Programming
CAN-based Fieldbus Systems using Java

Manuel Joaquim Pereira dos Santos,

Ricardo José Caetano Loureiro

Universidade de Aveiro, Aveiro, Portugal,

Helmut Dispert

Department of Computer Science and Electrical Engineering,

Kiel University of Applied Sciences, Kiel, Germany

FACHHOCHSCHULE KIEL
University of Applied Sciences

Contents

1. Introduction:
   Embedded Intelligent Devices
2. Java in Embedded Control:
   e.g.: Java Servlet Technology (the Embedded Java Controller - EJC)
3. Java and Native Code

Evolution

The evolution of embedded intelligent devices is driven by technological advancements:

- low cost microprocessors and peripheral devices
- Internet
- Java programming language

Examples:

- new hardware platforms (e.g. Strong ARM architecture)
- Internet and the HTTP to access devices
- Development of robust and reliable software using Java.

Opportunities

Sun Microsystems, Inc.:

"Combining the strengths of these (new) technologies, there is a huge market opportunity for companies that discover how to leverage the benefits of Java technology on embedded devices."

Solution:

A New Paradigm:

Write once, run anywhere

Java

History of Java (true story)

- **1990:**
  A small group is formed at Sun Microsystems with the task to think about the future of multimedia in private households.
  Group Member: James Gosling
- **Idea:**
  develop a generic and simple programming language to implement intelligent electronic devices (household).

  ⇒ **Embedded Programming**

Why Java?

- Object-oriented
  (encapsulation, polymorphism, inheritance),
- No multiple inheritance,
- Platform independent bytecode,
- Java primitive data types have fixed sizes,
- Automatic run-time bounds-checking,
- True Boolean type,
- No pointer programming,
- Automatic garbage collection,
- Language support for multithreaded applications.

Java Usage Models:

The proposed Java usage models fall into one of four categories:

- No Java
- Embedded Web Server Java
- Embedded Applet Java
- Application Java

These models are distinguished by two binary variables:

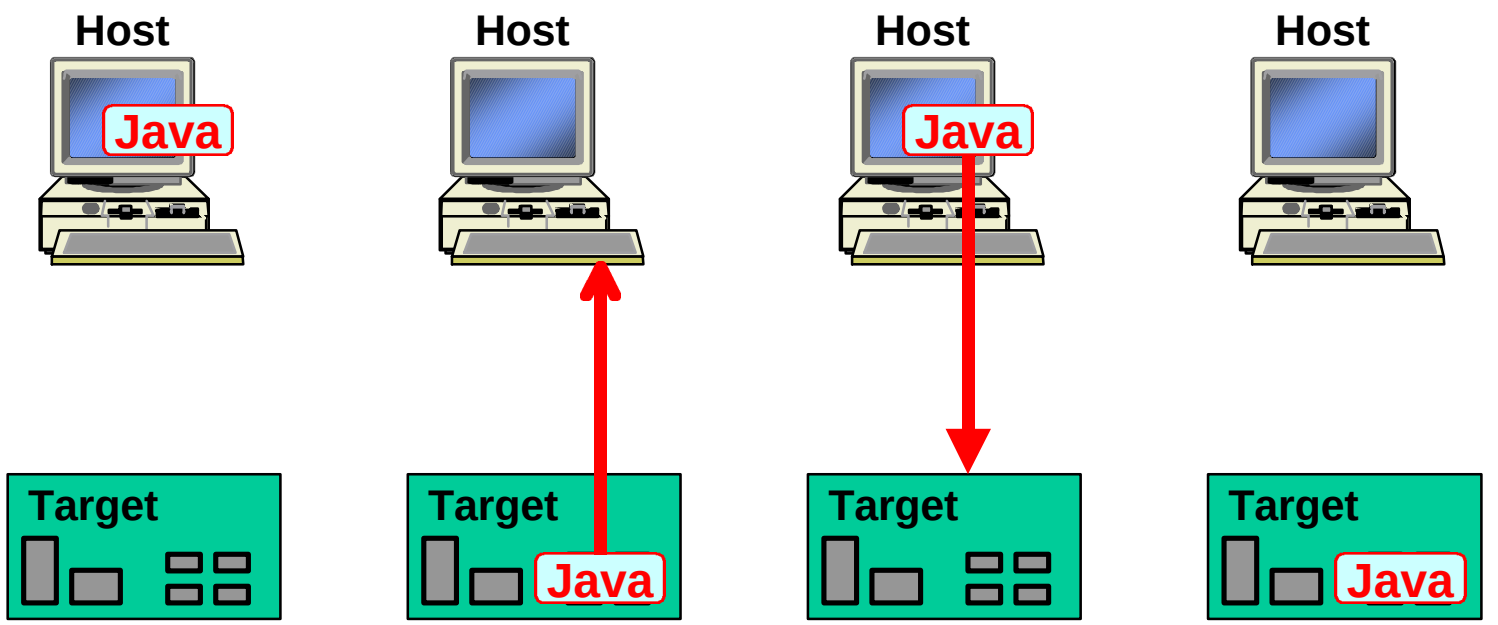
- location of the stored Java bytecodes
- the processor on which the bytecodes are executed

These variables can take one of two values:

- target (the embedded system)
- host (a general-purpose computer attached to the embedded system)

Ref.: Michael Barr

Java in Embedded Systems



No Java

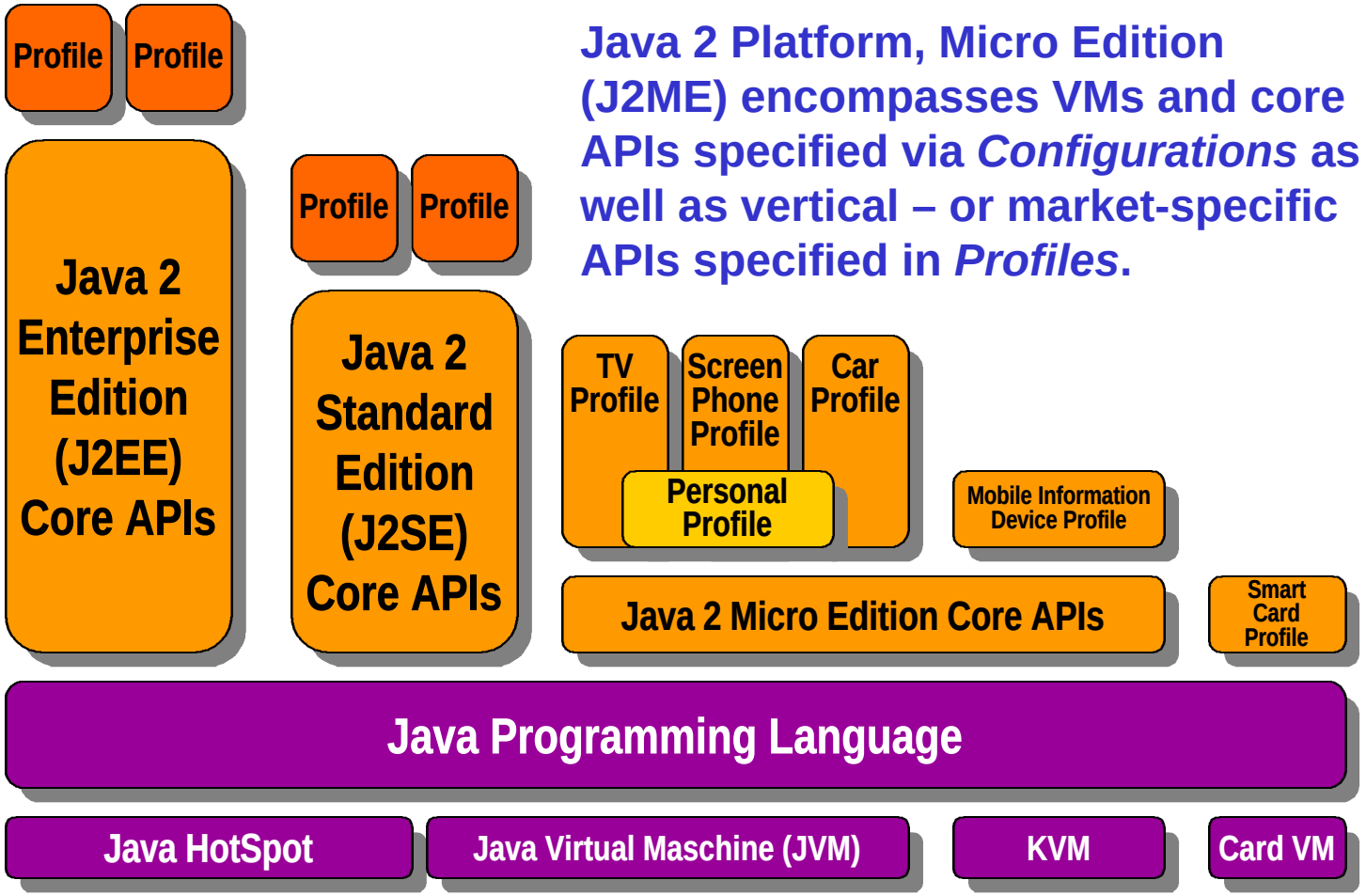
Embedded Web Server

Embedded Applet

Application

Ref.: Michael Barr

Java 2 Platform



Java 2 Platform, Micro Edition (J2ME) encompasses VMs and core APIs specified via *Configurations* as well as vertical – or market-specific APIs specified in *Profiles*.

