Multi-Agent Multi-Model Simulation of Smart Grids in the MS4SG Project

J. Vaubourg, Y. Presse, B. Camus, C. Bourjot, L. Ciarletta,
V. Chevrier, J.-P. Tavella and H. Morais

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Plan

1. **Smart Grids**
2. **Simulation Goals & Challenges**
3. **MECSYCO: Co-Simulation Platform**
4. **Co-Simulation Building Example**

Smart Grids

What? Why?

Smart Grids: What?

*"a **modernized grid** that enables **bidirectional flows of energy** and uses **two-way communication** and control capabilities that will lead to an array of **new functionalities and applications**"*

(from `nist.gov`)

Smart Grids: Why?

- **Renewable and intermittent** energy sources
- **Production & Consumption balance**
- **Voltage control**
- **Electric vehicles** increase

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- **Production & Consumption balance**
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New algorithms or original operating modes to test

Smart Grids: Simulation

- Some **demonstrator systems** in France (e.g. VENTEEA, MILLENER)
- **Not easy to find** local areas for experimentation
- **Long and expensive** to enroll participants (consumers, producers, EVs owners, utilities, etc.)

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Simulation is an attractive solution for testing
without real prototypes

Simulation Goals & Challenges

in the context of Smart grids

Fields of technology

Power Grid

Communication Network

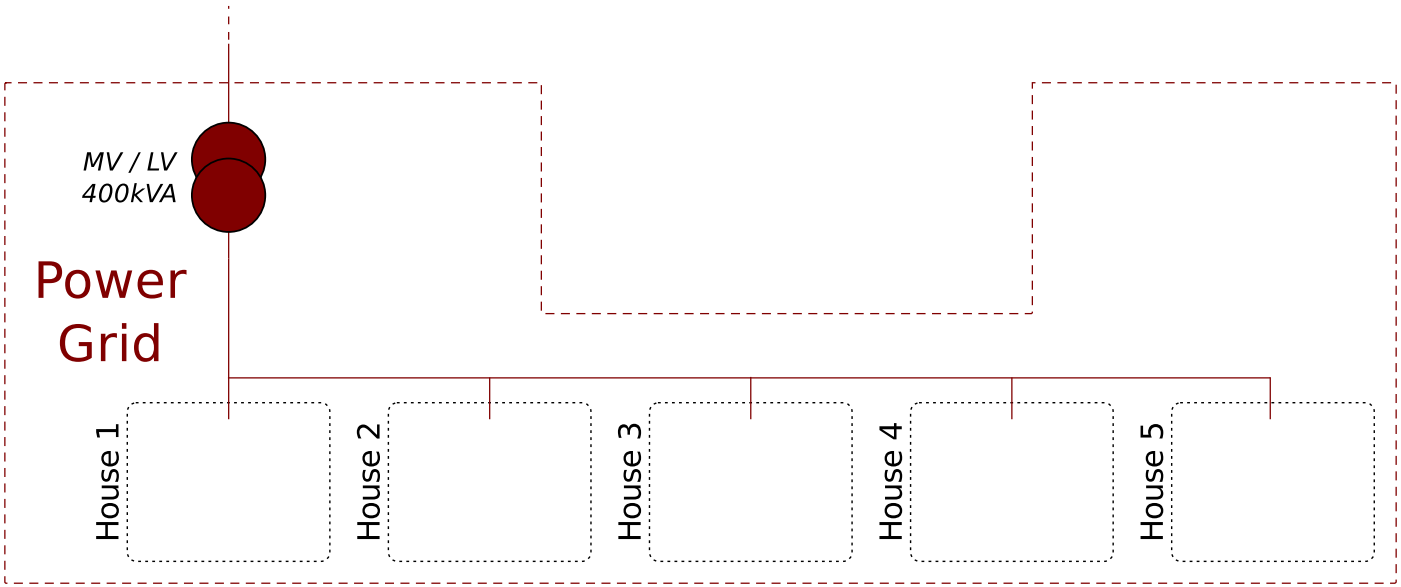
Information System

Smart grids are composed of
3 main fields of technology

Use Case Illustration

Concept Grid: Real use case provided by EDF
(French electricity utility)

