AADL for Secure & Safe Systems Design & Analysis

Part 2 – Introduction to AADL

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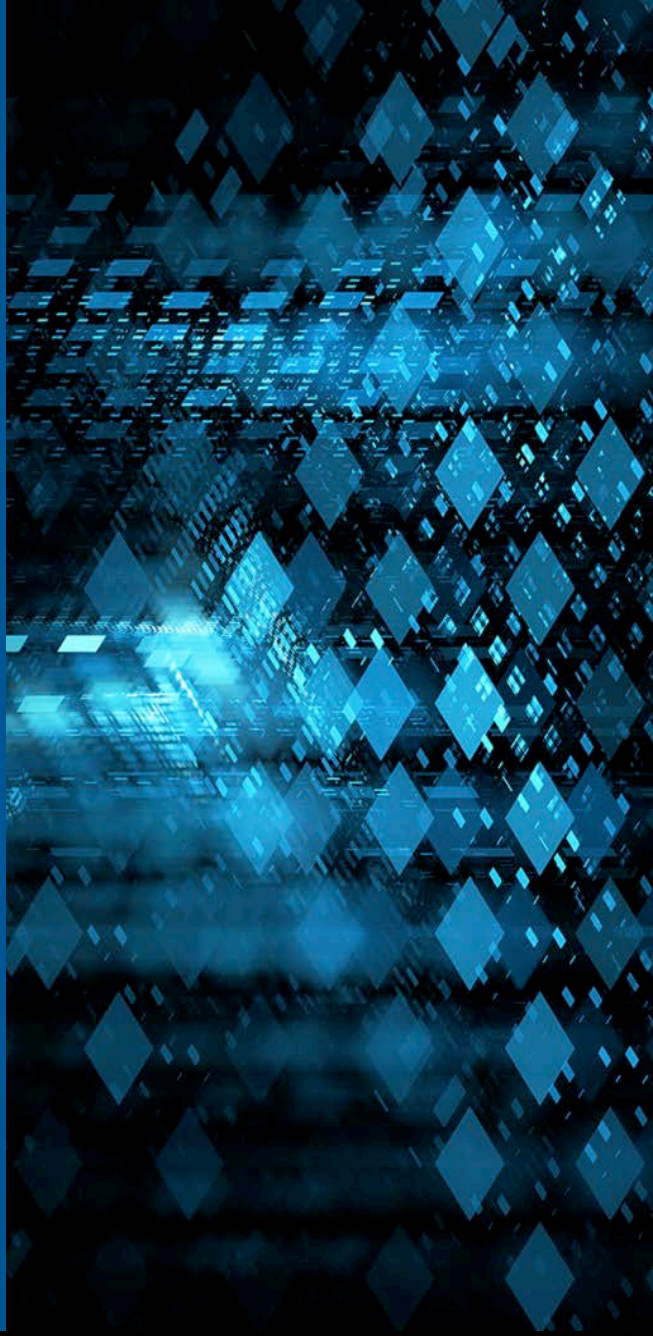

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Tutorial Agenda

Introduction: required background, role of MBE, tutorial overview

AADL Concepts: learn enough to use AADL and OSATE

Flow Latency: how to capture flow characteristics? How can I generate a flow analysis from my architecture model?

Safety Analysis: how to capture safety in an AADL model? What types of reports can I generate? How can I generate them?

Security Analysis: representation of security aspects. How to detect security issues? What type of reports can we generate?

Outline

AADL a quick overview

AADL key modeling constructs

- AADL components
- Properties
- Component implementation & connection

AADL: tool support

Hands on

Introduction

ADL, Architecture Description Language:

- **Goal** : modeling software and hardware architectures to master complexity … to perform analysis, simulate the system or generate code
- **Concepts** : components, connections, deployments.
- **Many ADLs** : formal/non formal, application domain, …

ADL for real-time critical embedded systems:
AADL (Architecture Analysis and Design Language).

AADL: Architecture Analysis & Design Language

International standard promoted by SAE, AS-2C committee, released as AS5506 family of standards

Version 1.0 (2004), version 2 (2009), 2.1 (2012)

- Based on feedback from partners working aerospace, avionics, medical industries

Standardized annex documents to address specific needs

- Behavior, data, error modeling, code generation, …

AADL objectives are "to model a system" …

- … with support through the complete life-cycle from design to implementation and tests
- … while complying with your own requirements and constraints using AADL extensions mechanisms

AADL components

AADL model : hierarchy/tree of components

- Textual, graphical representations, XMI serialization

AADL component models a software or a hardware entity

- Are organized in packages: reusable
- Must have a category
- May have interfaces
- May have * implementations with subcomponents and connections
- May extend/refine other components
- May have properties

Component interactions

- Modeled by component connections
- AADL features are connection points

AADL components

AADL distinguishes type and implementation

- **Component type**: high-level specification of a component
  - name, category, features, properties => interface
- **Component implementation**: internal structure (subcomponents), additional or refined properties, connections

Component categories: model abstractions

- Categories have well-defined semantics, refined through properties
- Denote software (threads, data, ..), hardware (processor, bus, ..)

