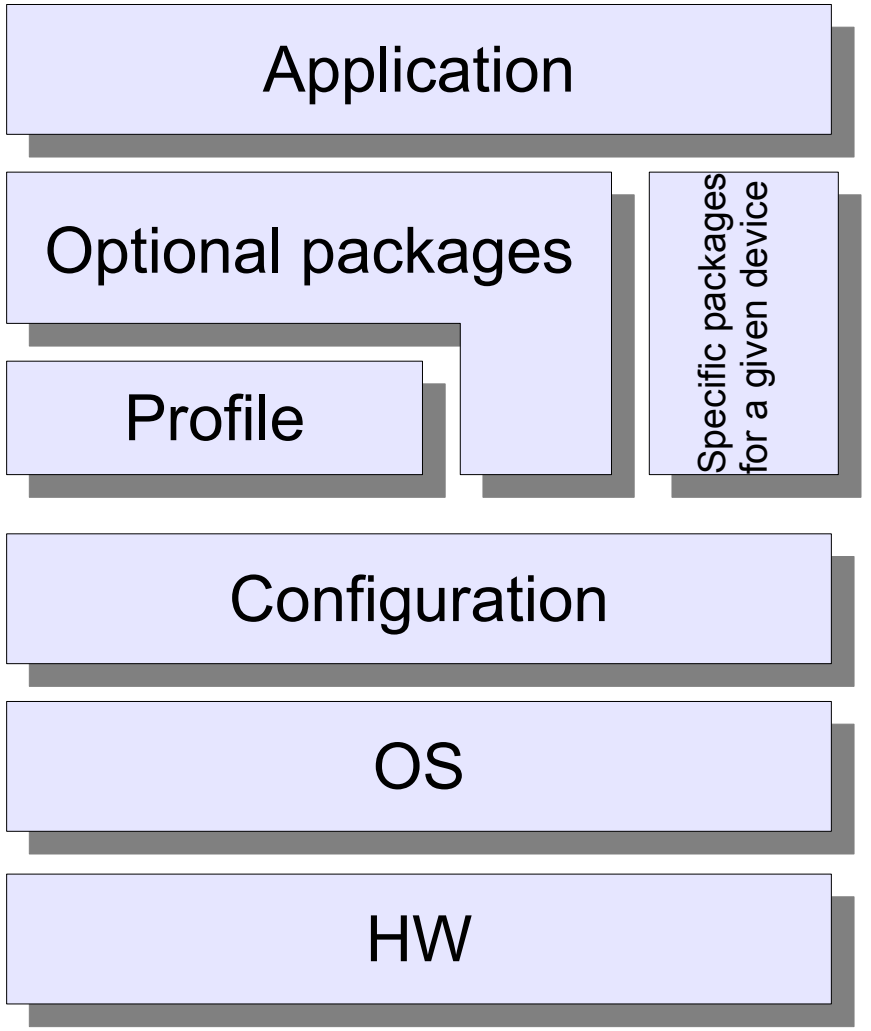
Java platform

- JSE – standard edition
- JEE – enterprise edition
- JME – micro edition



Architecture

- several layers
- **configuration**
  - VM specification
  - core API
  - requirements on device (memory, CPU,...)
- **profile**
  - API for application creation (for specific devices – mob. phone, PDA,...)
  - application lifecycle, GUI,...
- **optional packages**
  - APIs for specialized services



Software

- Java ME SDK
  - http://www.oracle.com/technetwork/java/javame/

Technology overview

- JSR 30 – CLDC 1.0 – Connected, Limited Device Configuration
- JSR 139 – CLDC 1.1 – Connected, Limited Device Configuration 1.1
- JSR 36 – CDC – Connected Device Configuration
- JSR 218 – CDC 1.1 – Connected Device Configuration 1.1

- JSR 37 – MIDP 1.0 – Mobile Information Device Profile
- JSR 118 – MIDP 2.0 – Mobile Information Device Profile 2.0
- JSR 271 – MIDP 3.0 – Mobile Information Device Profile 3.0
- JSR 46 – FP – Foundation Profile
- JSR 129 – PBP – Personal Basis Profile
- JSR 62 – PP – Personal Profile

- JSR 82 – BTAPI – Java APIs for Bluetooth
- JSR 120 – WMA – Wireless Messaging API
- ...

Configuration

- core specification
- intended for a large family of devices with similar features
- defines
  - requirements on CPU, MEM, net connectivity
  - features of VM
  - core API (derived from JSE)
- configurations
  - CLDC – Connected, Limited Device Configuration
    - mobile phones, PDA,...
  - CDC – Connected Device Configuration
    - PDA, navigation systems, set-top boxes,...

Profile

- over a configuration
- adds API for application creation
  - defines
    - application lifecycle
    - API for GUI
    - data persistence
    - …
- over CDLC
  - MIDP – Mobile Information Device Profile
- over CDC
  - Foundation Profile
  - Personal Profile

CLDC 1.0

- the smallest configuration
- for small devices with limited resources
- HW requirements
  - 16-bit or 32-bit processor
  - 128 kB permanent memory, 32 kB operating memory
  - energy source – battery
  - slow connection to network
- limited VM
  - KVM (Kilo VM)

CLDC 1.0 – KVM

- no floating-point operations and types
- no object finalization
- limited set of exceptions
- no
  - JNI
  - reflection
  - user defined classloaders
  - deamon threads and thread groups
  - weak references
- security model – *sandbox*
- two phases of code verifications

CLDC 1.0 – KVM – verification

- regular byte-code verification – resource demanding
  - size 50 kB, operation memory up to 100 kB
  - CPU performance demanding
- divided to two parts
  - preverification
    - during development
      - typically performed by a developer
    - the StackMap field added to every class
    - some instructions (jumps) replaced by equivalent ones
    - size of a class increased by approx. 5%
  - verifications
    - only linear analysis
    - fast, nondemanding
      - verifier size ~ 10 kB, operating memory < 100 B

CLDC 1.0 – API

- java.lang
  - Object, Class, Runtime, System, Thread, Runnable, String, StringBuffer, Throwable
  - Boolean, Byte, Short, Integer, Long, Character
  - Math
- java.util
  - Vector, Stack, Hashtable, Enumeration
  - Date, Calendar, TimeZone
  - Random
- java.io
  - InputStream, OutputStream, ByteArrayInputStream, ByteArrayOutputStream, DataInput, DataOutput, DataInputStream, DataOutputStream, Reader, Writer, InputStreamReader, OutputStreamWriter, PrintStream