Use Case Illustration



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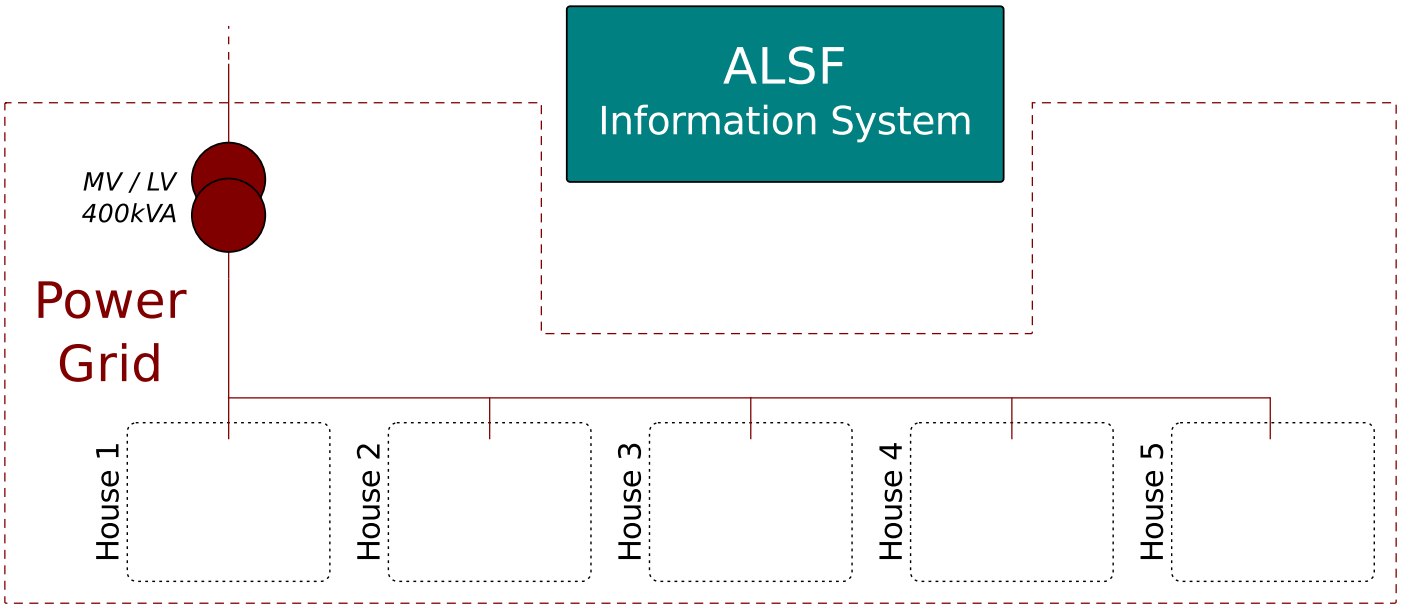

