The OpenAMP Project & its working groups:

Standardizing interactions between operating environments in a heterogeneous embedded system

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Agenda

- What is OpenAMP trying to solve?
- OpenAMP Intro
- OpenAMP Project working groups
- Examples of OpenAMP in industry
- Learning more & getting involved
- Q/A
Acronyms

- AMP: Asymmetric Multi-Processing
- API: Application Programming Interface
- APU: Application Processor Unit
- EL: Execution Level
- FPGA: Field-Programmable Gate Array
- FuSa: Functional Safety
- HCI: Host Controller Interface
- IPC: Inter-Processor Communication
- LAVA: Linaro Automation & Validation Architecture
- MPSoC: Multi-Processing System-on-Chip
- OE: Operating Environment
- OS: Operating System
- PMU: Platform Management Unit
- RPU: Real-Time Processor Unit
- RTOS: Real-Time Operating System
- SEL: Secure Execution Level
- SoC: System-on-Chip
- TEE: Trusted Execution Environment
- TSC: Technical Steering Committee
- TZ: TrustZone
- WG: Working Group
What is OpenAMP trying to solve?
Heterogeneous Embedded System

- Multiple core clusters
  - A53, R5, PMU, MicroBlaze

- Multiple Execution Levels (EL)
  - EL0 – User space – Linux apps, Containers, RTOS apps
  - EL1 – OS space – Linux kernel, RTOS + RTOS apps
  - EL2 – Hypervisor – Xen, …
  - EL3 – Firmware – Trusted Firmware

- Multiple Security Environments
  - TrustZone (TZ) – HW protecting resources (e.g. memory)
  - Trusted Execution Environment (TEE) – SEL1

- Multiple Operating Environments (OE)
  - Linux – including Android
  - Free and commercial RTOS’s
    - FreeRTOS, Zephyr, VxWorks, Integrity, Nucleus, uC/OS, OSE, ThreadX
    - QNX/Neutrino, Sciopix, eT-kernel, Lynx, PikeOS, …
  - Bare metal (no OS) is common on smaller cores
  - Hypervisors – Xen, Jailhouse, commercial
  - Firmware/boot loaders – Trusted FW, PMU FW, uboot, …
Simplifying SW for Heterogenous Environments

Today, most heterogeneous environments are cobbled together ad-hoc
- Everybody coming up with their own shared memory scheme

There is a need to standardize how environments interact
- Configuring the environments
- Managing (lifecycle) the environments
- Passing messages between environments
- Share resources between environments
- Porting any OS using a standardized abstraction layer

Open source implementation is fastest way to standardization
- Especially if based on already existing open source projects

*OpenAMP is solving these kinds of problems*
OpenAMP Intro
The OpenAMP Project seeks to standardize the interactions between operating environments in a heterogeneous embedded system through open source solutions for Asymmetric Multi-Processing.
OpenAMP is an open AMP framework that includes two efforts:

1. A standardized way of using AMP
2. A clean-room open source implementation/project

OpenAMP began as Multicore Association Working Group in 2014
- Focused on communication between 2 different cores with RPMsg and Remoteproc
- open-amp and libmetal

OpenAMP Project re-launched as a Linaro Community Project in September 2019
- Overlap in membership
- Independent organization
- Infrastructure
- Budget w/ low fee
The OpenAMP Project History & Launch

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OpenAMP, the framework

- OpenAMP currently includes the following components:
  - Lifecycle operations - Such as start/stop another environment
  - Messaging - Sending and receiving messages
  - Low level abstractions – Sharing memory, inter-processor interrupts, …
  - Proxy operations - Remote access to services, e.g. file system
  - Under development: Resource configuration using System Device Trees

- Built on top of existing open source projects/standards
  - Remoteproc, RPMsg, Virtio, Device Trees

- Accelerate adoption by working in open source
  - Linux, RTOS, and bare metal implementations
The OpenAMP Project going forward

- Latest status on the project
  - Increased scope: OpenAMP framework + more working groups
  - Official maintainer roles
  - Technical Steering Committee
  - Board
  - Governance
  - Budget
  - Logo!

- Member points-of-view:
  - Arm processors, non-Arm processors
  - Linux, RTOS, bare metal
  - High-performance systems, resource-constrained systems
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OpenAMP Project working groups
OpenAMP-rp working group

- Works on original parts of OpenAMP
  - Remoteproc, RPMsg, Virtio, libmetal

- Repositories
  - [https://github.com/OpenAMP/open-amp](https://github.com/OpenAMP/open-amp) (latest release 2020.04)
  - [https://github.com/OpenAMP/libmetal](https://github.com/OpenAMP/libmetal) (latest release 2020.04)

- Active work
  - Big buffers
  - Improving testing through integration with LAVA Continuous Integration
  - Getting outstanding patches upstreamed to Linux kernel
  - Addressing backlog of pull requests
  - Back to April, October release cadence
Ramping up: Application Services working group

