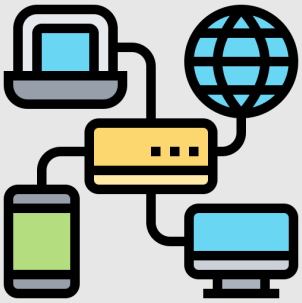


# Embedded Linux Networking training

Onsite training

## Course duration

**3** days – 24 hours

## Language

| | |
|---|---|
| Materials | English |
| Oral Lecture | English |
| | French |

## Trainer

One of the following engineers

- Maxime Chevallier

## Contact

training@bootlin.com
+33 484 258 097

## Audience

Engineers working on networking support in Linux-based embedded devices

## Training objectives

- Be able to understand the overall Linux kernel networking stack and configure complex network devices
- Be able to understand the flow of network packets in a Linux system, use different socket types, generate and filter traffic
- Be able to use the eBPF and XDP technologies for improved network traffic processing
- Be able to understand the architecture of Linux kernel network drivers
- Be able to understand how Ethernet PHYs and switches are supported in the Linux kernel
- Be able to debug and troubleshoot low-level network related issues

## Prerequisites

- **Minimal experience in embedded Linux development**: participants should have a minimal understanding of the architecture of embedded Linux systems: role of the Linux kernel vs. user-space, development of Linux user-space applications in C. Following Bootlin's Embedded Linux course allows to fulfill this pre-requisite.
- **Experience with low-level development in Linux and hardware interfaces**: participants should have a minimal understanding of memory management, interaction with common hardware interfaces (registers, interrupts), the interaction between Linux user-space applications and the Linux kernel (system calls). Following Bootlin's Linux kernel driver development course allows to fulfill this pre-requisite.
- **Minimal English language level: B1**, according to the *Common European Framework of References for Languages*, for our sessions in English. See the CEFR grid for self-evaluation.

## Pedagogics

- Lectures delivered by the trainer: 50% of the duration
- Practical labs done by participants: 50% of the duration
- Electronic copies of presentations, lab instructions and data files. They are freely available here.

## Certificate

Only the participants who have attended all training sessions, and who have scored over 50% of correct answers at the final evaluation will receive a training certificate from Bootlin.

## Disabilities

Participants with disabilities who have special needs are invited to contact us at *training@bootlin.com* to discuss adaptations to the training course.

## Required equipement

For on-site session delivered at our customer location, our customer must provide:

- Video projector
- One PC computer on each desk (for one or two persons) with at least 16 GB of RAM, and Ubuntu Linux 24.04 installed in a free partition of at least 30 GB
- Distributions other than Ubuntu Linux 24.04 are not supported, and using Linux in a virtual machine is not supported.
- Unfiltered and fast connection to Internet: at least 50 Mbit/s of download bandwidth, and no filtering of web sites or protocols.
- PC computers with valuable data must be backed up before being used in our sessions.

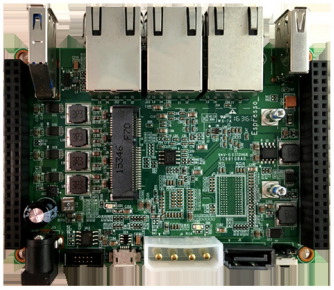
For on-site sessions organized at Bootlin premises, Bootlin provides all the necessary equipment.

## Hardware platform for practical labs

### Globalscale EspressoBin

**Globalscale EspressoBin** board

- Dual Cortex A53 Marvell Armada 3720 SoC
- Onboard switch with 2x 1Gbps interfaces
- Extra 1Gbps interface
- 1GB RAM
- 1x SATA interface
- 1x USB 3.0 interface



# Training Schedule

## Day 1 - Morning

| | | |
|---|---|---|
| Lecture | Networking stack and network devices in Linux | ▪ Network stack overview in the linux kernel<br>▪ What is a network interface, overview of a `net_device`<br>▪ Overview of Ethernet, Wifi, CAN, Bluetooth, 802.15.4<br>▪ Stacked network devices and virtual network devices for VLAN, bridging, bonding<br>▪ Switchdev and DSA devices<br>▪ Control plane through *Netlink* and *ioctl* |
| Lab | Setting up and configuring network interfaces | ▪ Basic setup with `iproute2`<br>▪ Create bridges, VLAN interfaces with `iproute2`<br>▪ Use network namespaces for interface isolation and testing<br>▪ Basic use of `tcpdump` and `wireshark`<br>▪ Using `ethtool` and `iproute2` to query the network interface features |

## Day 1 - Afternoon

| | | |
|---|---|---|
| Lecture | Path of a packet through the Linux networking stack | ▪ Discover the *Socket API*, the various families and types of sockets<br>▪ Sending and receiving data in userspace through sockets<br>▪ Using traffic generators and analysers in userspace with *Scappy* and *Wireshark*<br>▪ Path of a packet through the kernel, from a socket to a network driver<br>▪ Traffic filtering through *Netfilter* and `iptables`<br>▪ Traffic manipulation with the Traffic Control (`tc`) tool<br>▪ Queueing control with `tc` for performance optimisation and Time-Sensitive Networking (TSN) |
| Lab | Sending and receiving traffic through sockets | ▪ Write a small tool using the various socket types<br>▪ Analyze the traffic through `wireshark` and `tcpdump`<br>▪ Filtering the traffic with *Netfilter* and `tc`<br>▪ Using traffic generators and performance measuring tools |

## Day 2 - Morning

| | | |
|---|---|---|
| Lecture | eBPF for networking | ▪ Introduction to eBPF<br>▪ Compiling and loading eBPF programs<br>▪ BPF hooks in the networking stack<br>▪ Introduction to XDP |
| Lab | Writing and using an XDP program | ▪ Write and load a simple XDP program to filter incoming traffic<br>▪ Use maps to configure the filter from userspace |

## Day 2 - Afternoon

| | | |
|---|---|---|
| Lecture | Network device drivers | ▪ Overview of the hardware components and interfaces used in networking: MAC, PHY, MII, MDI, etc.<br>▪ Infrastructure of a typical Ethernet controller driver<br>▪ Sending and receiving packets with Napi<br>▪ Managing buffers and queues<br>▪ Packet timestamping for PTP<br>▪ Overview of *ethtool* driver operations for configuration and reporting<br>▪ Offloading network processing to the hardware |
| Lab | Advanced Ethernet configuration | ▪ Investigating ethernet parameters controllable with *ethtool*<br>▪ Using the various offloading features |

## Day 3 - Morning

| | | |
|---|---|---|
| Lecture | Ethernet PHYs and switch support | ▪ Ethernet PHYs support in the kernel with *phylib*<br>▪ Interacting with PHYs through MDIO<br>▪ Dealing with the PHY to MAC connection with *phylink*<br>▪ Switch support through the *DSA* framework<br>▪ Dealing with switch operations with *switchdev* |

## Day 3 - Afternoon

| | | |
|---|---|---|
| Lecture | Network debugging and troubleshooting | ▪ Analyzing performances and packet drops with monitoring tools<br>▪ Debugging techniques for driver troubleshooting<br>▪ Using tracing tools and `perf` for performance analysis<br>▪ Diagnose hardware-related issues |
| Lab | Optimizing the speed in various scenarios | ▪ Diagnosing and optimizing traffic speed<br>▪ Analyzing and troubleshooting latencies |