THE LINUX FOUNDATION
OPEN SOURCE SUMMIT
JAPAN

AUTOMOTIVE
LINUX SUMMIT

Beyond the AGL Virtualization Architecture

Michele Paolino
Virtual Open Systems

THE LINUX FOUNDATION

Acknowledgement

This work has received funding from the European Union's Horizon 2020 research and innovation program, NGPaaS, under grant agreement No 761557. The work presented in this paper reflects only authors' view and the European Commission is not responsible for any use that may be made of the information it contains.

www.ngpaas.eu

Why virtualization in automotive?

- Number of automotive functions is exploding
- Software time to market needs to be reduced
- Updates are required to be performed faster and at a lower cost
- Cyber security is today a threat
- Combination of different software ecosystems is extremely of interest

EG-Virt introduction

The Virtualization Expert Group (EG-VIRT) is the AGL team which aims to bring open source virtualization in production cars.

- Kicked-off at the beginning of 2017, EG-VIRT’s first achievement has been the creation of the AGL virtualization infrastructure
  - Meta-egvirt layer, agl-egvirt feature and KVM porting to the Renesas R-Car M3
- EG-VIRT is composed by virtualization professionals active in AGL
- Bi-weekly meeting are held on Wednesday
- Wiki page: https://wiki.automotivelinux.org/eg-virt

EG-Virt purpose

EG-VIRT’s purpose is:

- Introduce virtualization in AGL and set the ground for virtualized open source autonomous vehicles
- Provide a reference virtualization platform for future automotive systems
- Enable Tier-1 companies and automakers to differentiate their offer by adding customization and extensions

EG-Virt purpose: how?

EG-VIRT's purpose is:

- Introduce virtualization in AGL and set the ground for virtualized open source autonomous vehicles
- Provide a reference virtualization platform for future automotive systems
- Enable Tier-1 companies and automakers to differentiate their offer by adding customization and extensions

How to achieve the EG-VIRT purposes?

EG-VIRT white paper

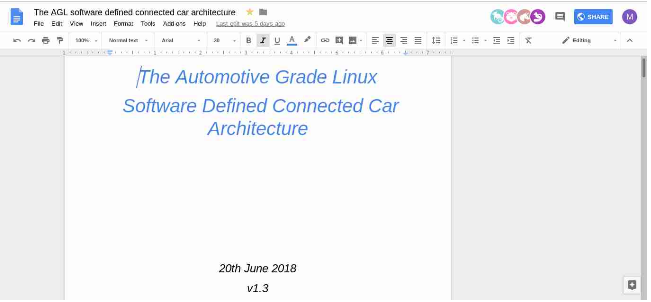
At the end of January 2018, the EG-VIRT group started to work at the definition of the AGL virtualization architecture and roadmap

- This work resulted in “The AGL software defined connected vehicle architecture” white paper
  - Published during ALS2018
  - Creative Commons 4.0 license (CC BY 4.0 international)
    - You are free to share and adapt. You must give credit
  - 15 authors

EG-VIRT white paper collaborative editing

The work has been done in a collaborative way:

- Google docs from the beginning
- Frequent sync meetings (more than 13 calls, one face to face at AGL AMM Japan 2018)
- Each section has been assigned to a contributor. After, these sections has been reviewed by all the group members



The Automotive Grade Linux

Software Defined Connected Car Architecture

20th June 2018

v1.3

EG-VIRT white paper objectives

- Disseminate automotive virtualization inside and outside AGL
- Identify virtualization use cases, requirements and solutions for AGL
- Define the AGL virtualized software defined vehicle architecture

EG-VIRT white paper key contributions

The key contributions of the work are:

- **Identification of virtualization benefits, challenges, use cases and requirements**
- Definition of the AGL EG-VIRT approach towards virtualization
- Survey of existing open source and commercial solutions
- Identification of the AGL role in open source virtualization
- Definition of the AGL architecture

Automotive virtualization benefits and challanges

Why should an automotive company start working with virtualization?