- What is needed to build on top of OpenAMP?
- Application developer issues that resonated most with members
  - Remote file access
  - Remote console
  - Proxy ports (e.g. proxy debug)
  - Messaging APIs (e.g. sockets)
- Working group (WG) will leverage common OS drivers & API standards where possible

![Diagram of Linux Services and Remote OS]

- Linux Services:
  1. File Systems
  2. Network Stacks
  3. Console PTYs
  4. Remote App Debug
  5. IPC

- Remote OS:
  - Application
  - Access to Linux services

Drivers specified by WG
System Device Tree working group

- Defines new Device Tree bindings
  - Describe Heterogeneous systems
    - Multiple CPUs clusters → multiple address views
  - Configure Execution Domains
    - Define the software execution context for each CPUs cluster
    - Execution level, memory ranges, devices available (by configuration)
    - RTOS'es can use it at build time and/or run time

- Repositories
  - https://github.com/devicetree-org/lopper
    - Lopper is a tool to prune the System Device Tree into a traditional device tree for a specific processor in the system
    - Reference Implementation of the System Device Tree bindings

- Upcoming work
  - Xilinx and STMicroelectronics to propose together bindings for bus-firewall configurations
  - Submit proposals to devicetree-spec@vger.kernel.org
Future: Hypervisor interfaces working group

- Document & "standardize" hypercall interfaces
- Implementable by any vendors / embedded hypervisors
- Documentation reusable for Safety Certifications
- Collaborate with existing Open Source efforts (e.g. Xen FuSa)
Examples of OpenAMP in industry
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- **Xilinx**
  - Default AMP solution for Zynq-7000, Zynq UltraScale+ MPSoC, and Versal devices
  - Cortex-A application processor units (APUs), Cortex-R real-time processor units (RPUs). Microblaze “soft” processors in programmable logic. Either APU or RPU can act as the master.

- **Mentor Graphics**
  - Core for the Mentor Embedded Multicore Framework and Multicore Framework Cert product offerings.
  - Expands on OpenAMP: Linux as a Remote, Large Buffer, Zero Copy, Proxy support for Ethernet
  - Communication between the safe and non-safe domains in Mixed Safety-Criticality systems

- **TI**
  - Enhancing the Linux kernel implementation of RemoteProc & RPMsg
  - Defining the wire protocol between processors
  - Contributed a limited scope version of remoteproc loader into U-Boot

- **Kalray**
  - Standard message passing solution within homogeneous Manycore architecture on MPPA®3 processor
  - MPPA®3 as accelerator: virtio over PCIe
  - Within MPPA®3 processor: virtio with shared memory
Examples of OpenAMP in industry

- **Zephyr**
  - OpenAMP integrated & available

- **Nordic Semiconductor**
  - Bluetooth Host Controller Interface (HCI) based on OpenAMP in Zephyr

- **Linaro**
  - Hosting OpenAMP project through Community Projects division
  - Involvement in Zephyr, openamp-rp, LAVA testing

- **STMicroelectronics**
  - IPC in multicore and multi-SoC STM32 solutions
    - OpenAMP-OpenAMP, Linux RPMsg-OpenAMP
  - OpenAMP library used with baremetal, FreeRTOS, Zephyr

- **Wind River**
  - To accelerate the ability of developers to create edge compute applications

- **Arm**
  - Active role in System Device Tree discussion
Learning more & getting involved
More information

- GitHub project
  - [https://github.com/OpenAMP/](https://github.com/OpenAMP/)
  - Also, Lopper lives at devicetree-org: [https://github.com/devicetree-org/lopper](https://github.com/devicetree-org/lopper)

- OpenAMP Wiki
  - [https://github.com/OpenAMP/open-amp/wiki](https://github.com/OpenAMP/open-amp/wiki)
  - Notes from calls
  - Features being worked on & under consideration

- Community Project Website
  - [https://www.openampproject.org/](https://www.openampproject.org/)

- Mailing lists
  - Sign up for the mailing lists at [lists.openampproject.org](https://lists.openampproject.org)
How to participate

› All are welcome to join the calls for the TSC & working groups!
  - Call invitations are sent to the mailing lists

› You can participate!
  - Not necessary to be from an OpenAMP Project member company

› Your company can become an OpenAMP Project member
  - Not necessary to be a Linaro member company
  - Member fees support administration for the project & infrastructure
  - OpenAMP Project membership gets the company
    • Vote on TSC
    • Vote on Board
How to become a member company

- Company representative signs Membership Agreement and Charter
- $2500 annual fee
- Current member companies (alphabetical order):
  
  - arm
  - KALRAY
  - Linaro
  - Mentor® (A Siemens Business)
  - NORDIC Semiconductor
  - life.augmented
  - Texas Instruments
  - WIND
  - XILINX®
Thank You