Java Application Environments

Desktop OS
Enterprise Servers
Mainframes

Java AE

RTOS Vendors
Set-top boxes
PDAs
ScreenPhones
Hi-end mobile phones
Internet TV
Car navigation

Personal Java AE

Industrial Controllers
Intrumentation
Automotive
Printers
Hi-end Pagers
Mid-range Phones

Embedded Java AE

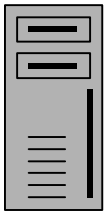
SmartCards
Java Ring

Java Card

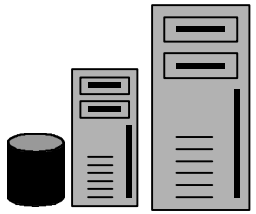
Java 2 Platform Editions

Java Technology Enabled Devices

Java Technology Enabled Desktop



Workgroup Server



High-End Server

Micro Edition

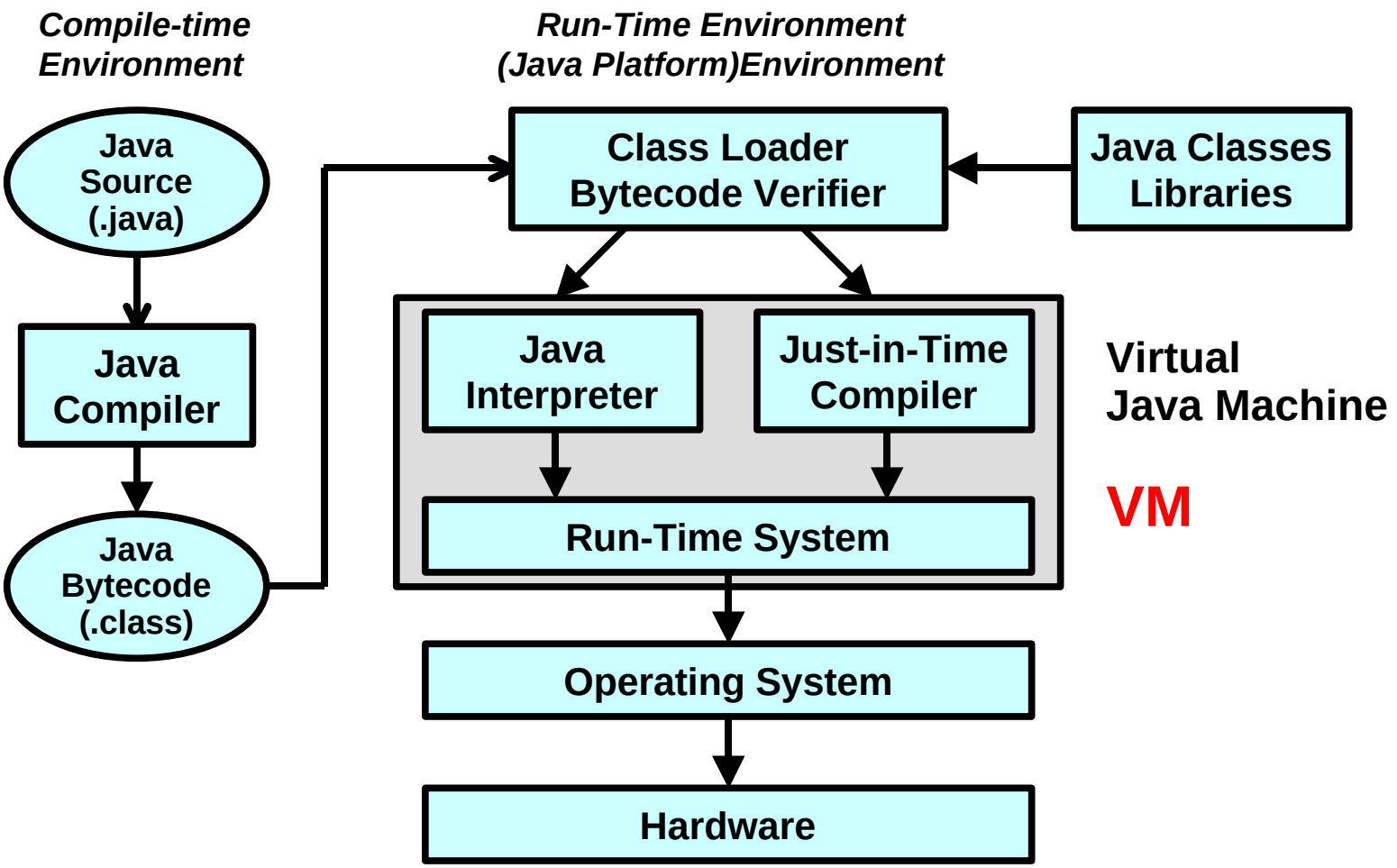
Standard Edition

Enterprise Edition

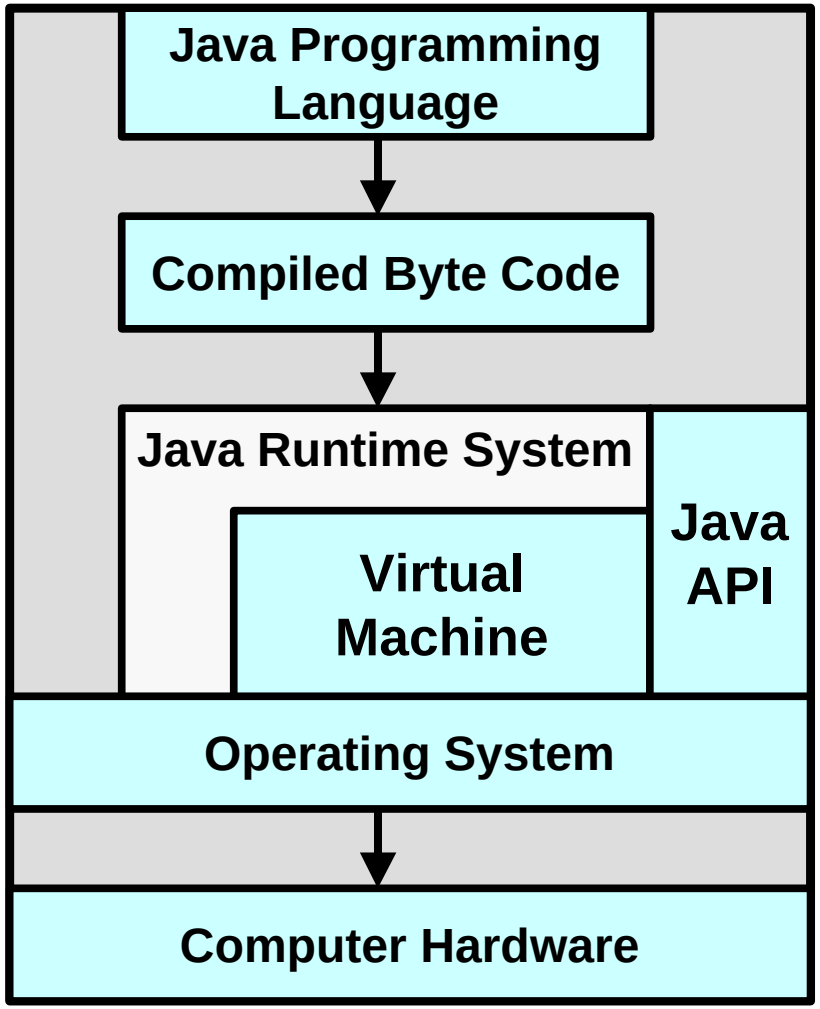
Application Portability:

1. mechanism for executing Java bytecodes on any processor
2. common set of class libraries

Java Development Cycle



Java Architecture



The Java Architecture

1. Programming Language
2. Virtual Machine (VM)
3. API

Access Hardware using Java

The basic idea of embedded control is to directly access hardware level properties:

- **Registers, I/O-interfaces, sensors, actuators, etc.**

Problem Basic Properties of Java:

- **Platform independent bytecode,**
- **No pointer programming,**
- **Automatic garbage collection,**

Access Hardware using Java

Solutions:

- Use dedicated hardware platform, dedicated OS and dedicated Java VM.