CLDC 1.0 – API

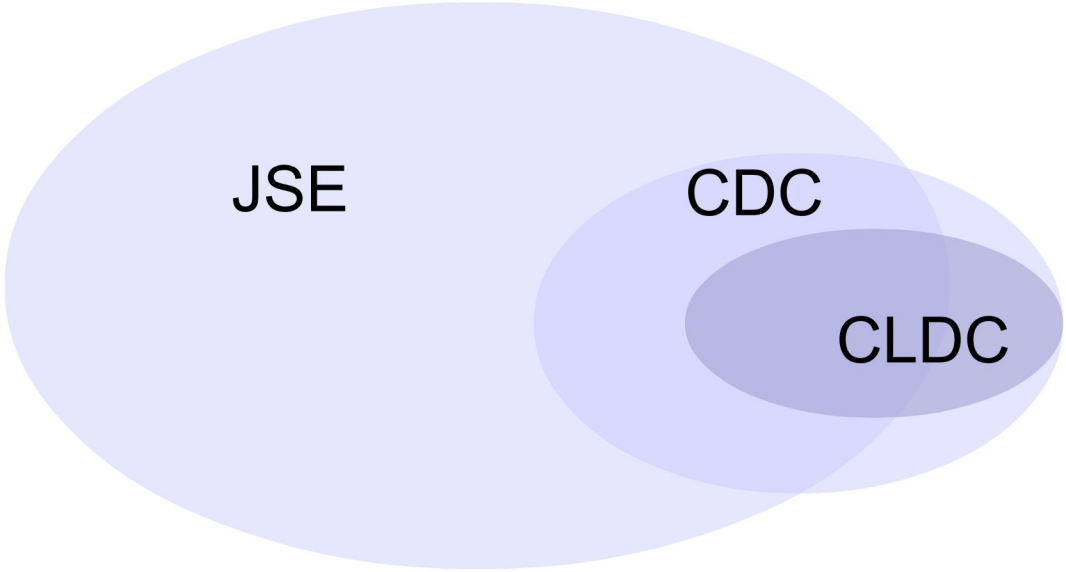
- Generic Connection Framework
  - javax.microedition.io
  - streams
  - a common abstraction for different kinds of connections
  - Connector.open("<protocol>:<address>;<parameters>")
  - e.g.:
    - Connector.open("http://www.foo.com");
    - Connector.open("socket://129.144.111.222:9000");
    - Connector.open("comm:0;baudrate=9600");
    - Connector.open("datagram://129.144.111.333");
    - Connector.open("file:/foo.dat");
  - no implementation at the configuration level

CLDC 1.1

- support of floating-point operations
- weak references
- enhanced classes Date, Calendar, TimeZone
- threads has names
- minimal required memory 192 kB

CDC

- 32-bit processor, 2 MB RAM, 2.5 MB ROM
- VM – complete features of JSE VM
- CDC is superset of CLDC
- java.io, java.util.zip, java.util.jar, java.net, java.security



$CLDC \subseteq CDC$

CDC profiles

- Foundation Profile
  - core profile
  - no GUI
  - text manipulation, HTTP, sockets
  - java.math
  - java.util.zip, java.util.jar
  - certificates, encryption
- Personal Basis Profile
  - over FP, subset of PP
  - part of AWT, JavaBeans support
  - application – Xlet
  - RMI communication
- Personal Profile
  - similar to JSE
  - complete AWT

MIDP

- Mobile Information Device Profile
- over CLDC
- for mobile phones
- HW requirements (MIDP 1.0)
  - display min. 96x54x1
  - aspect ratio 1:1
  - keyboard or touch screen
  - 128 kB permanent memory
  - 8 kB permanent memory for applications data
  - 32 kB operating memory
  - duplex connection to network
- HW requirements (MIDP 2.0)
  - 256 kB permanent memory
  - 128 kB operating memory
  - sound

MIDP 1.0

- application – MIDlet
- support for GUI
- support for network communication (GCF)
  - HTTP
- persistent application data
  - Record Management Storage (RMS)
- over the air (OTA)
  - a way to install application to a device
- packages
  - javax.microedition.midlet
  - javax.microedition.lcdgui
  - javax.microedition.rms

MIDP 2.0

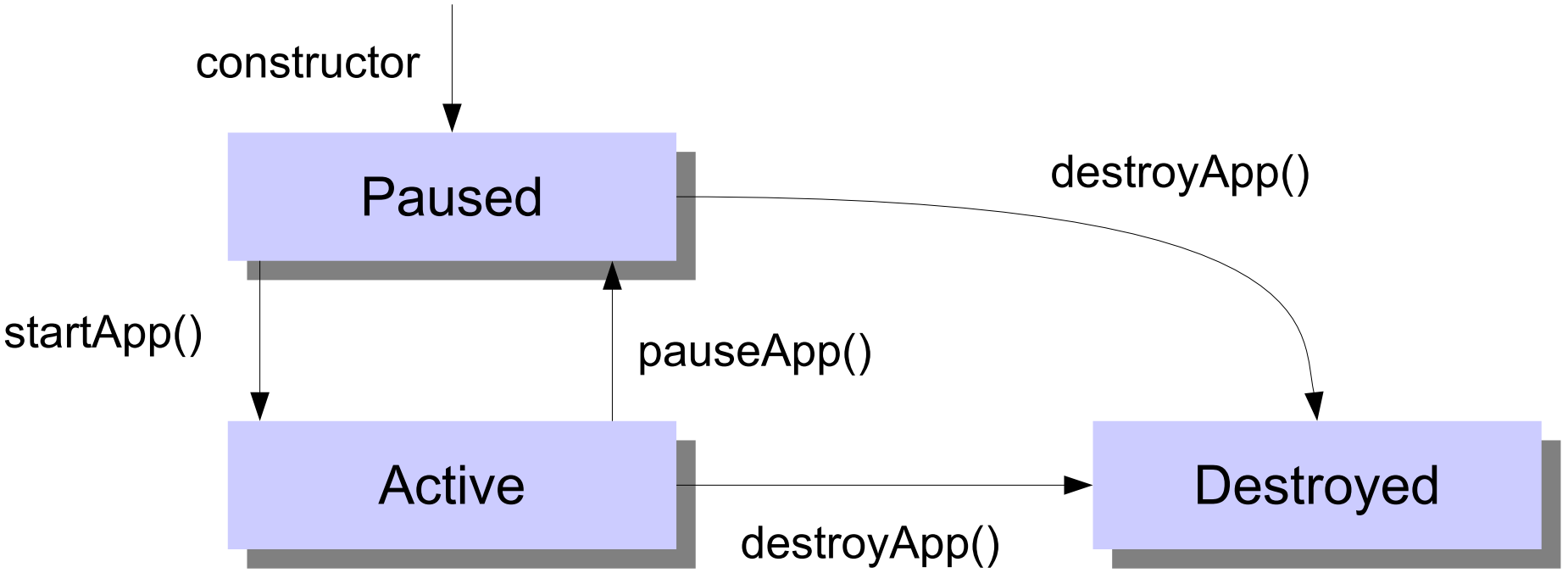
- better support of network
  - HTTPS, TCP and UDP sockets
- multimedia support
  - Mobile Media API (MMAPI)
- support for game creation
  - GameCanvas, Layers, Sprites
- certificates,...
- enhanced GUI
- push registry
  - launching MIDlets as a reaction to an incoming connection
- storage can be shared among several applications