Component type

All component type declarations follow the same pattern:

```
<category> foo [extends <bar>]
features
  -- list of features, interface
  -- e.g. messages, access to data, etc.
properties
  -- list of properties, e.g. priority
end foo;
```

Inherit features and properties from parent

Some properties describing non-functional aspect of the component

```
-- Model a schedulable flow of control
thread bar_thread                              --  bar_thread is a sporadic thread :
features                                       --  dispatched whenever it
  in_data : in event data port foo_data; --  receives an event on its port
properties
  Dispatch_Protocol => Sporadic;
  Period => 10 ms;
  Deadline => 5 ms;
end bar_thread;

process bar_process
features                                       --  dispatched whenever it
  in_data : in event data port foo_data; --  receives an event on its port
end bar_process;
```

Component implementation

Component Implementation complete the interface

```
<category> implementation foo.i [extends <bar>.i]
subcomponents
  -- internal elements
connections
  -- from external interface to internal subcomponents
properties
  -- list of properties
end foo.i;
```

foo.i implements foo

```
  process bar_process
  features                                    --  dispatched whenever it
    in_data : in event data port foo_data; --  receives an event on its port
  end bar_process;

  process implementation bar_process.i
  subcomponents
    thr : thread bar_thread;
  subcomponents
    c0 : port in_data -> bar_thread.in_data;
  end bar_process.i;
```

AADL concepts

AADL introduces many other concepts:

- **Related to embedded real-time critical systems :**
  - **AADL flows**: capture high-level data+execution flows
  - **AADL modes**: model operational modes in the form of an alternative set of active components/connections/…
- **To ease models design/management:**
  - AADL packages (similar to Ada/Java, renames, private/public)
  - AADL abstract component, component extension

AADL is a rich language

- 200+ entities in the meta-model
- BNF has 185 syntax rules
- Around 250 legality rules and more than 500 semantics rules
- 400 pages core document + various annex documents

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Software components categories

AADL component categories refer to well-known abstractions:

- **thread** : schedulable entity, maps to task/thread of an RTOS
- **data** : data placeholder, e.g. C struct, C++ class, Ada record
- **process** : address space. It must hold at least one thread
- **subprogram** : a sequential execution flow, associated to a source code (C, Ada) or a model (SCADE, Simulink)
- **thread group** : hierarchy of threads

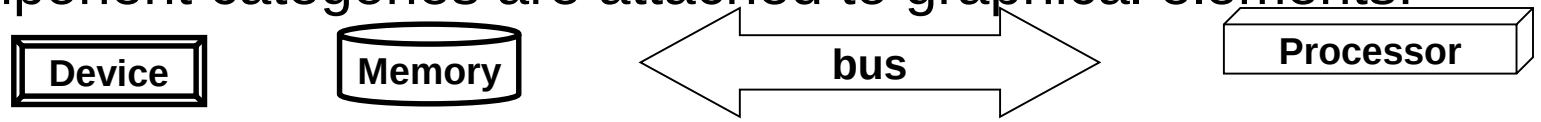
Component categories are attached to graphical elements:

Hardware components categories

Hardware categories model resources available:

- **processor/virtual processor** : schedule component (combined CPU and RTOS scheduler). A processor may contain multiple virtual processors.
- **memory** : model data storage (memory, hard drive)
- **device** : component that interacts with the environment. Internals (e.g. firmware) is not modeled.
- **bus/virtual bus** : data exchange mechanism between components

Component categories are attached to graphical elements:



