Model-Driven Engineering Approach for Simulating Virtual Devices in the OSATE 2 Environment

Fáber D. Giraldo and Mónica M. Villegas

Abstract—Simulating devices while developing software for embedded systems is advantageous if physical elements such as sensors are not available. In this work, we present the design and implementation of an extension named Custom Simulation of Virtual Devices (CSVD) for the Eclipse-based platform that has full support for the AADL meta-model, OSATE 2. The CSVD extension uses a Model-driven engineering approach to simulate virtual devices, which allows capturing an AADL model of a system that represents the connection between a local network of devices and a gateway through a serial bus, simulating its behavior at a data transmission level by being executed inside the QEMU emulator. Also, we present an example of our approach, based in a system modeled in AADL and its simulation using the CSVD extension.

Index Terms—AADL model, OSATE 2, QEMU, simulation.

I. INTRODUCTION

While developing software for embedded systems, sometimes is required to have devices for testing data transmission, support of a protocol, or some data to validate some software developed. In this work, we describe the design of a plugin named Custom Simulation of Virtual Devices (CSVD) developed as an extension to the OSATE 2 platform, which supports the simulation of serial devices connected to a gateway (emulated using QEMU) through a serial bus. This extension allows OSATE 2 to have a custom simulation system integrated with the QEMU emulator, a feature that supports to be extended for future development of another kind of protocols or devices.

The primary approach of the CSVD extension developed and added to OSATE 2 is to analyze an AADL model, obtain the configuration of the devices modeled and execute the simulation of those devices inside QEMU emulator which emulates an ARM-based embedded system.

This paper is organized as follows: Section II explains some of the related work found in the literature. Section III describes the purpose of AADL and its usage under OSATE 2. Section IV explains how the CSVD extension was designed, developed and implemented for its integration with the Eclipse-based platform OSATE 2. Section V shows a demonstration of our approach in which a system is designed, modeled in AADL and then simulated using the CSVD extension. Section VI concludes the paper. And finally, Section VII provides some future work proposed for this project.

II. RELATED WORK

In [1] authors describe an approach for the modeling, verification, and implementation of ARINC653 systems using AADL. It describes a modeling approach exploiting the new features of AADL version 2 for the design of ARINC653 architectures. In [2] authors propose an approach for the verification of the AADL architecture, which is assisted by a toolchain and defining a source meta-model for AADL and a target meta-model for the timed automata formalism; authors also define a transformation process in two steps, a Model2Model transformation and a transformation of a Model2Text. In [3] authors present a verification tool called ABV tailored for AADL models with a behavioral annex, in which given an architecture defined in AADL and its behavior specified in the associated language, their tool model-checks the latter against the requirements specified in Computation Tree Logic (CTL). In [4] authors propose to extend the capabilities of AADL-OSATE modeling notation and supporting toolset with Petri nets in a manner that facilitates formal analysis to verify the absence of deadlock and/or livelock phenomenon.

The difference between our project and the related works found is that the extension described in our work is developed to simulate serial devices connected to a gateway and which at the same time is integrated with QEMU emulator, features that allow an extensibility for another kind of simulations being executed using QEMU emulator.

III. MODELING WITH AADL

First, we need to have clear what modeling is in this context, a concept explained in [5] and which says that modeling seeks to explain the behavior of a complex system via a model that abstracts it.

The Architecture Analysis & Design Language (AADL) is a unifying framework for model-based software systems engineering. AADL can be used to capture the static modular software architecture, the runtime architecture regarding communicating tasks, the computer platform architecture on which the software is deployed, and any physical system or environment with which the system interacts [6]. AADL is also an SAE International (Society of Automotive Engineers) standard [AS5506A].

AADL provides concepts such as threads, processes, and devices, which allows doing a formal analysis of systems. In an AADL model can be represented the architecture of a
system as a hierarchy of interacting components, organizing interface specifications and implementation blueprints of software, hardware, and physical components into packages to support large-scale developments [6].