MIDP 3.0

- JSR 271
  - December 2009
- parallel execution of several MIDlets and their communication
- support of IPv6
- LIBlets
  - shared libraries

MIDlet

- an application for MIDP
- similar to applets
- extends javax.microedition.midlet.MIDlet
- application lifecycle



Methods of MIDlet

- startApp()
  - called when when the *ACTIVE* state is entered
  - intended to be overridden
- pauseApp()
  - called when when the *PAUSED* state is entered
  - intended to be overridden
- destroyApp(boolean unconditional)
  - called when when the *DESTROYED* state is entered
  - if the parameter is *false*, the midlet can refuse to be destroyed
  - intended to be overridden
- notifyDestroyed()
  - terminates the midlet (destroyApp is not called)

Methods of MIDlet (cont.)

- notifyPaused()
  - the midlet wants to enter the *PAUSED* state
  - the pauseApp is not called
    - similar to notifyDestroyed
- resumeRequest()
  - opposite to notifyPaused
  - the midlet wants from the *PAUSED* state to *ACTIVE*
  - can be called e.g. from a timer or a background thread

MIDlet – implementation

```
public class Main extends MIDlet {
  public Main() {
  }

  public void startApp() {
    Displayable current = Display.getDisplay(this).getCurrent();
    if (current == null) {
      HelloScreen helloScreen = new HelloScreen(this);
      Display.getDisplay(this).setCurrent(helloScreen);
    }
  }

  public void pauseApp() {  }

  public void destroyApp(boolean b) {  }

  void exitRequested() {
    destroyApp(false);
    notifyDestroyed();
  }
}
```

MIDlet UI

- a single window can be shown at a single moment
  - several windows – switching

```
Display.getDisplay(this).setCurrent(helloScreen);
```

- if several MIDlets run concurrently, only one of them can access the display

MIDlet distribution

- 2 files
  - JAR archive – application code
  - JAD – Java Archive Descriptor
    - format
      - attribute-name: attribute-value
    - the same information must be also in the JAR manifest
- a JAD example

```
MIDlet-Name: HelloWorld
MIDlet-Version: 0.0.1
MIDlet-Vendor: PH
MIDlet-Jar-URL: HelloWorld.jar
MIDlet-Jar-Size: 1949
MIDlet-1: HelloWorld,,cz.cuni.mff.java.helloworld.Main
MicroEdition-Profile: MIDP-1.0
MicroEdition-Configuration: CLDC-1.0
```

MIDlet distribution (cont.)

- several midlets can be in a single package

  MIDlet-1: HelloWorld,,cz.cuni.mff.java.helloworld.Main
  MIDlet-2: HelloWorld2,,cz.cuni.mff.java.helloworld.Main2
  MIDlet-3: HelloWorld3,,cz.cuni.mff.java.helloworld.Main3

- the descriptor can contain user-defined attributes
  - can be obtained from the application
    - MIDlet.getAppProperty(String key)

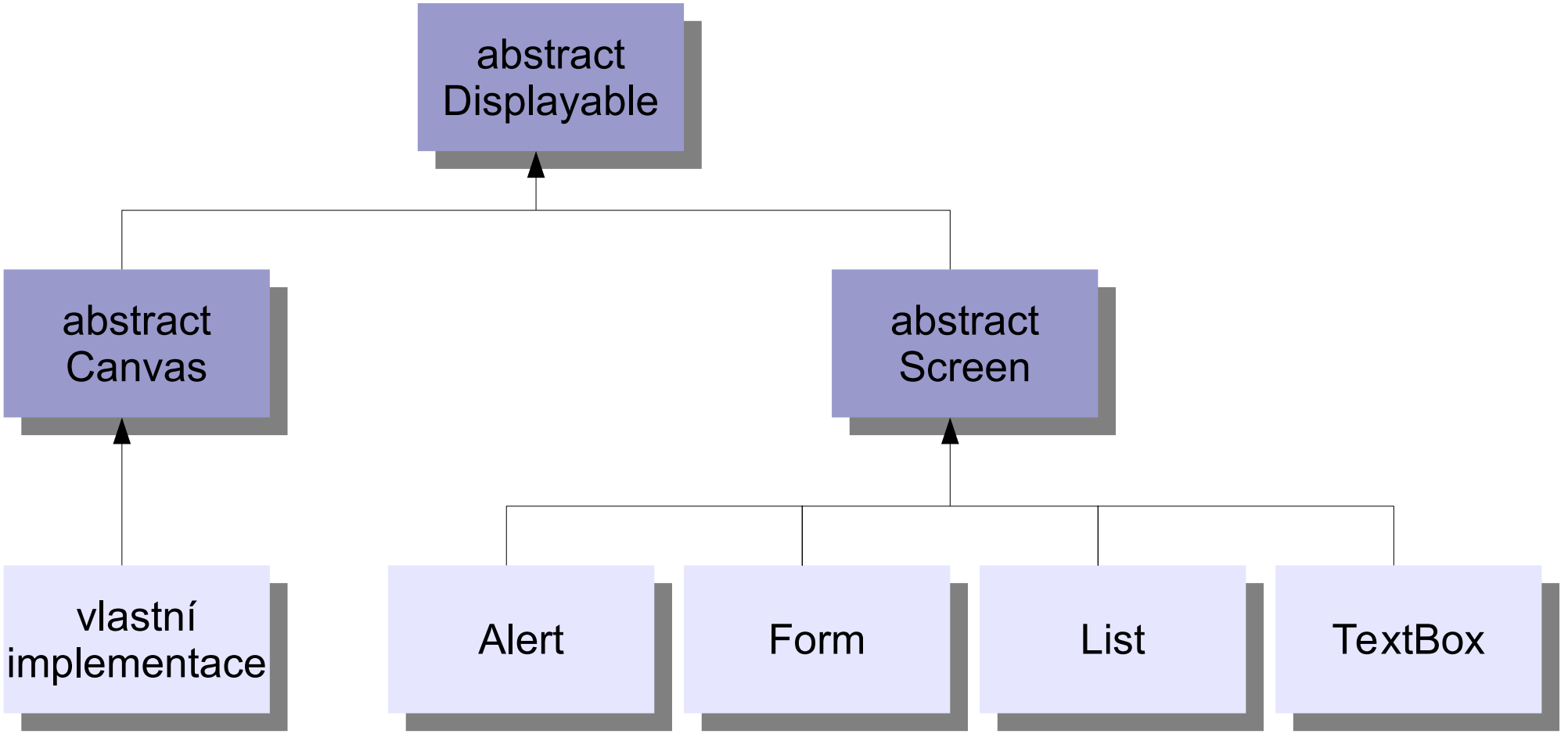
Record Management Store

- storing byte arrays
  - it is not a filesystem
- each midlet has own storage
  - MIDP 2.0 – storages can be shared
- operations are atomic
- stored data are persistent
- if the midlet is removed from a device, its storage is also deleted
- the javax.microedition.rms package
  - the RecordStore class
    - openRecordStore()
    - addRecord()
    - getRecord()