	Challenge	Benefit of virtualization
1	Enable Software Defined Autonomous Car	Abstraction, Flexibility and Interoperability
2	Costs	Consolidation and flexible architecture
3	Security	Isolation
4	Mixed criticality	Certification

Automotive virtualization use cases

When should virtualization be used? When it is of interest for AGL?

Consolidation of one or more of the following functions:

- Instrument cluster
- Safety call system
- IVI systems
- Telematics
- Safety critical functions (ADAS, AUTOSAR, etc)

Hardware requirements for automotive virtualization

What hardware do we need to run virtualization?

Electronic Control Unit (ECU) requirements to enable virtualization

- **Hardware virtualization support** for CPU, Cache, Memory and interrupts to create execution environments
- **Multicore processor** with possibility to allocate one or multiple cores to each execution environment
- **Trusted Computing Module** to isolate safety-security critical applications and assets
- **IO virtualization** support for GPU and connectivity sharing

Automotive functions requirements for virtualization solutions

What are the automotive software requirements for the virtualization solution?

Automotive functions requirements for virtualized ECUs	
Computing	Static resource partitioning and flexible on-demand resource allocation, memory/IO bus bandwidth allocation and rebalancing.
Peripherals sharing	GPU, displays, inputs, audio, network, storage shall be shared
Security	Root of Trust, Secure boot, Trusted Computing, hardware isolation shall be supported (cache, interrupts, IOMMUs, firewalls, etc.).
Performance and Power consumption	Minimal overhead, fast boot, power management, predictability shall be guaranteed
Safety	System monitoring, independent restart, redundanc, real time shall be supported

EG-VIRT white paper key contributions

The key contributions of the work are:

- Identification of virtualization benefits, challenges, use cases and requirements
- **Definition of the AGL EG-VIRT approach towards virtualization**
- Survey of existing open source and commercial solutions
- Identification of the AGL role in open source virtualization
- Definition of the AGL architecture

How to approach virtualization for AGL? Modularity

The key pillars of the AGL virtualization are: **Modularity**, Openness and mixed criticality

- Hypervisors, virtual machines, AGL Profiles and automotive functions are seen by the AGL architecture as interchangeable modules.
- The combination of these modules differentiates AGL products.
- To achieve modularity, interoperability will be required, especially between open and proprietary components.

How to approach virtualization for AGL? Openness

The key pillars of the AGL virtualization are: Modularity, **Openness** and mixed criticality

- There is no restriction in the way the AGL virtualization platform can be used, deployed and extended.
- The AGL virtualization architecture supports multiple hypervisors, CPU architectures, software licenses and can be executed as a host and guest.

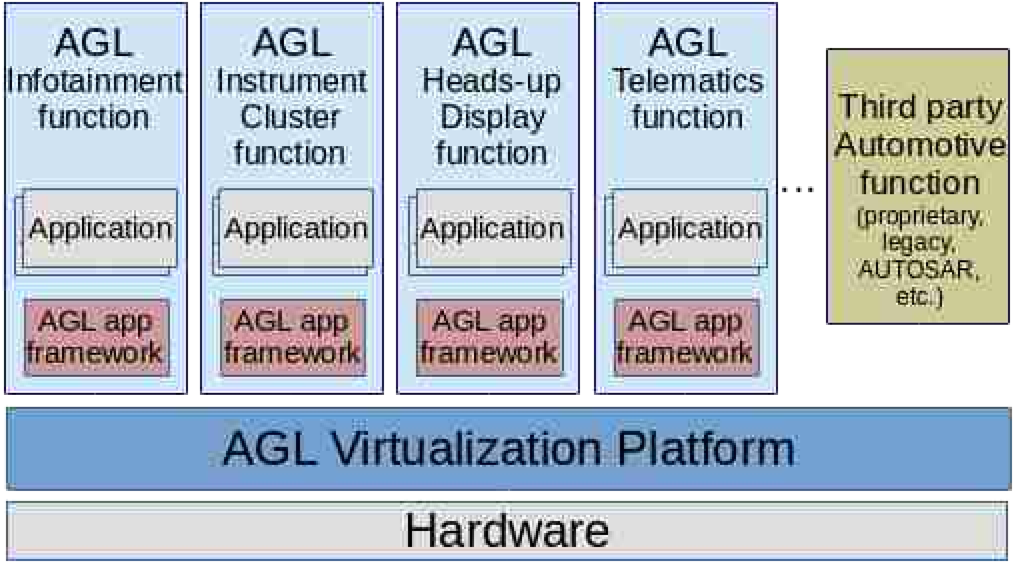
How to approach virtualization for AGL? Mixed-criticality