Models in AADL are composed of AADL components, AADL properties, and graphical AADL notations. For components, AADL describes a taxonomy of model elements which can be component category, component type, component implementation, packages and property sets. Component categories can be of the type data, thread, thread group, subprogram, process, memory, bus, processor, device, virtual processor, virtual bus, system and abstract. Components can have features of type data port, event (data) port, port direction, requires access or provides access. For properties, there are predefined property sets such as deployment_properties, thread_properties, timing_properties, communication_properties, memory_properties, programming_properties, modeling_properties, and aadl_project. For graphical notations, AADL provides the ones illustrated in Fig. 1, which allows representing graphically the model of a system.

For the implementation of AADL models, OSATE 2 can be used. OSATE 2 is an Eclipse-based platform that has a full support of the AADL meta-model and which can be extended in functionalities. This platform relies on EMF, UML2 and XText, and its core by itself provides the fundamentals to use the basics of AADL (textual and hierarchical editor, instantiation of the model) and build OSATE 2 plugins [8].

One way to extend OSATE 2 is developing and integrating Eclipse plugins, which can use all the resources from the Eclipse platform and at the same time, use the elements of the OSATE core to process and analyze AADL models.

IV. EXTENDING OSATE 2

In this work, we extend OSATE 2 by developing and integrating a plugin that allows processing an AADL model with the purpose of generating files and codes from its analysis as resources that are required to launch the simulation of the modeled system by being executed using the QEMU emulator. The launch parameters of the QEMU emulator, such as Operating System (OS) image, kernel image, CPU type and RAM size need to be configured in the AADL model of the system designed.

The structure of the CSVD plugin is shown in Fig. 2, which also describes the process of executing a simulation. The usage of the CSVD plugin consists of loading an AADL model through a file search, the execution of the files generation after the AADL model is loaded and then, the execution of the simulation if required files were successfully generated. Fig. 3 shows the graphical user interface (GUI) of the CSVD plugin, allowing to identify the simple usage of the extension.

For the required files generation, the CSVD plugin executes a Python script that analyzes the AADL model and then, based on some rules specified in a JSON file which links AADL with custom syntax (that can be specific commands or codes) generates the required files as shown in Fig. 4.

On a side, the required files generator, generates a text file containing the specifications of the devices that are going to be simulated, and on the other side, it creates the script that unpacks/configures/repacks the OS image, and which contains the command that launches the QEMU emulator.

After the generation of the required files finishes...
successfully, the execution of the QEMU emulator with the simulation system inside is launched.

Before QEMU is executed, there is an OS image configuration process, which consists of unpacking the image, adding the generated and required files to it, configure it as needed and then, repack it to be executed with QEMU. The structure of this process is shown in Fig. 5.

![Fig. 5. Structure of the OS image modifier.](image)

After QEMU is executed with the modified OS image, the simulated devices send data to the serial port that was created in the emulated platform, allowing software processes to capture serial data packages, which contain besides the data, the specified identifiers of each modeled device for proper identification.

V. DEMONSTRATION OF OUR APPROACH

This demonstration is based on the design of a system that is composed of 3 sensors connected to a serial receiver, which through a serial bus is connected to a gateway sending serial data received from the sensors, as shown in Fig. 6. Fig. 7, 8, 9 and 10 show the AADL text model of the system designed. Fig. 7 shows the specification of the entities imported for the usage of memories, ARM processors and UART.

![Fig. 6. System for the demonstration.](image)

![Fig. 7. Importing AADL entities.](image)

Fig. 8 shows the declaration of the systems that describe the desired design. For this demonstration, the design is based on two systems, a first system named top_system that contains all the components and subsystems, and a second system called gw_system which includes the specifications of the gateway. This second system must be specified with the extra parameters of the OS image path, CPU type, and kernel image path because these are specifications required by QEMU and are not currently supported by AADL, so one of the ways to specify them is as annex types.

![Fig. 8. Declaration of the systems for the AADL model designed.](image)

Fig. 9 shows the declaration of the devices and the serial bus. In this case, there are two types of devices, sensors and a serial receiver which is named as serial radio. The sensor devices are configured with a MAC address as the identifier; mean and deviation values that will be used during the simulation for the random data generation; and a period value, which represents how often the data will be transmitted to the serial receiver from the sensors. Also, in the declarations must be included the features of each device, in which for this case, it specifies that each sensor will have a data port as output.