GUI

- the javax.microedition.lcdui package
- low-level
  - Canvas
    - drawing to display
    - handling keyboard/touch events
- high-level
  - device independent
  - low-level features cannot be influenced
    - fonts, etc.
  - portable

GUI


abstract
Displayable
abstract
Canvas
abstract
Screen
vlastní
implementace
Alert
Form
List
TextBox

GUI – MIDP 2.0

- javax.microedition.lcdui.game
  - GameCanvas
    - extends Canvas
    - allows for
      - querying keys states
      - off-screen buffer
  - Layer
    - the abstract class for visible elements of a game
    - children
      - Sprite
      - TiledLayer
  - LayerManager
    - the manager of the visible elements

GUI – MIDP 2.0

- javax.microedition.media
  - playing multimedia
  - the Manager class
    - static methods
    - void **playTone**(int note, int duration, int volume)
    - String[] **getSupportedContentTypes**(String protocol)
    - String[] **getSupportedProtocols**(String content_type)
    - Player **createPlayer**(String locator)
    - Player **createPlayer**(InputStream stream, String type)

Optional packages

- extend profiles
- defined based on JCP
- separately for CLDC or CDC (or for both)

- Wireless Messaging API (WMA) JSR 120, JSR 205
- JME Web Services APIs (WSA) JSR 172
- Bluetooth API JSR-82

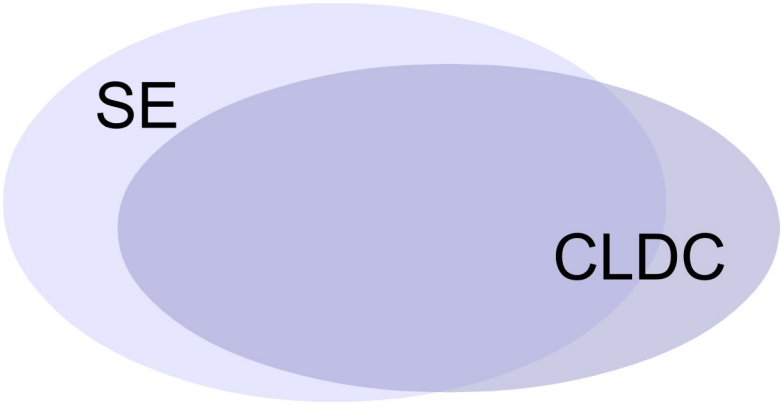
- JME RMI Optional Package (RMI OP) JSR 66
- JDBC Optional Package for CDC/Foundation Profile API JSR 169

Java ME 8

- 2014
- goal – unifying ME and SE
- CLDC 8
- MEEP 8
  - ME Embedded Profile 8

CLDC 8

- CLDC 8 – extended strict subset of SE 8



- VM supports
  Java VM specification for SE 7
  - without
    - the InvokeDynamic instruction
    - reflection and runtime annotations
- language almost as Java 8
  - without
    - lambda functions
    - reflection
    - serialization
    - JNI
    - user-defined classloaders
    - ...

CLDC 8

- verification
  - bytecode versions 51+ (JDK 7+)
    - without preverification
  - bytecode versions 48 and older (JDK 1.4)
    - mandatory preverification
- enhanced Generic Connection Framework
  - supporting more protocols
  - IP multicast
  - specific options for protocols
    - ConnectionOption
  - listing “access points”
    - 3GPP, CDMA, Wi-Fi,...
- supporting ServiceLoader

MEEP 8

- Java ME Embedded Profile (MEEP) 8
- built on CLDC 8
- profiles
  - minimal
    - core API, application model
    - minimum – 128 kB RAM & 1 MB Flash
  - standard
    - services, multitasking, ...
    - minimum – 512 kB RAM & 2 MB Flash
  - full
    - complete API
    - minimum – 2 MB RAM & 4 MB Flash

MEEP 8

- packages
  - mandatory
    - javax.microedition.midlet
  - optional
    - javax.microedition.swm
    - javax.microedition.cellular
    - javax.microedition.event
    - javax.microedition.power
    - javax.microedition.io
    - javax.microedition.lui
    - javax.microedition.key
    - javax.microedition.media
    - javax.microedition.rms

MEEP 8

- applications
  - MIDlets (IMlets), LIBlets
  - javax.microedition.midlet.MIDlet
    - notifyPaused(), pauseApp(), resumeRequest() deprecated
- services
  - ServiceLoader
  - service provider and consumer can be in different applications

MEEP 8

- Device I/O API
  - accessing devices
  - GPIO, I2C, SPI, UART,...

Java Embedded

- a complete Java platform
- several variants
  - Java ME Embedded
  - Java ME Embedded Client
  - Java SE Embedded
  - Java Embedded Suite

Java ME Embedded

- based on JME and CLDC
- intended for microcontrollers, etc.
- headless
  - no UI
- platforms
  - ARM
    - Raspberry Pi
  - STM32F7
  - ...
- < 1 MB RAM

Java ME Embedded Client

- based on JME and CDC
- < 10 MB RAM

Java SE Embedded

- based on JSE
- ARM, x86
- JavaFX UI

  - Starting with JDK 9, Oracle doesn't plan to offer a separate Java SE Embedded product download.