The key pillars of the AGL virtualization are: Modularity, Openness and **mixed criticality**

- Applications with different level of criticality are targeted to coexist and run in a virtualized manner.
- AGL targets to consolidate applications different certification requirements.

How to approach virtualization for AGL?

Putting together modularity, openness and mixed criticality



EG-VIRT white paper key contributions

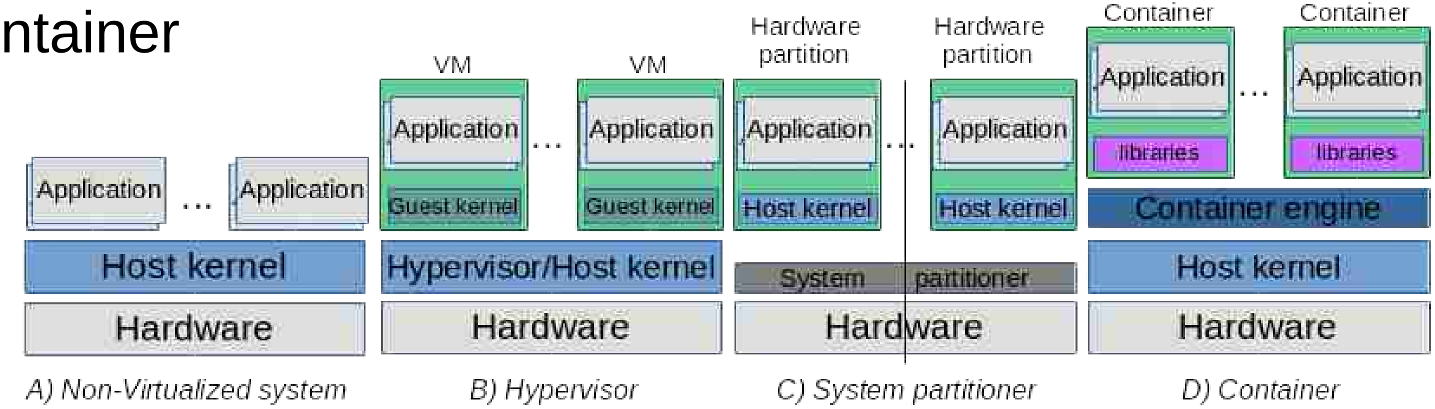
The key contributions of the work are:

- Identification of virtualization benefits, challenges, use cases and requirements
- Definition of the AGL EG-VIRT approach towards virtualization
- **Survey of existing open source and commercial solutions**
- Identification of the AGL role in open source virtualization
- Definition of the AGL architecture

Virtualization technologies today available

Different virtualization technologies exist today, all with different characteristics and strenghts:

- Hypervisor (Type-1 and Type-2)
- System Partitioner
- Container



Components today available

A number of components is already available to serve as building blocks:

- Open Source solutions
  - XEN, KVM, L4Re, ACRN, Jailhouse, ATF, Docker
- Proprietary (certified) solutions from AGL members
  - COQOS, Crucible, Integrity Multivisor, Nautilus, PikeOS, VOSYSmonitor

EG-VIRT white paper key contributions

The key contributions of the work are:

- Identification of virtualization benefits, challenges, use cases and requirements
- Definition of the AGL EG-VIRT approach towards virtualization
- Survey of existing open source and commercial solutions
- **Identification of the AGL role in open source virtualization**
- Definition of the AGL architecture

The role of AGL in the open source virtualization developments

AGL's role is the one of virtualization technology integrator, aiming at supporting different virtualization technologies and to make them interoperable and interchangeable.