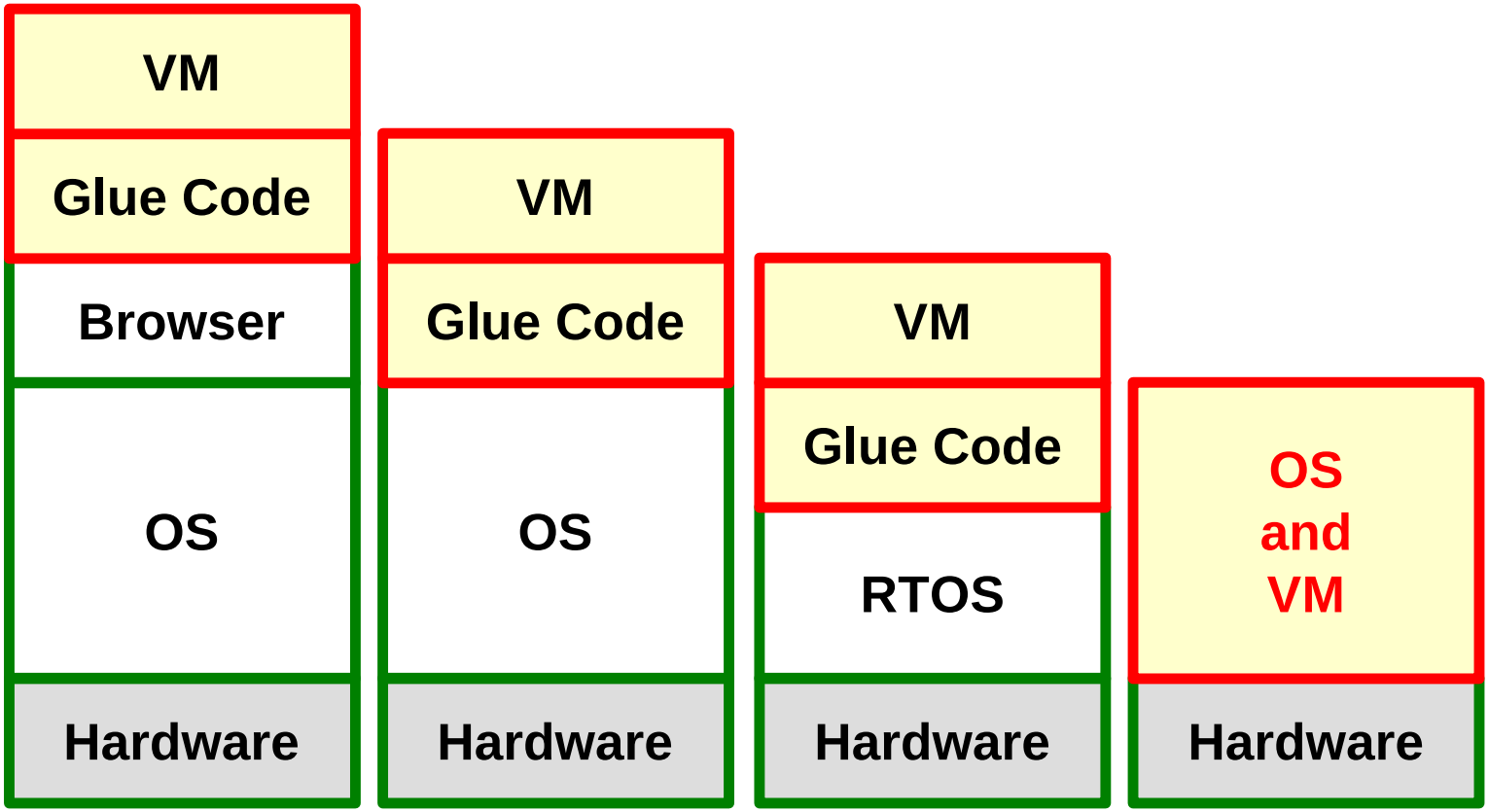
  Example:

  Snijder Embedded Java Controller (EJC).

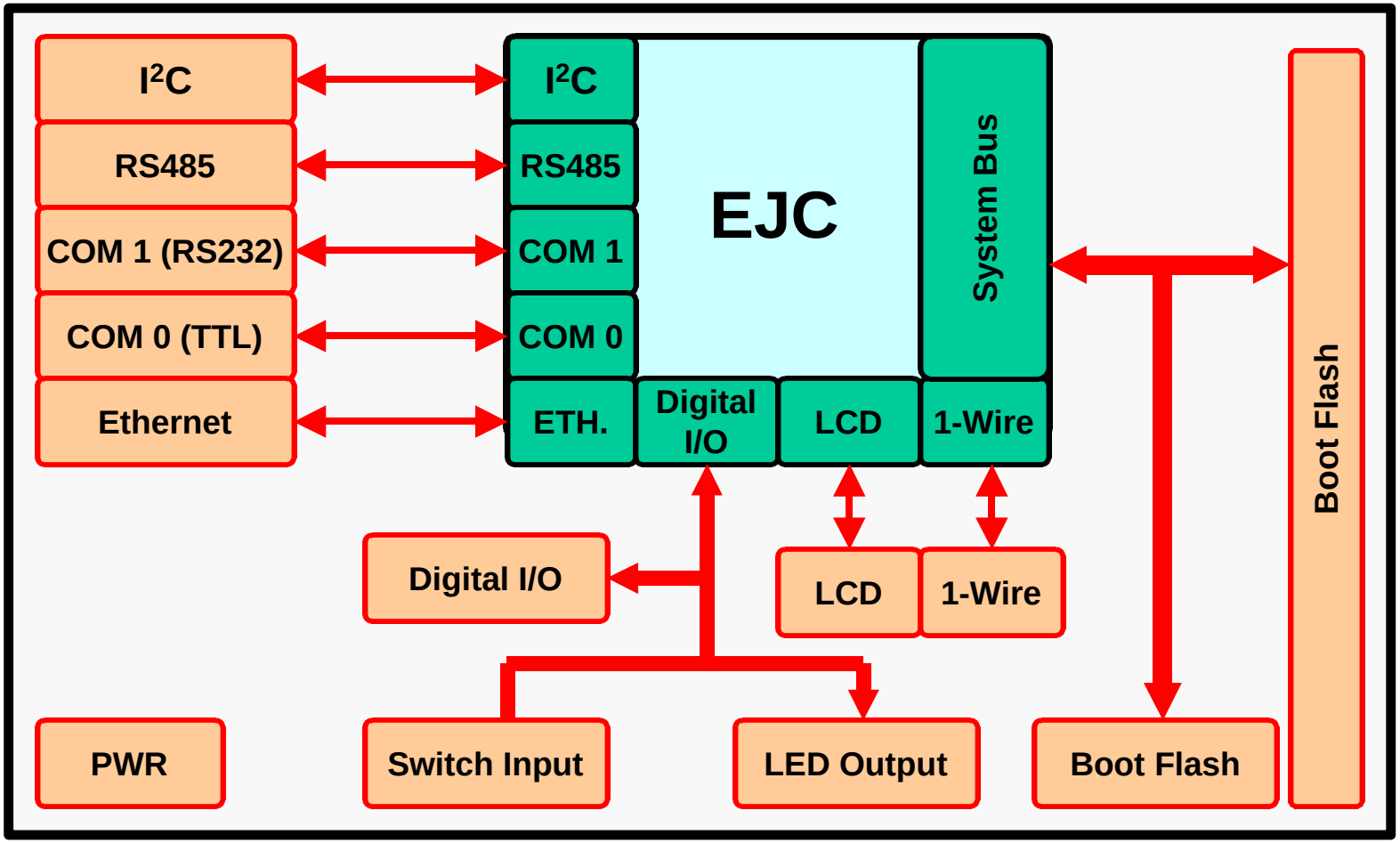
  see: 1st Int. Workshop, Vaasa, 2002

- Use native languages that allow access to hardware level functions.