Java Embedded Suite

- Java SE Embedded
  + „enterprise“ features

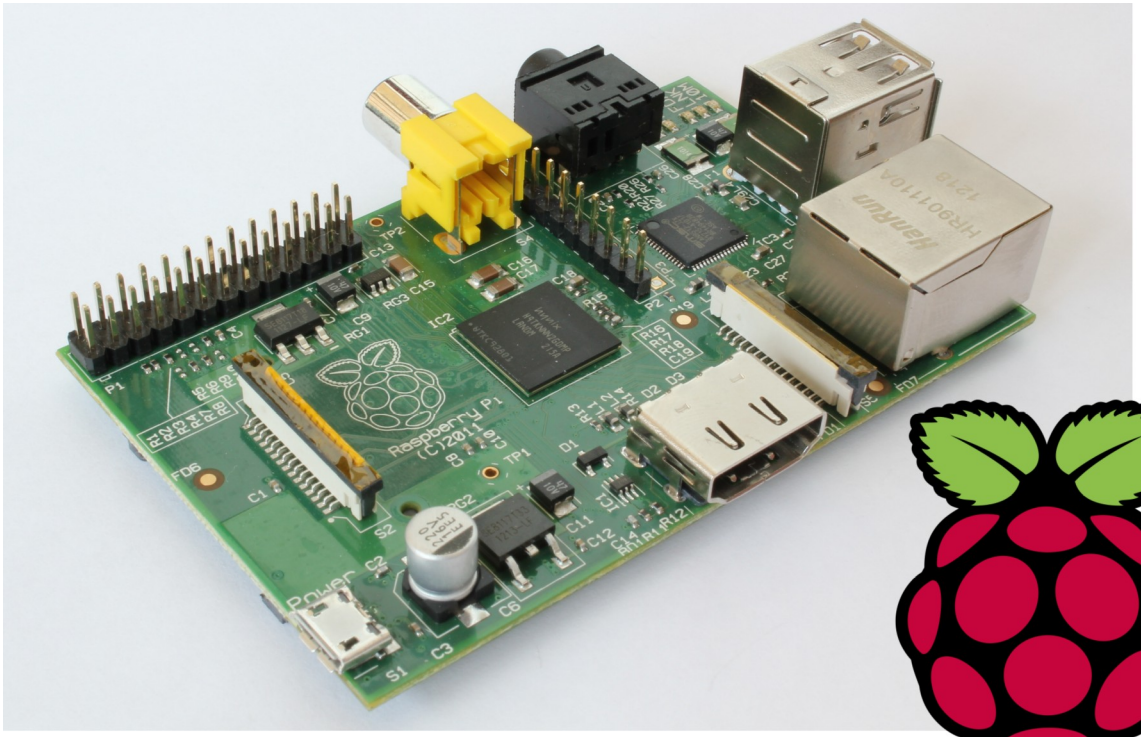
  - JavaDB
  - servlets
  - RESTFull web services

JAVA

Pi4J

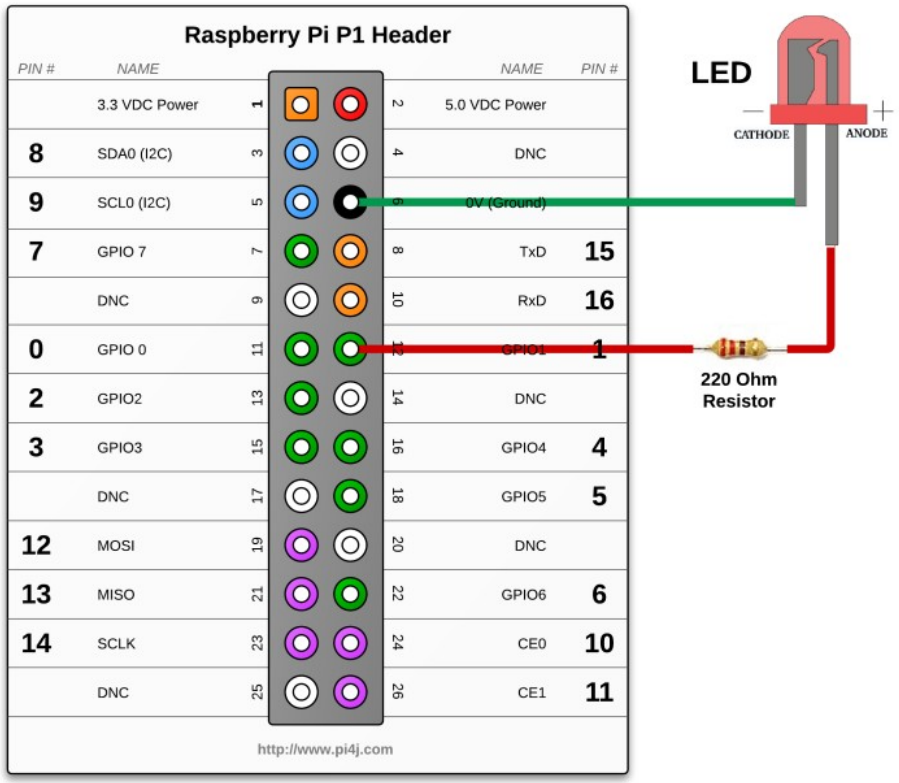
Pi4J

- http://pi4j.com/
- Raspberry Pi
- pro JSE
- GPIO, UART



Pi4J: example

```
final GpioController gpio = GpioFactory.getInstance();

final GpioPinDigitalOutput pin =
     gpio.provisionDigitalOutputPin(RaspiPin.GPIO_01,
        "MyLED", PinState.HIGH);
pin.setShutdownOptions(true, PinState.LOW);

Thread.sleep(5000);

pin.low();

Thread.sleep(5000);

pin.pulse(1000, true);

gpio.shutdown();
```



Real-Time Java

Real-time system

- non-real-time system
  - a system behaves correctly if produces correct results
- real-time system
  - a system behaves correctly if produces correct results at required time

Real-time system

- example
  - a medical device has to detect changes of patient state and react on time