The system & abstract categories

An **abstract** component must be refined later to specify its type

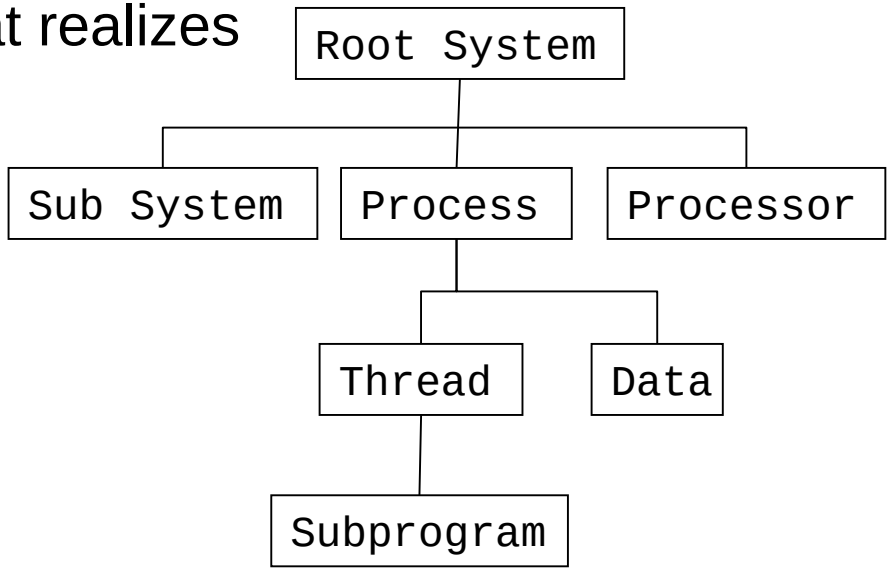
Useful in early design process when real type is unknown

A **system** component has two main uses

Model at high-level of abstraction

Define the structure of the system (**root component**)

An **AADL instance model** contains a root system that contains all subcomponents that realizes the system.



About subcomponents

Semantics: some restrictions apply on subcomponents

- A hardware cannot contain software, etc.

data	data, subprogram
thread	data, subprogram
thread group	data, thread, thread group, subprogram
process	thread, thread group, data
processor	Memory, virtual processor, bus,
memory	Memory, bus
system	All except subprogram, thread et thread group

- Similar restrictions on semantic connections, binding of elements, etc.

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AADL properties

Property: Typed attribute, associated to components

- **Property declaration** = name + type + allowed components
- **Property association** = property name + value.
- Can be propagated to subcomponents: inherit
- Can override parent's one, case of extends

Property sets: group property definitions.

- Property sets part of the standard, e.g. Thread_Properties.
- Or user-defined, e.g. for new analysis such as power analysis

```
property set Thread_Properties is
  Dispatch_Protocol: Supported_Dispatch_Protocols
    applies to (thread, device, virtual processor);

  Priority: inherit aadlinteger
    applies to (thread, thread group, process, system, device, data);
 end Thread_Properties;
```

AADL properties

Properties are typed with units to model physical systems, related to embedded real-time critical systems.

```
property set AADL_Projects is
Time_Units: type units (
    ps,
    ns  => ps  * 1000,
    us  => ns  * 1000,
    ms  => us  * 1000,
    sec => ms  * 1000,
    min => sec * 60,
    hr  => min * 60);
-- …
end AADL_Projects;
```

```
property set Timing_Properties is

 Time: type aadlinteger
    0 ps .. Max_Time units Time_Units;

 Time_Range: type range of Time;

 Compute_Execution_Time: Time_Range
  applies to  thread, device, subprogram
    event port, event data port);

end Timing_Properties;
```

AADL properties

Properties are associated to a **component type (1)** or **implementation (2)**, as part of a **subcomponent instance (3)**, or a **contained property association (4)**.

```
thread foo
properties  -- (1)
  Compute_Execution_Time => 3 .. 4 ms;
  Deadline => 150 ms ;
end foo;

thread implementation foo.impl
properties -- (2)
   Deadline => 160 ms;
   Compute_Execution_Time => 4 .. 10 ms;
end foo.impl;
```

Property value depends on the context!

```
process implementation bar.others
subcomponents
  foo0 : thread foo.impl;
  foo1 : thread foo.impl;
  foo2 : thread foor.impl
        {Deadline => 200 ms;};  -- (3)
properties -- (4)
   Deadline => 300 ms applies to foo1;
end bar.others;
```

Question: what is the Deadline property value of `foo0`, `foo1` and `foo2` in `bar.others`?