Java - Jbed

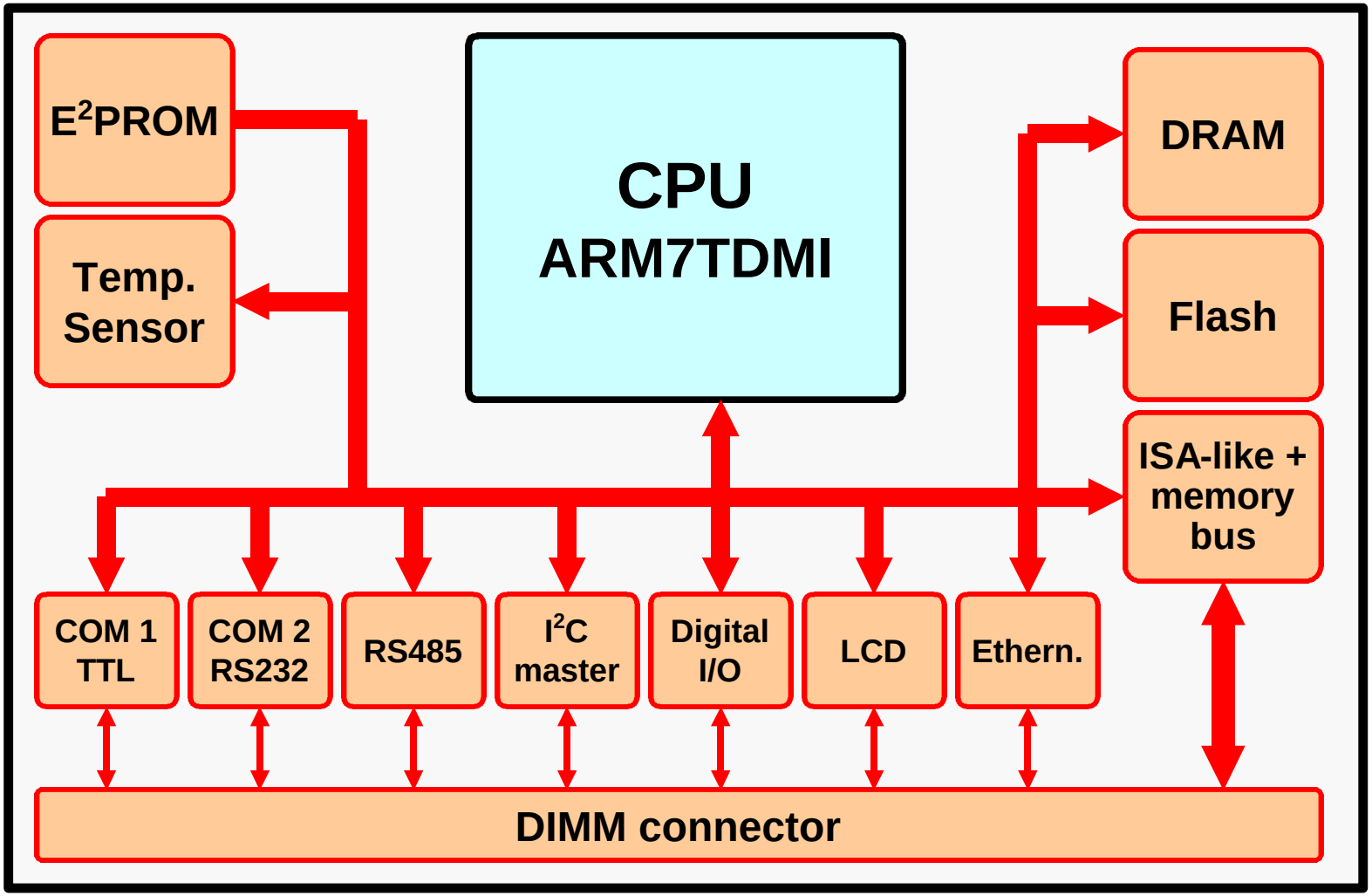

VM
Glue Code
Browser
OS
Hardware
VM
Glue Code
OS
Hardware
VM
Glue Code
RTOS
Hardware
OS
and
VM
Hardware
Java in a WWW browser
Java on a desktop OS
Java on a RTOS
Java on the bare metal

EJC - Embedded Java Controller



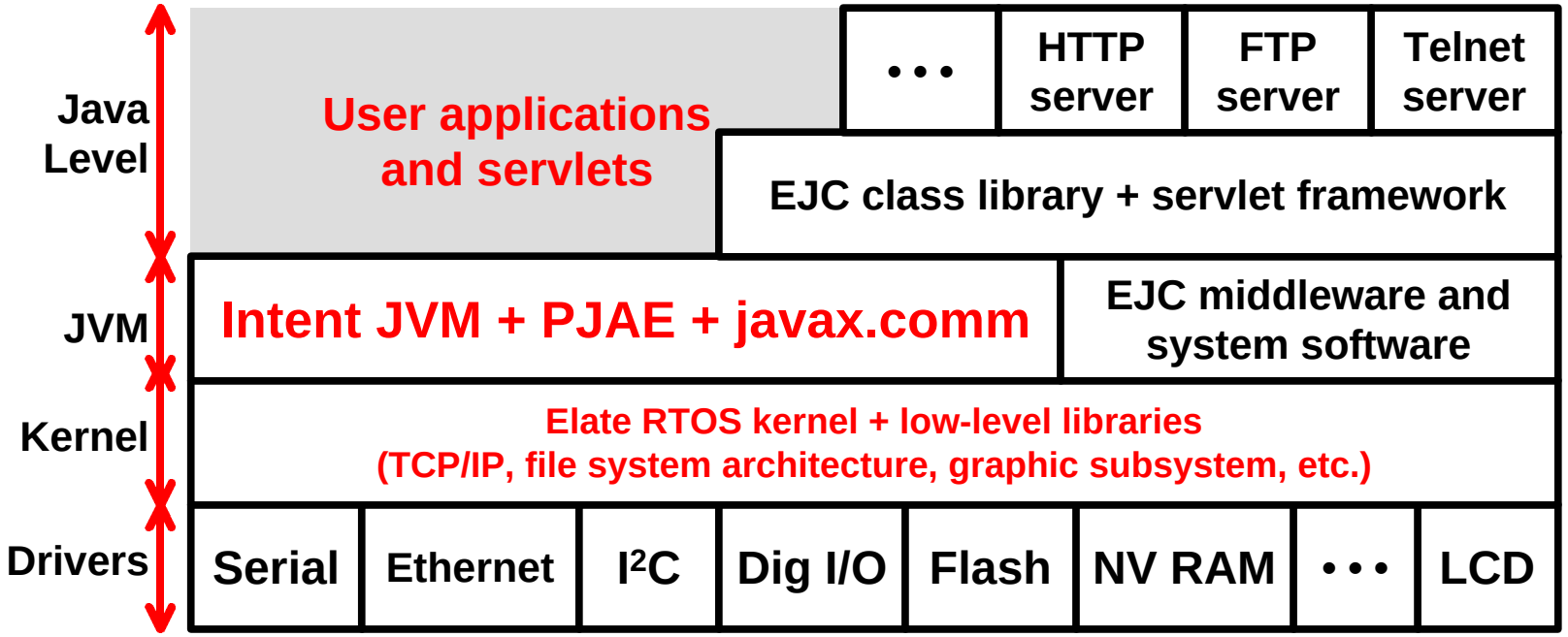
EJC-SK1 carrier board block diagram

EJC - EW1A block diagram



Embedded Java Controller block diagram

EJC



Overview of the EJC software architecture.