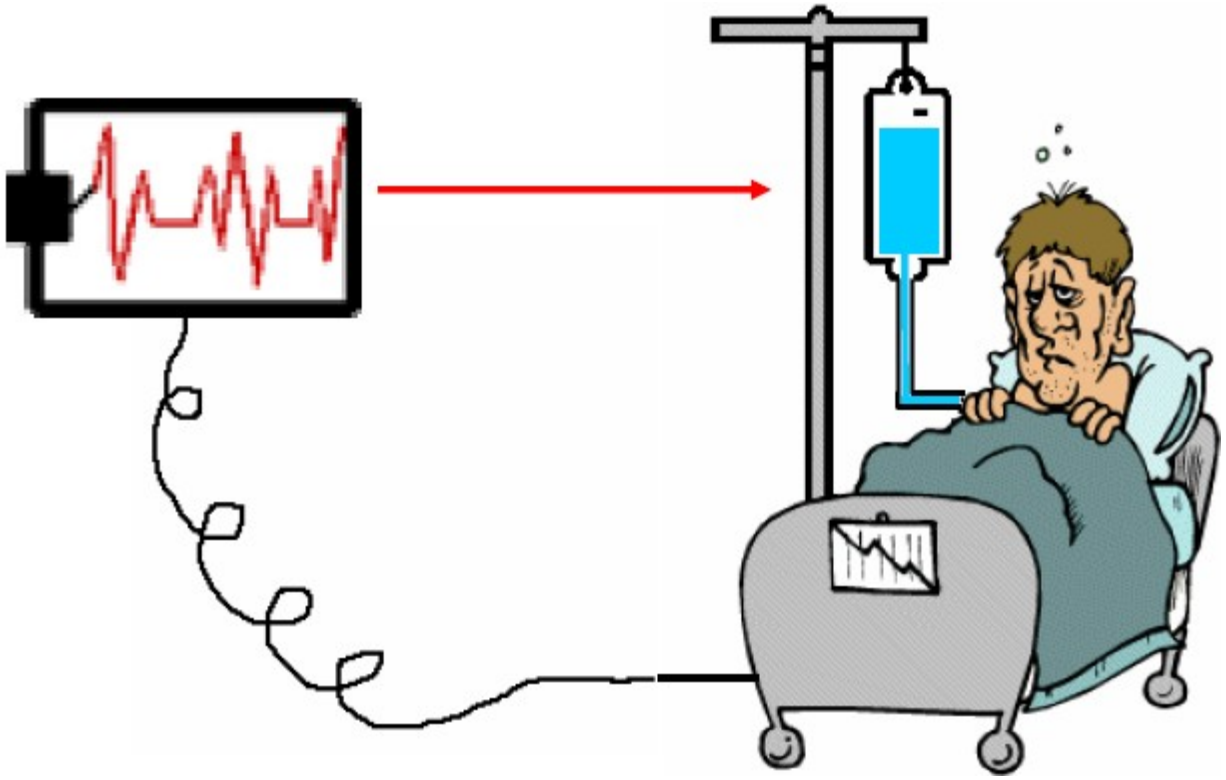
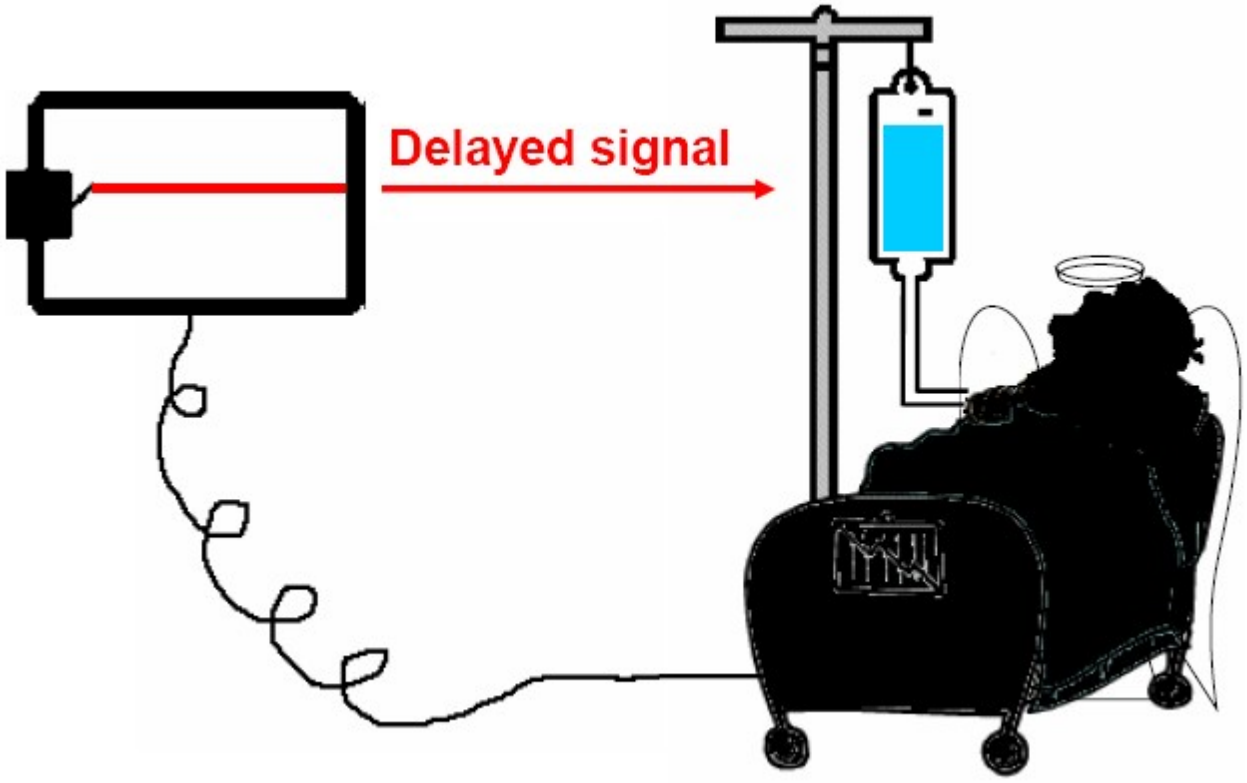


image source Issovic, D.:Real-time systems, basic course

Real-time system

- or...



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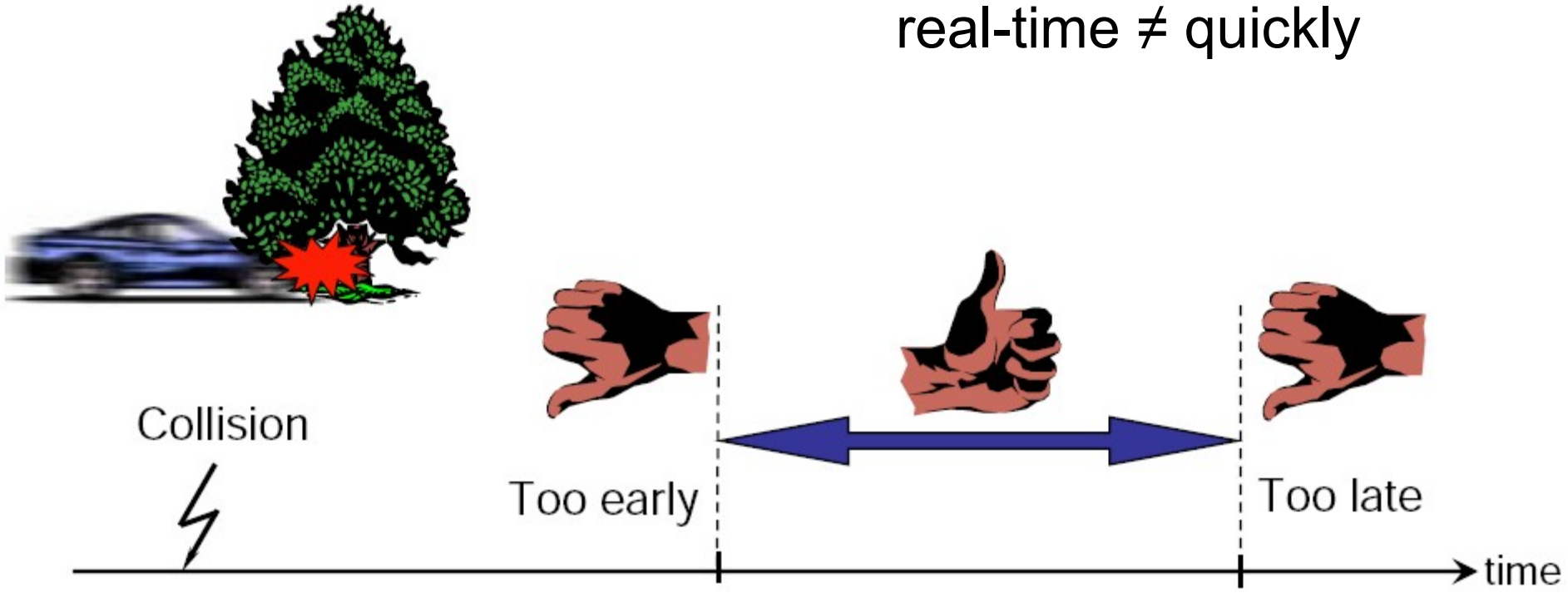
Real-time system