- AGL will not develop a new hypervisor but will leverage on existing open source solutions
- The developments will aim to enhance openness, modularity and portability of its platform

AGL: enhancing existing Virtual Platforms, EEs

As a consequence, the developments will aim to enhance openness, modularity and portability of its platform. Practical examples are:

- Development of new open/standard APIs
  - communication, software defined automotive functions life management, etc
- But also
  - Portable drivers for IO virtualization, test bench, image building tools for different virtualization solutions, etc.

EG-VIRT white paper key contributions

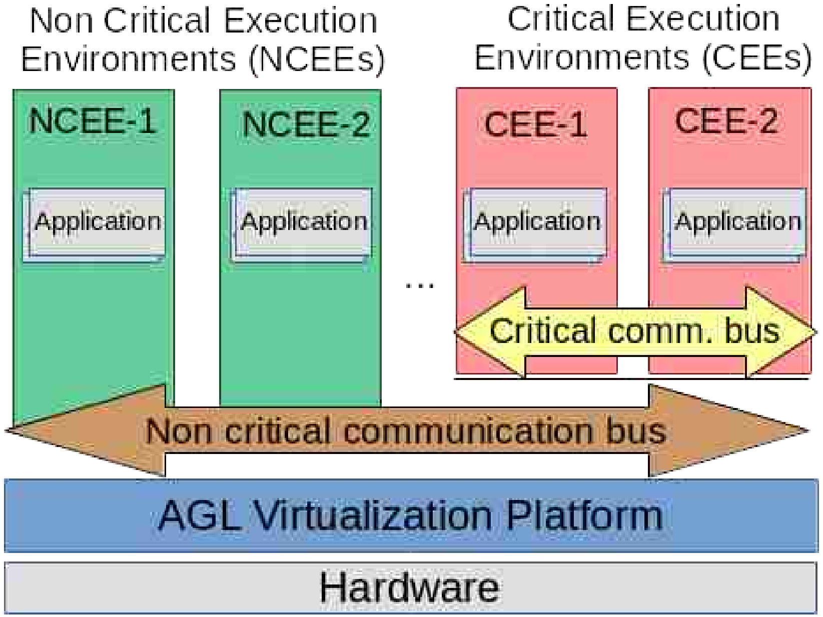
The key contributions of the work are:

- Identification of virtualization benefits, challenges, use cases and requirements
- Definition of the AGL EG-VIRT approach towards virtualization
- Survey of existing open source and commercial solutions
- Identification of the AGL role in open source virtualization
- **Definition of the AGL architecture**

The AGL virtualized architecture

The AGL virtualized architecture is composed by:

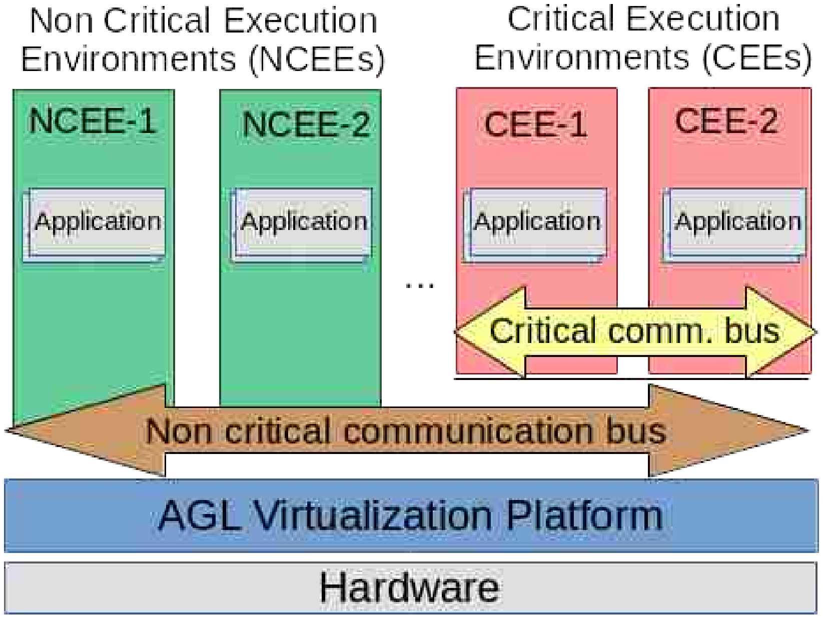
- Execution environments (EEs)
- Virtualization platform
- Communication buses