EJC - Native Code

Access to hardware or peripherals through native code:

Special feature of the EJC (the intent JVM):

Java classes can be directly written in VP assembler. VP assembler is a high-level assembler language which is targeted at a special Virtual Processor, and that is translated to native code either statically, at sysgen-time, or dynamically, when a class is loaded by the device (happens automatically).

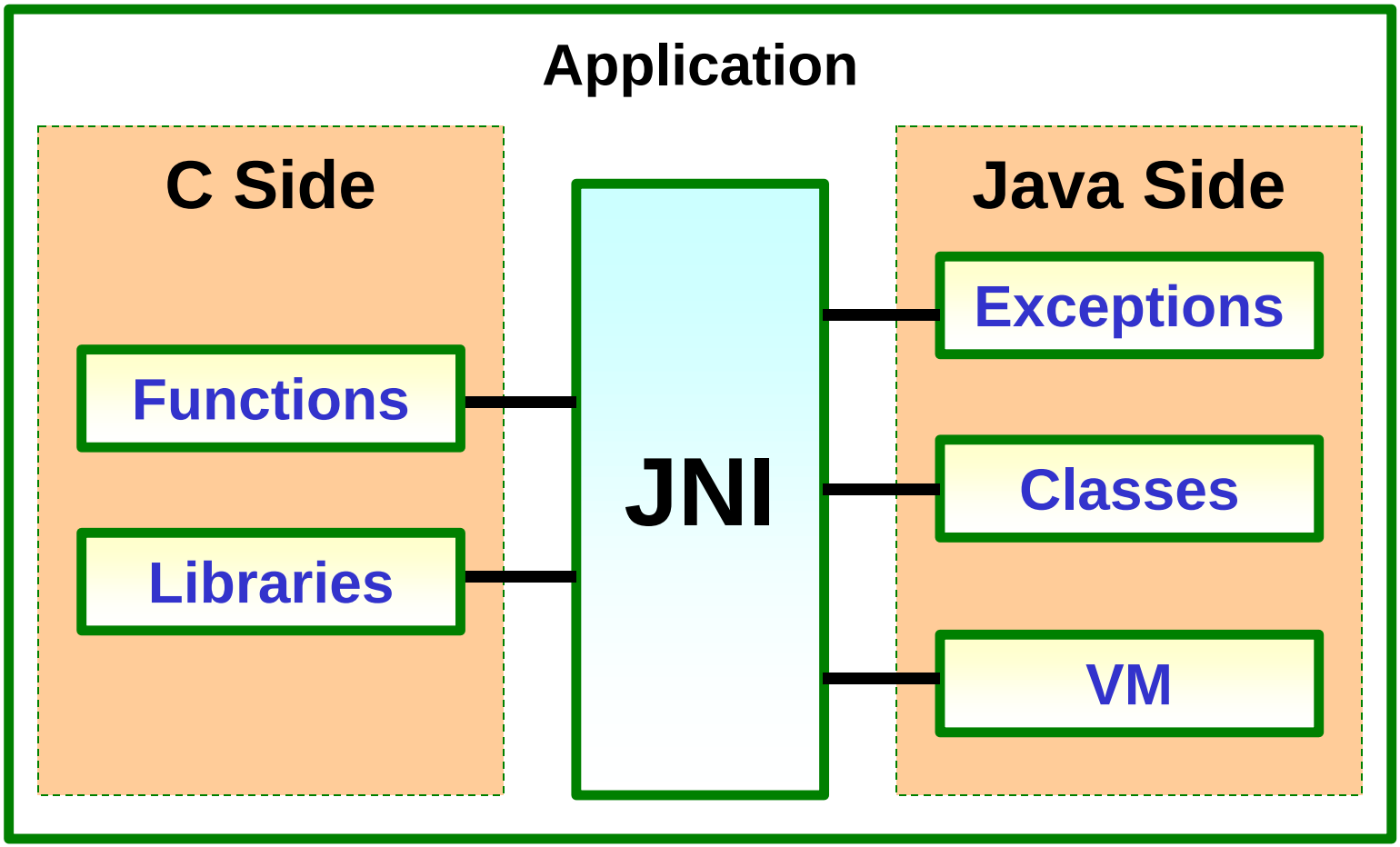
⇒ **Access to hardware is possible without the runtime overhead of JNI or other similar mechanisms.**

JNI - The Java Native Interface

Advantages:

- Support platform-dependent features.
- Integration: Make existing libraries or applications written in another programming language available to Java.
- Speed: Implement time-critical code.