- example
  - the airbag cannot inflate too early or too late

real-time ≠ quickly



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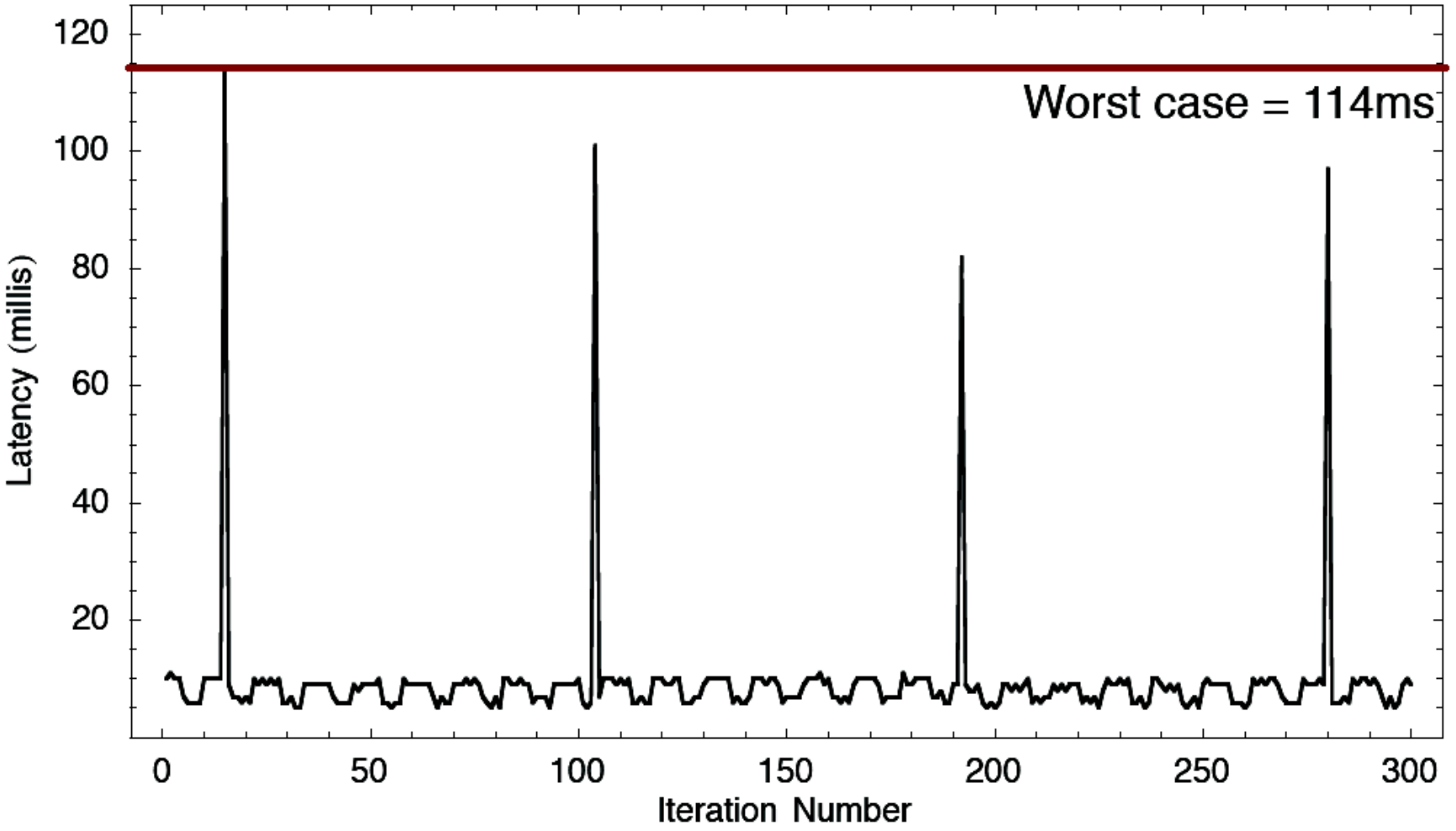
Real-time system

- soft real-time
- hard real-time
- safety-critical

Java and RT

- Java
  - simple
  - widely used
  - many libraries
  - portable
- but
  - no real-time scheduling
  - no support for periodic execution
  - no support for aperiodic events
  - GC issues
  - issues with direct access to memory
  - issues with managing devices
  - ...

