


## Embedded Linux Networking training

Course duration \_\_\_\_\_

 3 days – 24 hours

Language \_\_\_\_\_

Materials English

Oral Lecture English  
French


Trainer \_\_\_\_\_

One of the following engineers

- Maxime Chevallier

Contact \_\_\_\_\_

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### 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.

### 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](mailto:training@bootlin.com) to discuss adaptations to the training course.



Onsite  
training

## Required equipment

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

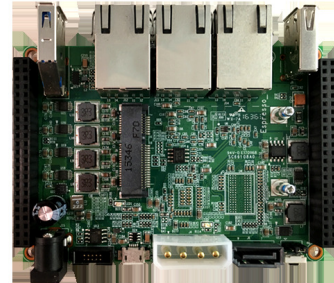
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### Hardware platform for practical labs

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#### **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



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### Day 1 - Morning

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Lecture	Networking stack and network devices in Linux	<ul style="list-style-type: none"><li>▪ Network stack overview in the linux kernel</li><li>▪ What is a network interface, overview of a <code>net_device</code></li><li>▪ Overview of Ethernet, Wifi, CAN, Bluetooth, 802.15.4</li><li>▪ Stacked network devices and virtual network devices for VLAN, bridging, bonding</li><li>▪ Switchdev and DSA devices</li><li>▪ Control plane through <i>Netlink</i> and <i>ioctl</i></li></ul>
Lab	Setting up and configuring network interfaces	<ul style="list-style-type: none"><li>▪ Basic setup with <code>iproute2</code></li><li>▪ Create bridges, VLAN interfaces with <code>iproute2</code></li><li>▪ Use network namespaces for interface isolation and testing</li><li>▪ Basic use of <code>tcpdump</code> and <code>wireshark</code></li><li>▪ Using <code>ethtool</code> and <code>iproute2</code> to query the network interface features</li></ul>

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### Day 1 - Afternoon

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Lecture	Path of a packet through the Linux networking stack	<ul style="list-style-type: none"><li>▪ Discover the <i>Socket API</i>, the various families and types of sockets</li><li>▪ Sending and receiving data in userspace through sockets</li><li>▪ Using traffic generators and analysers in userspace with <i>Scappy</i> and <i>Wireshark</i></li><li>▪ Path of a packet through the kernel, from a socket to a network driver</li><li>▪ Traffic filtering through <i>Netfilter</i> and <code>iptables</code></li><li>▪ Traffic manipulation with the Traffic Control (<code>tc</code>) tool</li><li>▪ Queueing control with <code>tc</code> for performance optimisation and Time-Sensitive Networking (TSN)</li></ul>
Lab	Sending and receiving traffic through sockets	<ul style="list-style-type: none"><li>▪ Write a small tool using the various socket types</li><li>▪ Analyze the traffic through <code>wireshark</code> and <code>tcpdump</code></li><li>▪ Filtering the traffic with <i>Netfilter</i> and <code>tc</code></li><li>▪ Using traffic generators and performance measuring tools</li></ul>

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### Day 2 - Morning

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Lecture	eBPF for networking	<ul style="list-style-type: none"><li>▪ Introduction to eBPF</li><li>▪ Compiling and loading eBPF programs</li><li>▪ BPF hooks in the networking stack</li><li>▪ Introduction to XDP</li></ul>
Lab	Writing and using an XDP program	<ul style="list-style-type: none"><li>▪ Write and load a simple XDP program to filter incoming traffic</li><li>▪ Use maps to configure the filter from userspace</li></ul>

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## Day 2 - Afternoon

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Lecture	Network device drivers	<ul style="list-style-type: none"><li>▪ Overview of the hardware components and interfaces used in networking: MAC, PHY, MII, MDI, etc.</li><li>▪ Infrastructure of a typical Ethernet controller driver</li><li>▪ Sending and receiving packets with Napi</li><li>▪ Managing buffers and queues</li><li>▪ Packet timestamping for PTP</li><li>▪ Overview of <i>ethtool</i> driver operations for configuration and reporting</li><li>▪ Offloading network processing to the hardware</li></ul>
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Lab	Advanced Ethernet configuration	<ul style="list-style-type: none"><li>▪ Investigating ethernet parameters controllable with <i>ethtool</i></li><li>▪ Using the various offloading features</li></ul>
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## Day 3 - Morning

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Lecture	Ethernet PHYs and switch support	<ul style="list-style-type: none"><li>▪ Ethernet PHYs support in the kernel with <i>phylib</i></li><li>▪ Interacting with PHYs through MDIO</li><li>▪ Dealing with the PHY to MAC connection with <i>phylink</i></li><li>▪ Switch support through the <i>DSA</i> framework</li><li>▪ Dealing with switch operations with <i>switchdev</i></li></ul>
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## Day 3 - Afternoon

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Lecture	Network debugging and troubleshooting	<ul style="list-style-type: none"><li>▪ Analyzing performances and packet drops with monitoring tools</li><li>▪ Debugging techniques for driver troubleshooting</li><li>▪ Using tracing tools and <code>perf</code> for performance analysis</li><li>▪ Diagnose hardware-related issues</li></ul>
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Lab	Optimizing the speed in various scenarios	<ul style="list-style-type: none"><li>▪ Diagnosing and optimizing traffic speed</li><li>▪ Analyzing and troubleshooting latencies</li></ul>
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