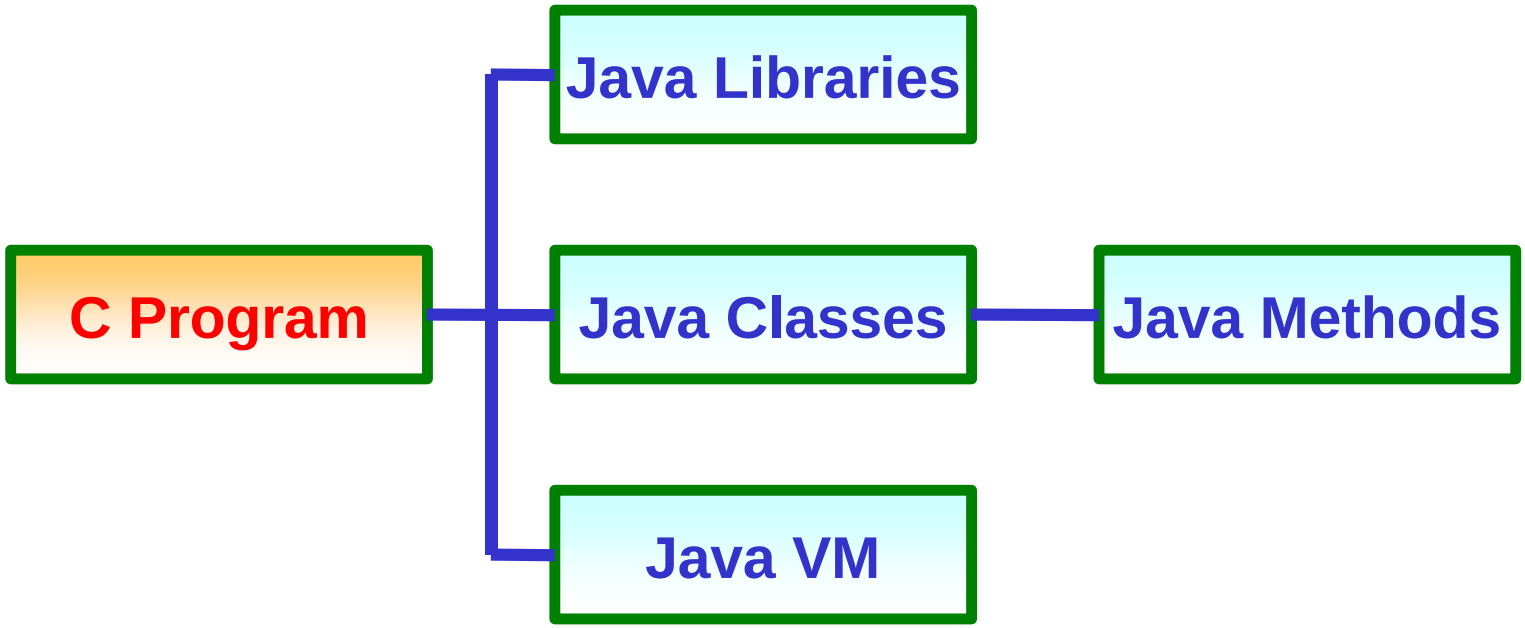
JNI


Application
C Side
Functions
Libraries
JNI
Java Side
Exceptions
Classes
VM

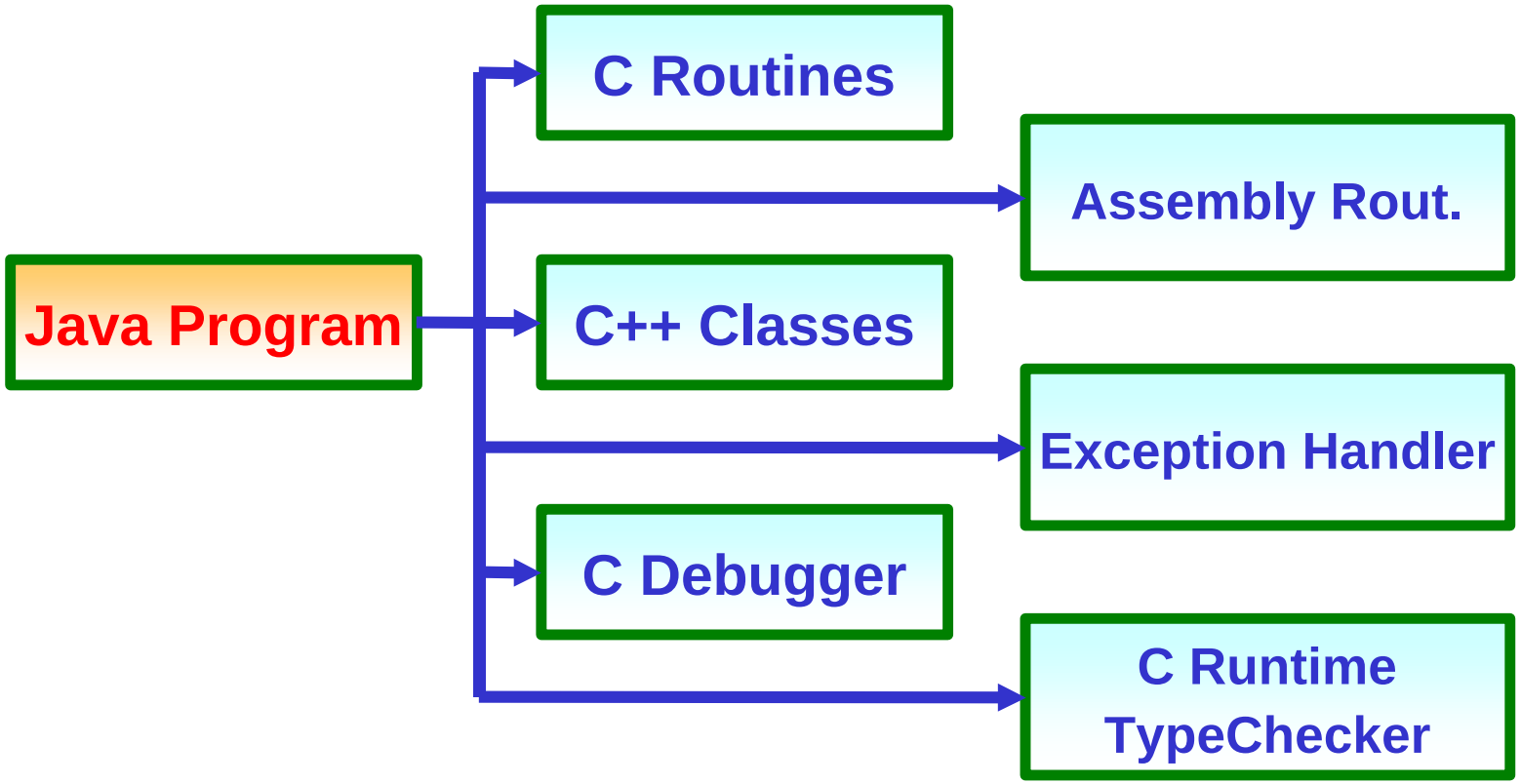
JNI allows interaction in two directions:

- Java programs can use native methods written in other languages
- Native methods can use Java objects and methods out of Java applications

JNI



JNI


Java Program
C Routines
Assembly Rout.
C++ Classes
Exception Handler
C Debugger
C Runtime
TypeChecker

JNI-Example

Java-File: HelloWorld.java

```
class HelloWorld
{
  public native void displayHelloWorld();
  static
      {
      System.loadLibrary("hello");
      }
  public static void main(String[] args)
      {
      new HelloWorld().displayHelloWorld();
      }
}
```

JNI-Example

Java Code Compilation:

```
javac HelloWorld.java
```

Creating the C header file:

```
javah –jni HelloWorld
```

JNI-Example

Name of native language function that implements the native methods:

prefix + class name + _ + method name

java_ + HelloWorld + _ + displayHelloWorld

```
JNIEXPORT void JNICALL
    Java_HelloWorld_displayHelloWorld(JNIEnv *, jobject);
```

JNI-Example

Native Methods (C code):

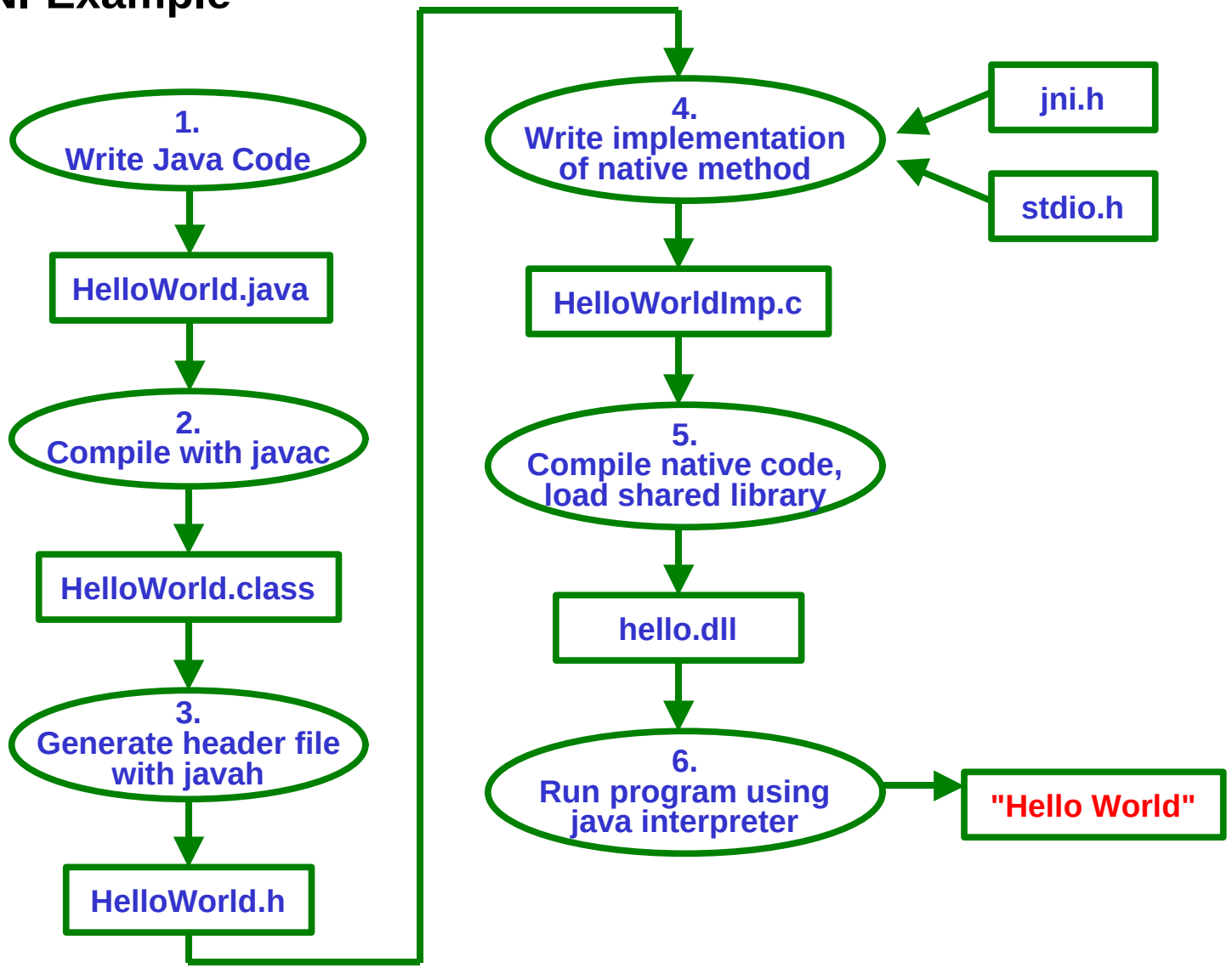
```
#include <jni.h>
#include "HelloWorld.h“
#include <stdio.h>
JNIEXPORT void JNICALL
     Java_HelloWorld_displayHelloWorld
     (JNIEnv *env, jobject obj)
{
printf("Hello World!\n");
return;
}
```

JNI-Example

HelloWorldImp.c contains three header files:

1. `jni.h`
   This file contains information needed by the native language to exchange data with the Java runtime system.
2. `HelloWorld.h`
   The generated header file.
3. `stdio.h`
   Contains the printf function.