Garbage collector



Real-time Specification for Java

- RTSJ
- 1999 – JSR-1
- no changes in syntax
- it extends Java by
  - Thread Scheduling and Dispatching
  - Memory Management
  - Synchronization and Resource Sharing
  - Asynchronous Event Handling
  - Asynchronous Transfer of Control and Asynchronous Thread Termination
  - High resolution time
  - Physical and Raw Memory Access

RTSJ – scheduling

- Fixed-priority round robin scheduler
  - own one can be added
- At least 28 real-time priorities (in addition to 10 common ones)

- Periodic threads
  - can start at specific time
  - have period and deadline

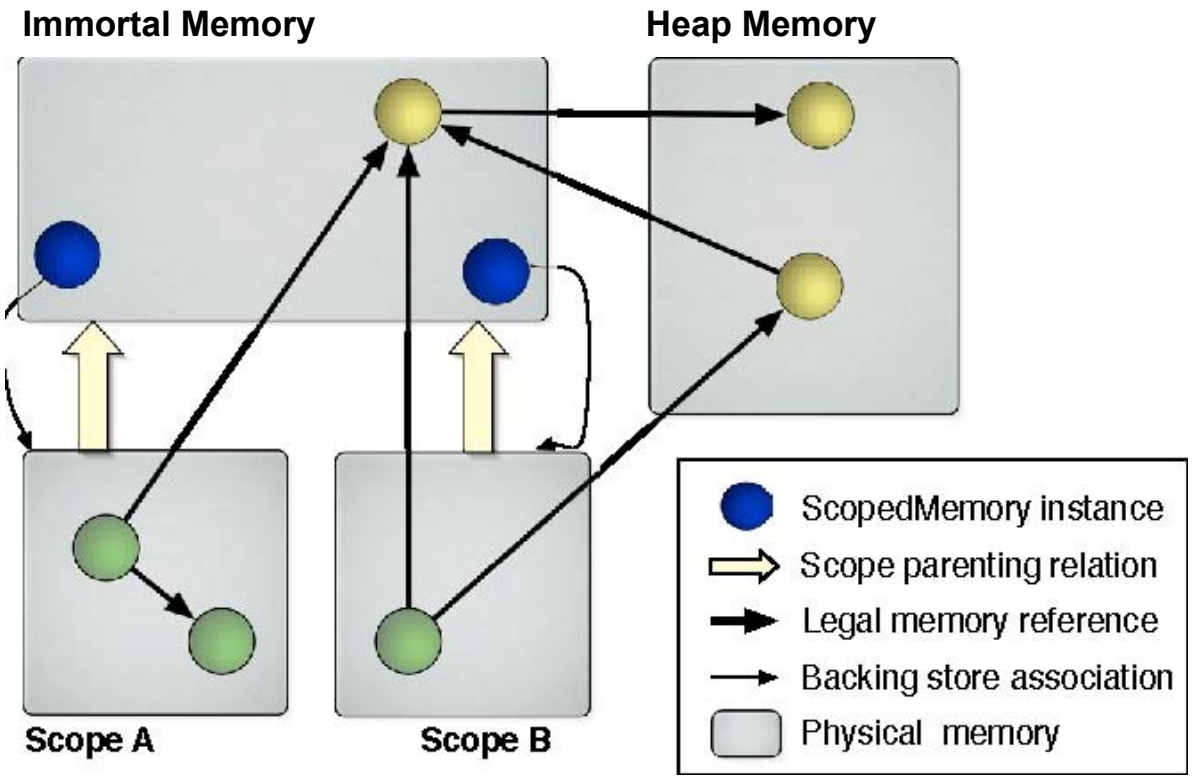
- Aperiodic events
  - a schedulable object, which is executes as a reaction to an event

RTSJ – memory

- NoHeapRealtimeThread
  - a thread without heap access
  - cannot be blocked by GC
- heap
  - as usual
- immortal memory
  - objects in the im. memory cannot be freed
  - for global data
- scoped memory
  - memory regions
  - objects freed at once when all threads leave the region
  - suitable for calling methods from the std library

RTSJ – memory

- rules for references between objects



RTSJ

- problems
  - memory regions are not intuitive
  - change of the classical programming model with GC
  - assigning a reference can fail

- there are real-time garbage collectors

Ravenscar Java

- restriction of RTJS
- inspired by “Ravenscar for Ada”
- goal
  - better analyzability and predictability

- an example of the restriction
  - no GC

RTSJ

- RTSJ 2.0 – JSR 282
  - draft

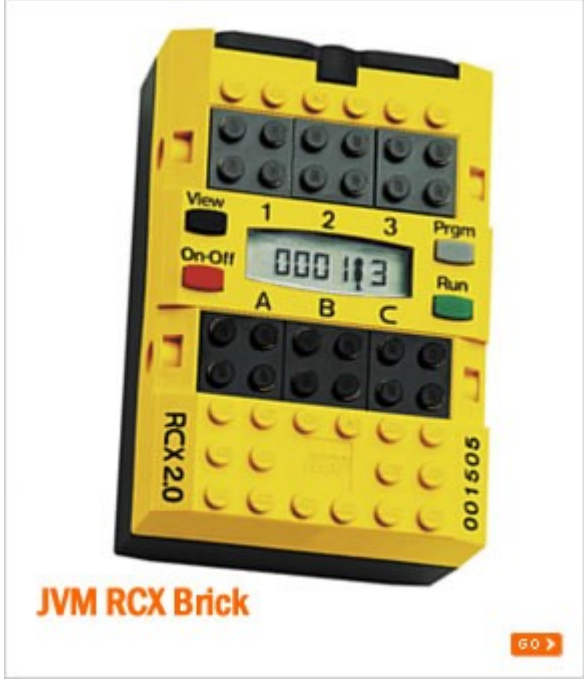
- Base Module
  - Schedulables
  - Events & Handlers
  - Priority Inheritance
  - Clock
  - MemoryArea
    - HeapMemory
    - ImmortalMemory
  - ...
- Device
  - Happenings
  - RawMemory
  - ISR (Option)
- Alternate Memory
  - physical
  - scoped
- POSIX
  - POSIX signals

JAVA

LeJOS

Overview

- http://www.lejos.org/
- a firmware for LEGO Mindstorm
- contains a Java virtual machine
  i.e. LEGO robots can be programmed in Java



Example

```
public static void main(String[] argv) {
  TouchSensor touchL = new TouchSensor(SensorPort.S4);
  TouchSensor touchR = new TouchSensor(SensorPort.S1);
  UltrasonicSensor sonar = new UltrasonicSensor(SensorPort.S2);

  Motor.A.forward();
  Motor.C.forward();
  LCD.drawString("Press ESC to quit", 0, 0);
  while (true) {
    if (Button.ESCAPE.isPressed()) { System.exit(0);   }
    if (touchL.isPressed() || touchR.isPressed() || (sonar.getDistance() <
                                                                    40)) {
      Motor.A.stop(); Motor.C.stop();
      sleep(1000);
      Motor.A.backward(); Motor.C.backward();
      sleep(1000);
      Motor.A.forward(); Motor.C.backward();
      sleep(1000);
      Motor.A.stop(); Motor.C.stop();
      sleep(1000);
      Motor.A.forward(); Motor.C.forward();
      }
    }

  }
```

LeJOS

- Java 7
- mix Java SE a ME
- limitations
  - no classloaders
  - small size of applications

  - after compilation, a binary image of the application is created
    - it is loaded to the “brick”

    - nxjlink -v ClassWithMain -o App.nxj
    - nxjupload App.nxj