Non Critical Execution Environments (NCEEs)
Critical Execution Environments (CEEs)
NCEE-1
NCEE-2
CEE-1
CEE-2
Application
Application
Application
Application
...
Critical comm. bus
Non critical communication bus
AGL Virtualization Platform
Hardware

The AGL EEs

Execution environments (EEs) are software silos created by the virtualization platform:

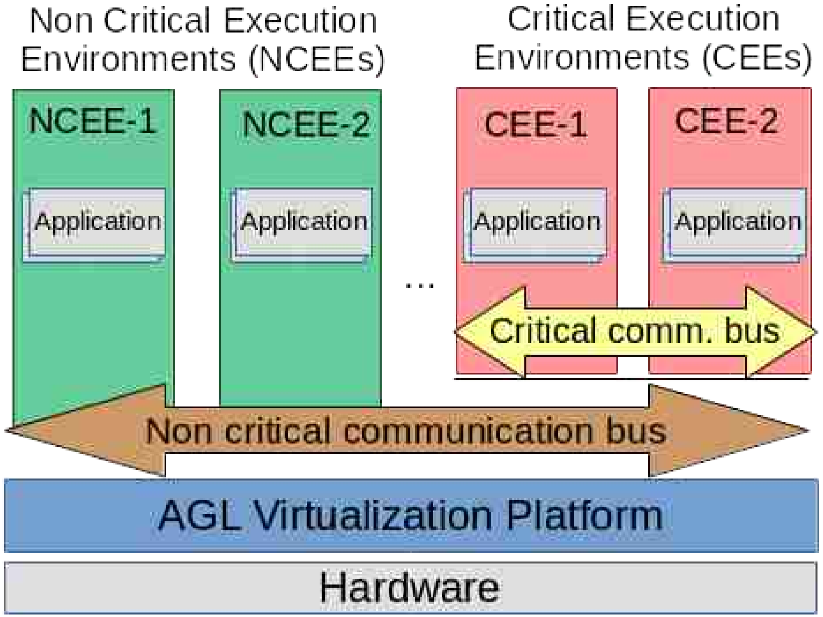
- They run isolated from each other
- EEs can be implemented as bare metal applications, virtual machines, etc.
- Can execute critical or non critical functions


Non Critical Execution Environments (NCEEs)
Critical Execution Environments (CEEs)
NCEE-1
NCEE-2
CEE-1
CEE-2
Application
Application
Application
Application
...
Critical comm. bus
Non critical communication bus
AGL Virtualization Platform
Hardware

The AGL Virtualization Platform

It a safe and secure execution of multiple EEs consolidating them in a single hardware/software platform