JNI-Example


1.
Write Java Code
HelloWorld.java
2.
Compile with javac
HelloWorld.class
3.
Generate header file
with javah
HelloWorld.h
4.
Write implementation
of native method
jni.h
stdio.h
HelloWorldImp.c
5.
Compile native code,
load shared library
hello.dll
6.
Run program using
java interpreter
"Hello World"

Why Embedded Java?

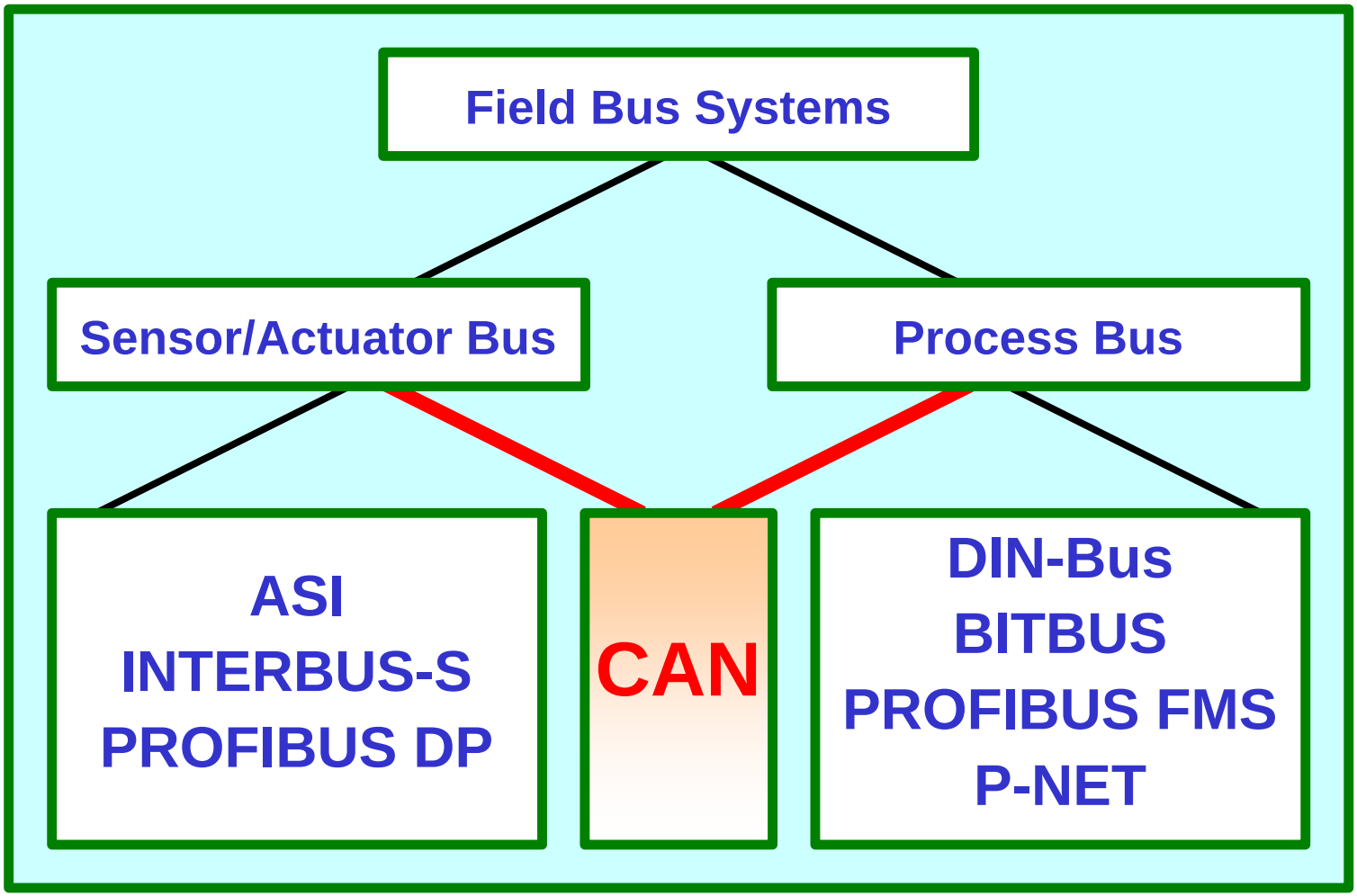
- Hardware Independence (greater than with C/C++)
- Downloading capabilities:
  Software downloaded into device
- Internet Connectivity
- Security
- Better Productivity

Application: CAN-Bus

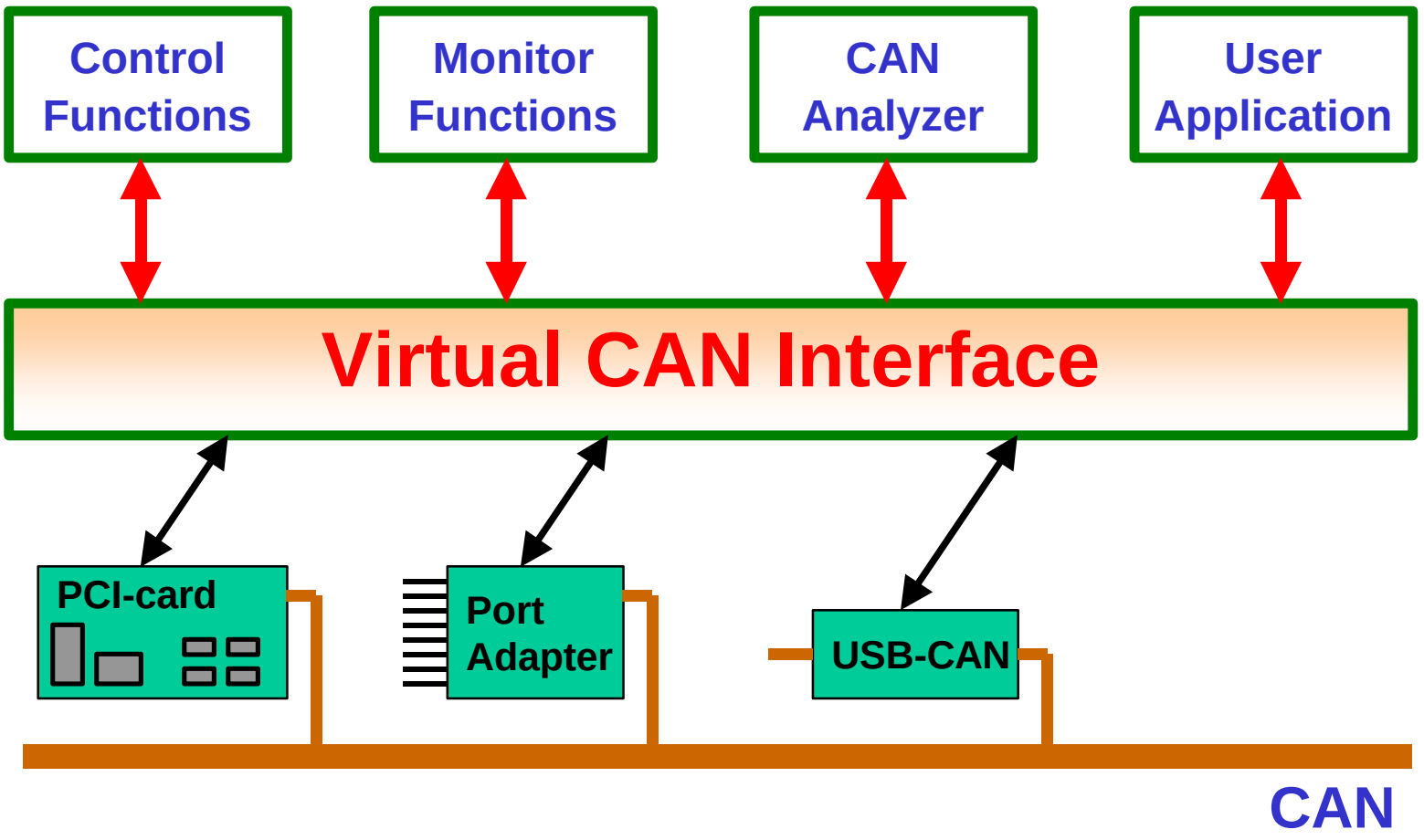
CAN-Bus ⇒ Controller Area Network

Serial 2-wire bus system
aimed at autombile applications,
developed by Bosch.
International Standard (ISO 11898)

