

## D4 - Real-time Linux

### Real-time Linux with RT-Preempt patch and Xenomai

#### Objectives

- ▶ Understand Real-Time programming
- ▶ Discover the various solutions under Linux
  - The Preempt\_RT patch
  - Xenomai
  - Real-Time drivers and networking with Xenomai
  - Programming with Xenomai

*Labs are conducted on the PC or on ARM-based target boards (Quad Cortex-A9 Sabrelite boards from NXP)  
We use the latest available kernel supported by Xenomai*

#### Course environment

- ▶ A PC for two trainees, with Linux and Xenomai on a target board
- ▶ Printed course material

#### Prerequisite

- ▶ Linux application programming skills ([D0 - Linux user mode programming](#) course)
- ▶ Embedded Linux knowledge ([D1 - Embedded Linux with Buildroot and Yocto](#) course)
- ▶ For RTDM, Linux Driver Programming ([D3 - Linux Drivers](#) course)
- ▶ Notions of real-time programming ([RT1 - Real Time and Multi-Core programming](#) course)

#### Plan

##### First Day

#### Linux overview

- ▶ Linux
  - History
  - Version management
- ▶ The various licenses used by Linux (GPL, LGPL, etc)
- ▶ Linux distributions
- ▶ Linux architecture and modularity

*Exercise: Boot Linux automatically starting a user application*

## The Linux Boot

- ▶ Linux kernel parameters
- ▶ The Linux startup sequence
- ▶ Various initialization systems (busybox init, system V init, systemd)
- ▶ Automatically starting an embedded system

*Exercise: Boot Linux automatically starting a user application*

## The Linux kernel

- ▶ Downloading stable source code
  - Getting a tarball
  - Using GIT
- ▶ Configuring the kernel
- ▶ Compiling the kernel and its modules
  - The Linux build system
  - Modules delivered in-tree
  - Out-of-tree modules
- ▶ Installing the kernel and the modules
- ▶ The Linux Device Tree

*Exercise: Configuring and compiling a target kernel for the target board*

## Second Day

## Real-Time programming

- ▶ Scheduling
- ▶ Threads
  - Definition of a thread
  - POSIX threads
- ▶ Synchronization and communication primitives
  - Mutexes and Condition Variables
  - Barriers
  - Semaphores
  - Message queues
- ▶ Thread-specific Data

*Exercise: Implement a multi-threaded server*

- ▶ Classic real-time problems
  - Dead-Locks
  - Live-Locks
  - Priority Inversion

*Exercise: Solve the Readers-Writer problem*

## Debug and Analysis Tools

- ▶ The Kernel tracing infrastructure
  - Tracepoints
  - The ftrace function tracer
  - Kprobes
  - Event tracers
- ▶ Performance monitoring in the Linux kernel
  - Perfcounters
  - Perf events
- ▶ Debugging the kernel using traces
- ▶ LTTng

*Exercise: Trace context switches and measure latency times*

*Exercise: Use LTTng to trace multi-task context switches*

## Third Day

### **Real-Time Solutions for Linux**

- ▶ The specificities of Real-Time
- ▶ Why Linux is not Real-Time
- ▶ Configuration Options in Vanilla Kernel
- ▶ The Preempt\_RT patch
- ▶ The co-kernel approach

*Exercise: Install Preempt\_RT and check the effect on latencies*

### **Xenomai**

- ▶ Architecture
  - Adeos
  - Skins
  - Shadow Threads and Scheduling Domains
- ▶ Xenomai Schedulers
  - The Real-Time class schedulers
  - The Weak class schedulers
- ▶ Configuring Xenomai

*Exercise: Install Xenomai*

*Exercise: Cross-compile an application for Xenomai*

## Fourth Day

### **Xenomai programming**

- ▶ The Xenomai Skins
  - POSIX
  - RTDM
- ▶ Specificities of the POSIX skin
- ▶ Programming RTDM drivers
  - Creating a kernel module
  - Integration in the Linux Device Model
- ▶ Xenomai traces
- ▶ Porting to Xenomai

*Exercise: Identify and Debug Spurious Relax problems*

*Exercise: Port an application on Xenomai and test real-time characteristics*

*Exercise: Write a simple RTDM driver*

### **RTNet**

- ▶ Overview of RTNet
  - Architecture
  - Non-determinism of Ethernet
  - Time Division Multiple Access
- ▶ Configuration
- ▶ Network Programming with RTNet

*Exercise: Add RTNet support to the Xenomai kernel*

*Exercise: Test using udp client and server*

## Renseignements pratiques

**Duration : 4 days**

**Cost : 2490 € HT**