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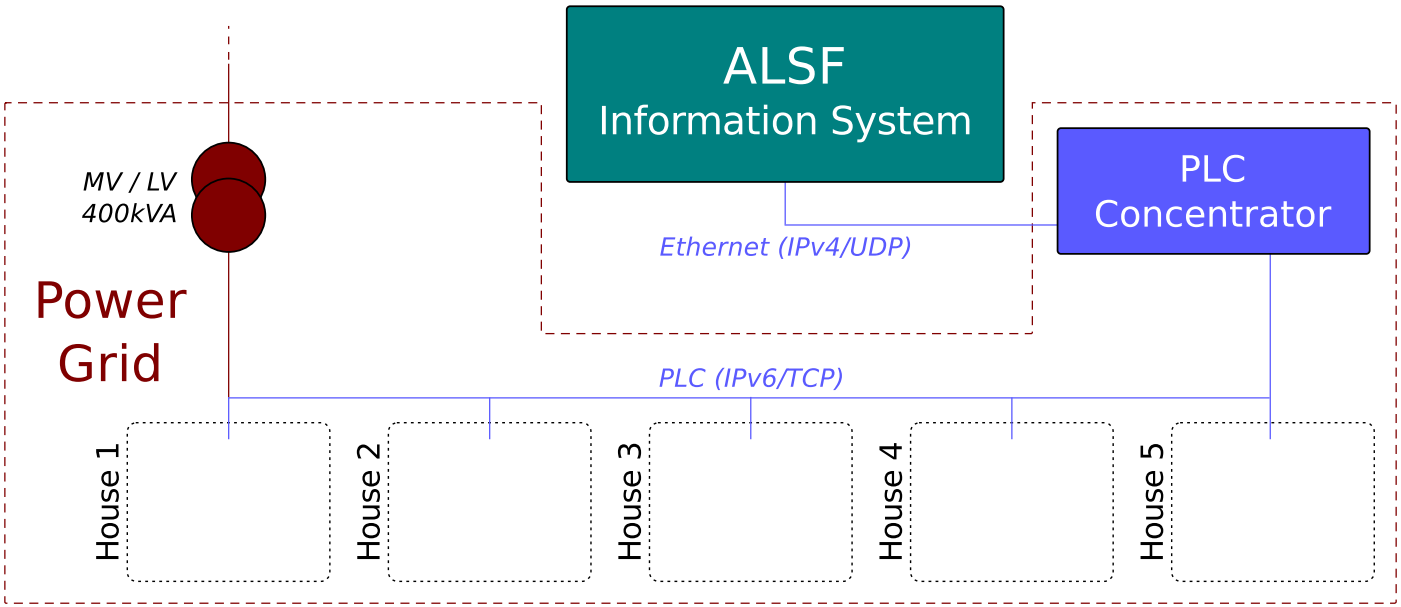

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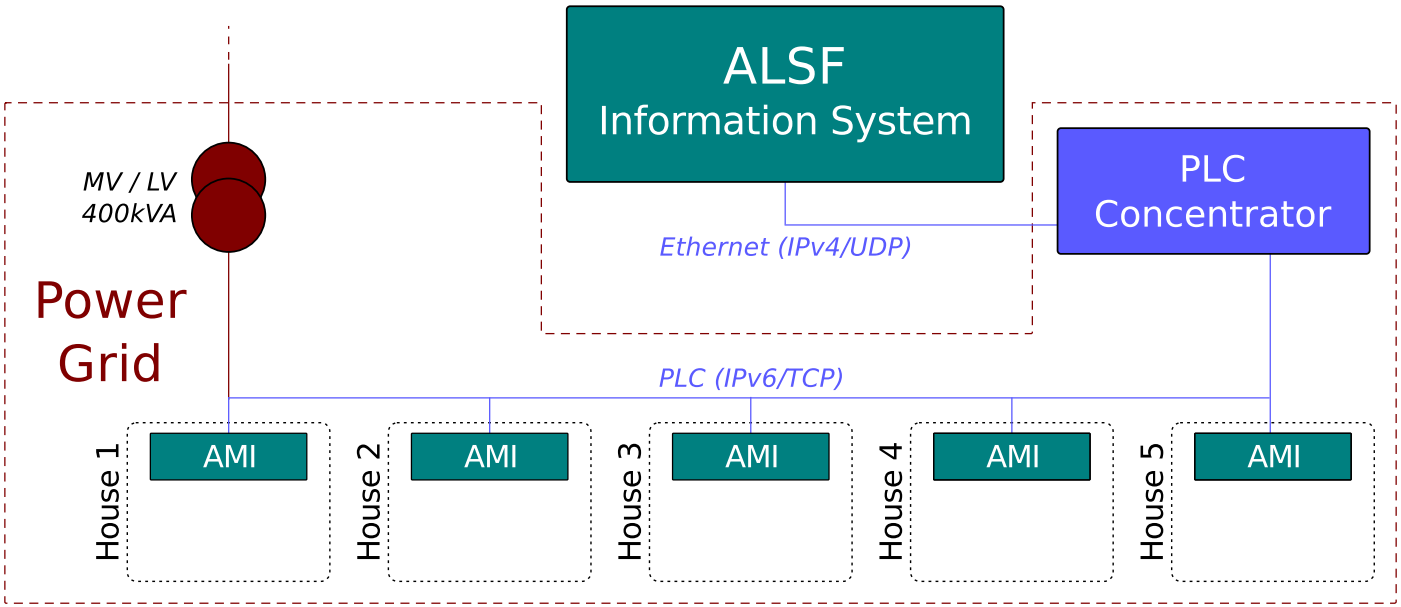