Field Bus Organizations



Virtual CAN Interface



Java based CAN Program

```
class:  VCIJNI.java
**      Function: VCI2_PrepareBoard
**      Native method declaration

public native int VCI2_PrepareBoard(CAN_Analyser myApp,
                        int board_type,
                        short board_no,
                        String AddInfo,
                        byte AddInfoLength,
                        JCallback receive,
                        byte [] m_callback_databytes);
```

Dynamic Link Libraries

Operating System	Extension
Windows	.dll
Unix	.so
Mac OS X	.dylib

Code in class `VCIJNI.java` to load DLL (`VCIJNI.dll`) into memory

```
**    JNI-function
**    for loading of the VCIJNI.DLL

static {
    System.loadLibrary("VCIJNI");
  }
  public VCIJNI() {
  }
```

Dynamic Link Libraries

Java Code Compilation:

```
javac VCIJNI.java
```

Creating the C header file:

```
javah –jni VCIJNI
```

Dynamic Link Libraries

Generated Header File IXXAT_VCIJNI.h

```
/* DO NOT EDIT THIS FILE - it is machine generated */
#include <jni.h>
/* Header for class IXXAT_VCIJNI */

#ifndef _Included_IXXAT_VCIJNI
#define _Included_IXXAT_VCIJNI
#ifdef __cplusplus
extern "C" {
#endif
/*
 * Class:     IXXAT_VCIJNI
 * Method:    VCI2_PrepareBoard
 * Signature:
(LIXXAT/CAN_Analyser;ISLjava/lang/String;BLIXXAT/JCallback;[B)I
 */
JNIEXPORT jint JNICALL Java_IXXAT_VCIJNI_VCI2_1PrepareBoard
  JNIEnv *, jobject, jobject, jint, jshort, jstring, jbyte,
jobject, jbyteArray);
```

Dynamic Link Libraries

File VCIJNI.cpp implementeing the native code for function Java_IXXAT_VCIJNI_VCI2_1PrepareBoard

```
JNIEXPORT jint JNICALL Java_IXXAT_VCIJNI_VCI2_1PrepareBoard
  (     JNIEnv * env,
        jobject jObj,
        jobject myApp,
        jint board_type,
        jshort board_no,
        jstring AddInfo,
        jbyte AddInfoLength,
        jobject JReceiveCallback,
        jbyteArray callback_databytes)
{
        int i_test;
        jboolean *isCopy = NULL;

//Produce a new global reference to Object " JReceiveCallback "
        g_JObj_JCallback = env->NewGlobalRef(JReceiveCallback);
```

Dynamic Link Libraries

Create Object:

```
// Object with the Java Native Interface
static VCIJNI vci = new VCIJNI();


// prepare board for further configuration
   i_test = vci.VCI2_PrepareBoard(
                     myApp,
                     BoardConfStruct.board_type,
                     BoardConfStruct.board_no,
                     AddInfo,
                     AddInfoLength,
                     JReceiveCallback,
                     JReceiveCallback.m_a_data);
```

Java/CAN - demo

IXXAT AUTOMATION GMBH

a) CAN Interface:

USB-to-CAN Module

Intelligent CAN module for the USB-Port

Java/CAN - demo

PEPPERL+FUCHS
FACTORY AUTOMATION

b) Connected Device:

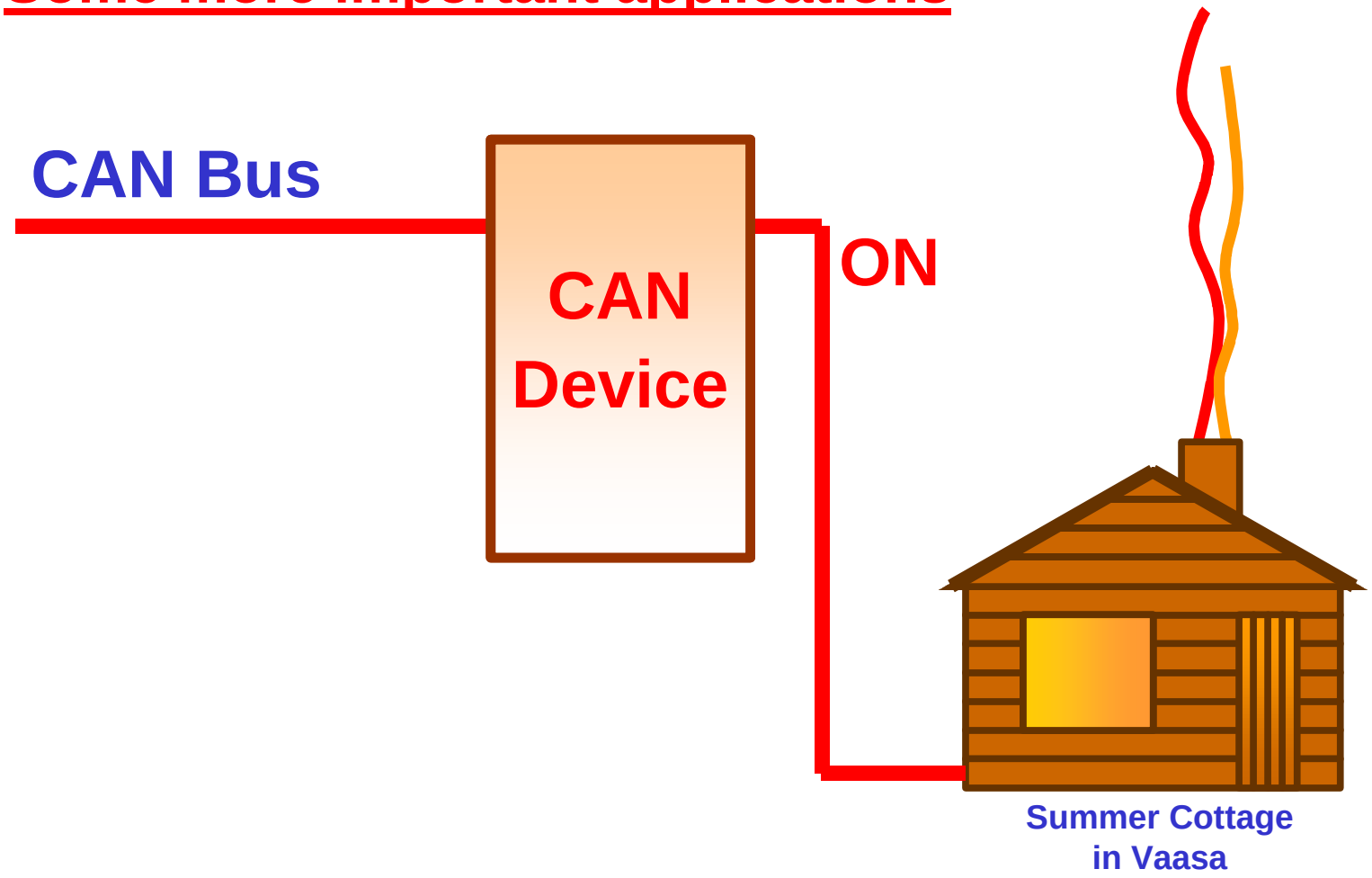
Absolute Rotary Encoders

Allows a direct read-out of the angular position

Java/CAN - demo

Program Code:	**Java**
CAN Code:	**C++**
GUI:	**Java Swing**
Future Expansion:	
Internet Connectivity:	**Java**

Some more important applications



The end

Thank you!

FACHHOCHSCHULE KIEL
University of Applied Sciences

The End

Contact:
Prof. Dr. Helmut Dispert
University of Applied Sciences Kiel
Faculty of
Computer Science and Electrical Engineering
Grenzstr. 3
24149 Kiel, Germany
Tel.: +49-431-210-4114/4123
Fax.: +49-431-210-64114
E-Mail: helmut.dispert@fh-kiel.de