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Component connection

Component connection: model component interactions

- Control flow and/or data flow: exchange of messages, shared data access, remote subprogram call (RPC), …

Connections connect component features

- Feature declared in component type
- Each feature has a name, a direction, and a category

Features direction for port and parameter:

- input (in), output (out), both (in out)

Features category: specification of the type of interaction

- **event port**: event exchange (e.g. alarm, interruption)
- **data port/event data port**: synchronous/asynchronous exchange of data/message
- **subprogram parameter**
- **data access**: access to a data, possibly shared
- **subprogram access**: RPC or rendez-vous

Component connection

Features of subcomponents are connected in the `connections` subclause of the enclosing component

Ex: threads & thread connection on data port

```
process acc_process
features
  acc1_output: out data port SHM_DataType::accData;
  -- …
end acc_process;

process implementation acc_process.impl
subcomponents
  acc1: thread threads::acc1_dataOutput.impl;
  -- …
connections
  C7: port acc1.acc1out -> acc1_output;
  -- ..
```

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1. AADL a quick overview

2. AADL key modeling constructs
    1. AADL components
    2. Properties
    3. Component connection

3. AADL: tool support

AADL toolchains

Multiple AADL toolchains exist, they can be easily combined via the textual syntax. Most of them have a FLOSS license

OSATE (SEI/CMU, http://aadl.info)

- Eclipse-based tools. Reference implementation
- Textual and graphical editors + various plug-ins (latency, security, …)

Ocarina (ISAE, http://www.openaadl.org)

- Command line tool, library to manipulate models in Python
- AADL parser + code generation + analysis (Petri Net, WCET, …)

AADLInspector (Ellidiss, http://www.ellidiss.com)

- Lightweight tool to inspect AADL models. AADLv1 and v2
- Industrial version of Cheddar + Simulation Engine