For the serial receiver, the features specify the data port connections as inputs, to which the sensors will be connected, and the serial bus requirement used for the connection with the gateway. The data ports specified for all the devices will be used in the implementation of the model for the interconnection between devices and systems.

![Fig. 9. Declaration of the devices and bus for the AADL model.](image)
Finally, Fig. 10 shows the implementation of the systems and devices, in which all the connections between devices and systems are specified. In this case, the sensors are connected to the serial receiver and the serial receiver to the serial bus that will make the connection to the gateway for the serial data transmission.

Fig. 10. Implementation of systems and devices in AADL model.

Besides the AADL text files, AADL is composed of diagrams and graphical notations. In Fig. 11, is shown the diagram that represents the declarations with the implementations for systems, devices, and buses. This diagram is generated using an OSATE 2 functionality and allows to observe an abstraction layer of the composition of the AADL model. Also, OSATE 2 allows watching the graphical view of instances and implementations, a view that is corresponding to the AADL text model. Fig. 12 and 13 show the graphical view of the AADL model described in Fig. 7, 8, 9 and 10, this view allows to have a better view of the system designed and which will be simulated using the QEMU emulator, that in this case is represented as the gateway.

Fig. 11. Diagram of the AADL model.

Fig. 12. Graphical view of instances and implementations of the AADL model for the primary system modeled.

Fig. 13. Graphical view of instances and implementations of the gateway modeled in AADL.

After designing the AADL model of the system, the next step is to execute the simulation from the button ‘Execute Simulation’ at the CSVD GUI as shown in Fig. 3. When QEMU is executed, it runs the specified OS image, that in this case is a Linux-based OS image for an ‘ARM’ based CPU and with a RAM value of 256 MB as modeled for the system in Fig. 10 and shown in Fig. 13, also, under the QEMU emulation will be generated a serial interface to simulate the connection between the serial receiver and the gateway. Fig. 14 shows the serial interface named /dev/ttyV0 and Fig. 15 shows the data being sent to the serial receiver to the gateway through the serial interface.

Fig. 14. Serial interface in Linux OS for the connection with the serial receiver simulated device.

As shown in Fig. 15, there are three different types of packages, a data package coming from sensor 1, sensor 2 and sensor 3. As configured for each sensor in the AADL model, there is a different MAC address for each sensor as shown in Fig. 9 and Table I, and which can be verified in Fig. 15 by observing the MAC value in the data packages received (inside the red squares).
Fig. 15. Serial data being received through the serial interface.

<table>
<thead>
<tr>
<th>Sensor Number</th>
<th>MAC Address</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensor 1</td>
<td>20DE55AB2051CF03</td>
</tr>
<tr>
<td>Sensor 2</td>
<td>20EF50AE2071CF03</td>
</tr>
<tr>
<td>Sensor 3</td>
<td>20EF500E4081CF03</td>
</tr>
</tbody>
</table>

By obtaining data in the serial port, simulating a device connected to the emulated gateway, software or service requiring reading data from the specified port can do it for testing or other specific purposes. This simulation can be extended for X number of sensor devices and Y number of serial receivers connected to the emulated gateway (QEMU emulator), all by specifying the required characteristics of the system in the AADL model.

VI. CONCLUSION

The extensibility of OSTATE 2 allows developers to adapt extensions to it for different kinds of purposes including simulation, analysis or other specific features that can be useful during the development of embedded hardware and software processes. Also, the fact that the meta-model of AADL can be improved, this allows developers to extend the language to support other platforms, protocols, and components with the purpose of modeling another kind of systems and being able to simulate them. The work described in this paper could be modified for future developments, which is helpful for related works needing integration between OSTATE 2 and QEMU for simulation of systems or components modeled in AADL.

VII. FUTURE WORK

As future work, we propose to add support for the extension of other architectures and platforms that could be emulated. Also, we propose to extend the types of devices and protocols that can be simulated, with the purpose of expanding the usage of the CSVD extension developed for OSTATE 2.

REFERENCES


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