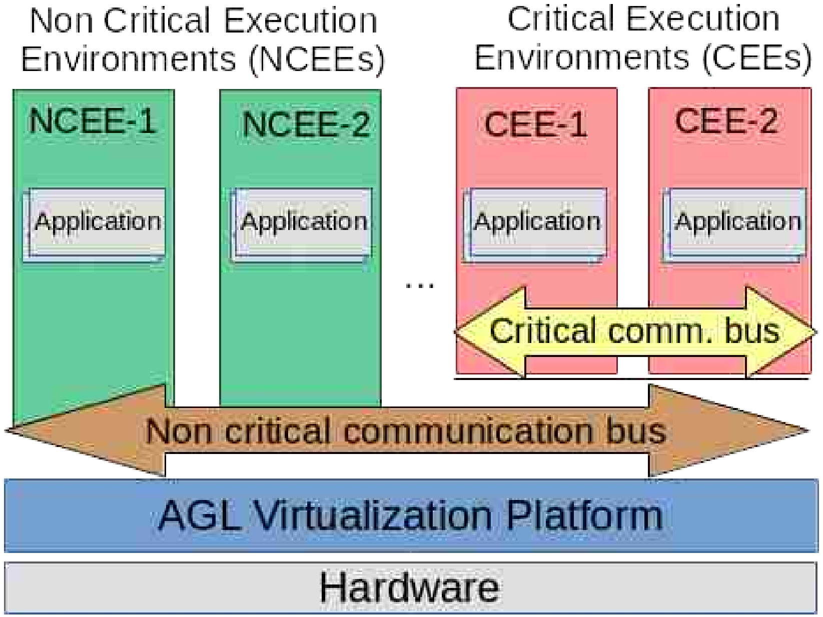
- Can be implemented as a hypervisor, system partitioner, container engine, etc.
- Has to use hardware mechanisms to properly isolate EEs
- Provide tools to enhance modularity, openness and mixed criticality


Non Critical Execution Environments (NCEEs)
Critical Execution Environments (CEEs)
NCEE-1
NCEE-2
CEE-1
CEE-2
Application
Application
Application
Application
...
Critical comm. bus
Non critical communication bus
AGL Virtualization Platform
Hardware

The AGL Communication Buses

Create connection endpoints between EEs as well as between the Virtualization Platform and each EE

- Have different level of criticality (requirements, objectives, etc)
- There is no existing solution today that already implements them


Non Critical Execution Environments (NCEEs)
Critical Execution Environments (CEEs)
NCEE-1
NCEE-2
CEE-1
CEE-2
Application
Application
Application
Application
...
Critical comm. bus
Non critical communication bus
AGL Virtualization Platform
Hardware

Conclusions

With the AGL Software Defined Car Architecture white paper, AGL and EG-VIRT took a first step in the direction of bringing Virtualization in AGL

- An open, modular and mixed critical virtualized architecture for software defined connected vehicles has been defined
- The EG-VIRT and AGL roles have been identified as technology integrators in the context of virtualization
- A roadmap has been prepared

AGL EG-VIRT Roadmap

In future, the EG-VIRT group and of its members will focus on:

- Design and develop standardized communication buses (critical and non critical).
  - This is seen as an enabler of virtualized automotive functions portability, interoperability, performance, security and safety.
- Add support for IO virtualization
  - Especially for safety critical virtualization of devices like GPUs
- AGL virtualization support
  - To enable AGL usage both as a EE (a guest) and as a virtualization platform (host)
- Demonstration
  - Graphical virtual machine manager application for AGL

A special thanks to..

The contributors of this work

Toni Hoang - Daimler

Tero Antero Salminen - OpenSynergy

Dan Mender - Green Hills Software

Walt Miner - The Linux Foundation

Denys Balatsko - GlobalLogic

Rich Persaud - OpenXT

Artem Mygaiev - EPAM

Tiejun Chen - VMware

Ciwan Gouma - SYSGO

Daniel Bernal - Arm

Jonathan Kline - Star Lab

Adam Lackorzynski - Kernkonzept

Praveen Kumar - Sasaken

Alexander Damisch - Kevix

Thank You

Questions?

m.paolino@virtualopensystems.com

THE LINUX FOUNDATION

OPEN SOURCE SUMMIT

JAPAN

AUTOMOTIVE LINUX SUMMIT

THE LINUX FOUNDATION