Others: RAMSES, PolyChrony, ASSIST, MASIW, MDCF, TASTE, …

In the following, we will concentrate on OSATE

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3. AADL: tool support

4. Hands-on

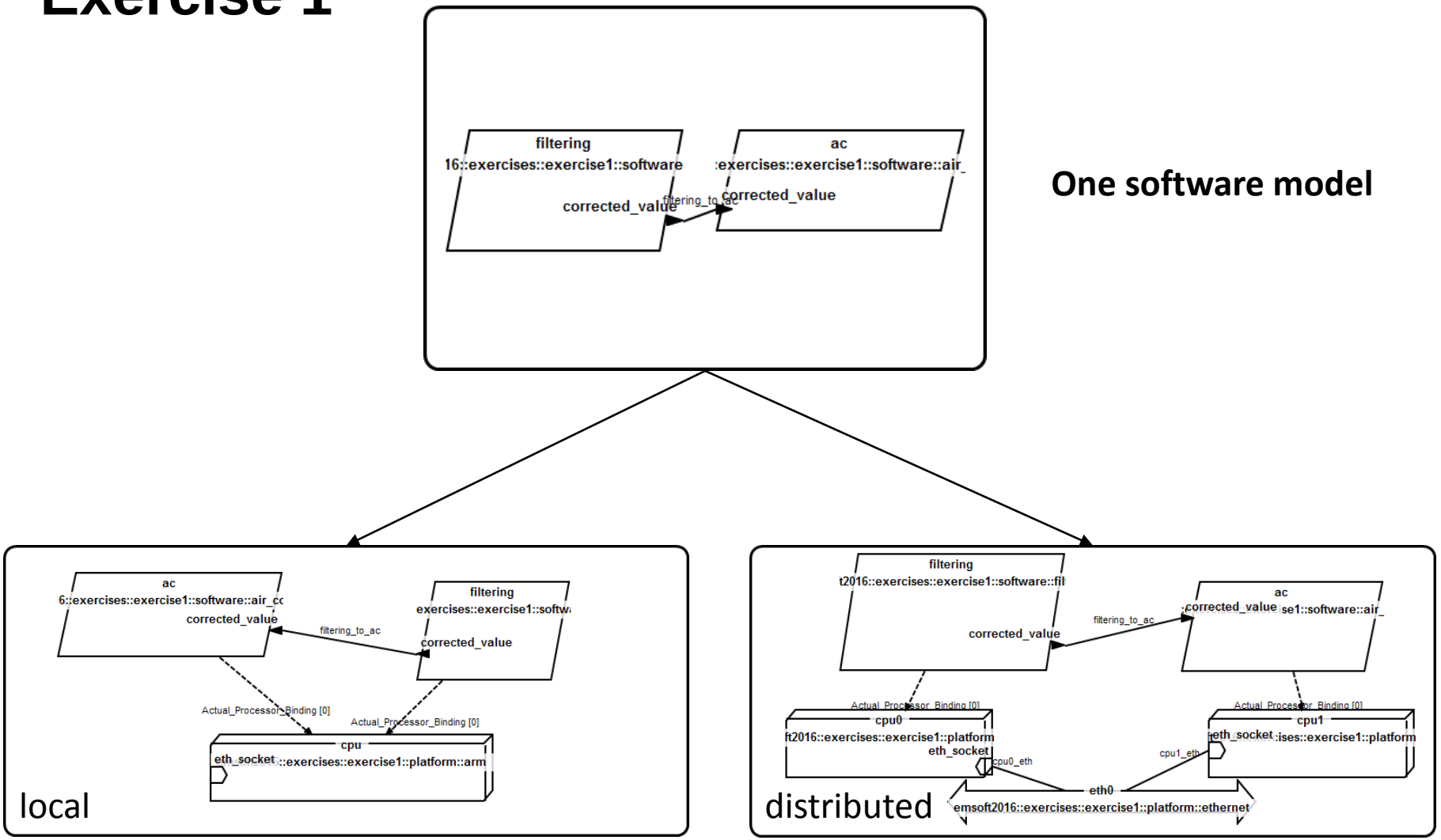
Exercise 1 - Objectives

Connect features from filtering and AC

In the local implementation, deploy all processes on the same processor (CPU). Use the Actual_Processor_Binding property.

In the distributed implementation, deploy the processes on separate processors. Bound the connection to an Ethernet bus. Use the Actual_Processor_Binding and Actual_Connection_Binding property.

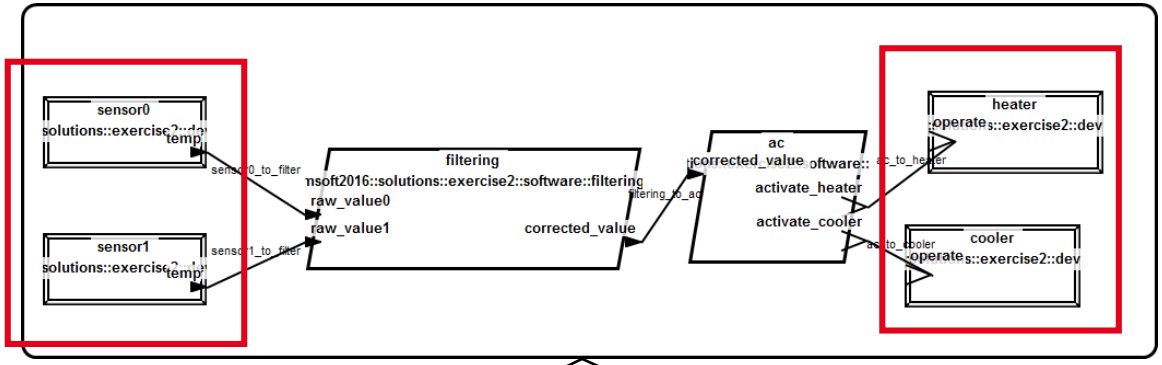
Exercise 1

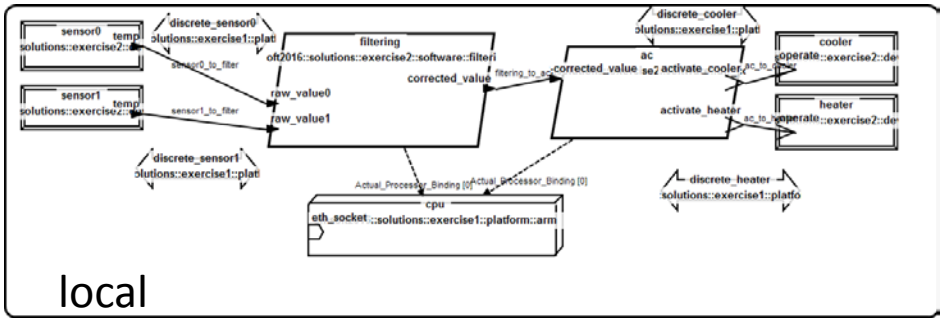


Different deployment approaches

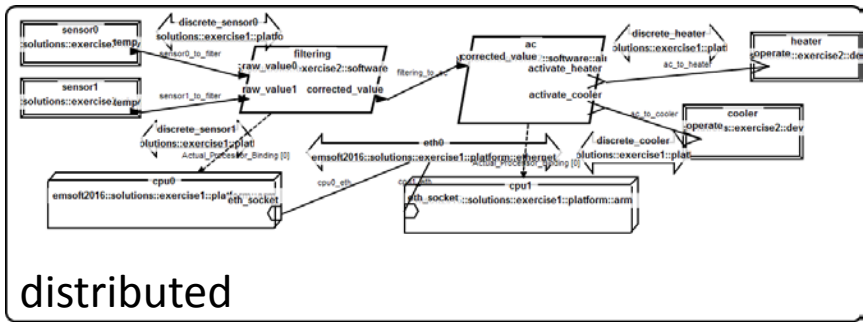
Exercise 2

Extended software model





local



distributed

Impact deployment approaches