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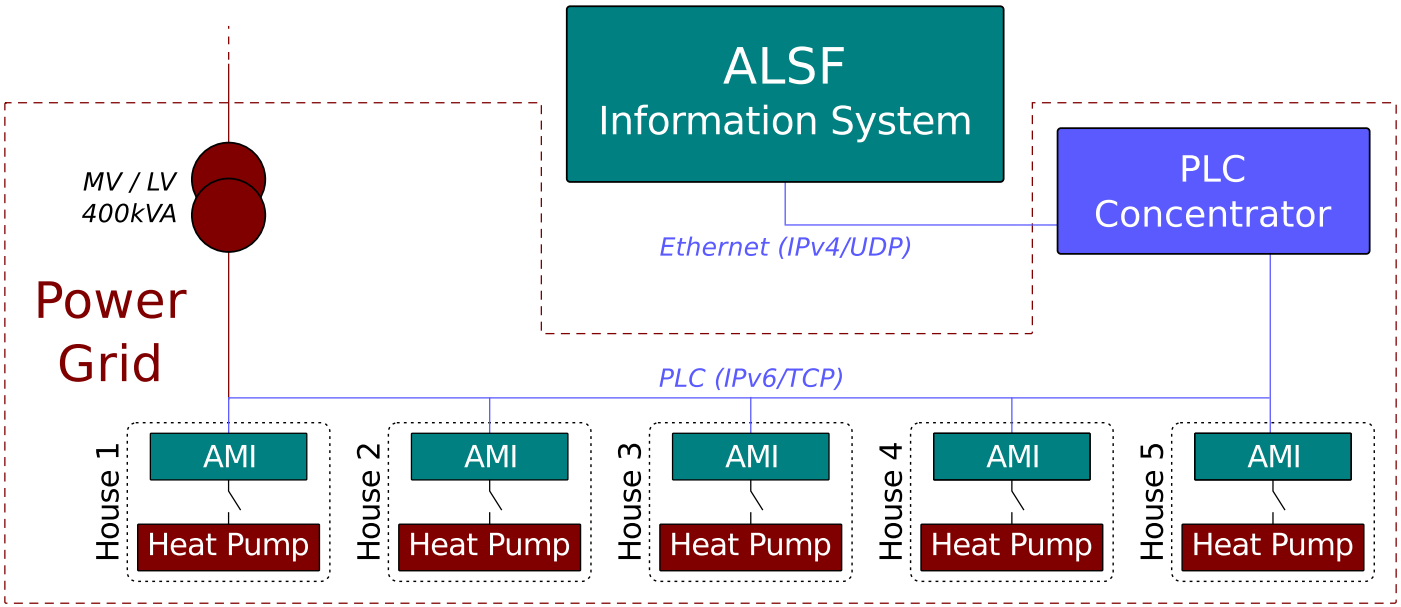

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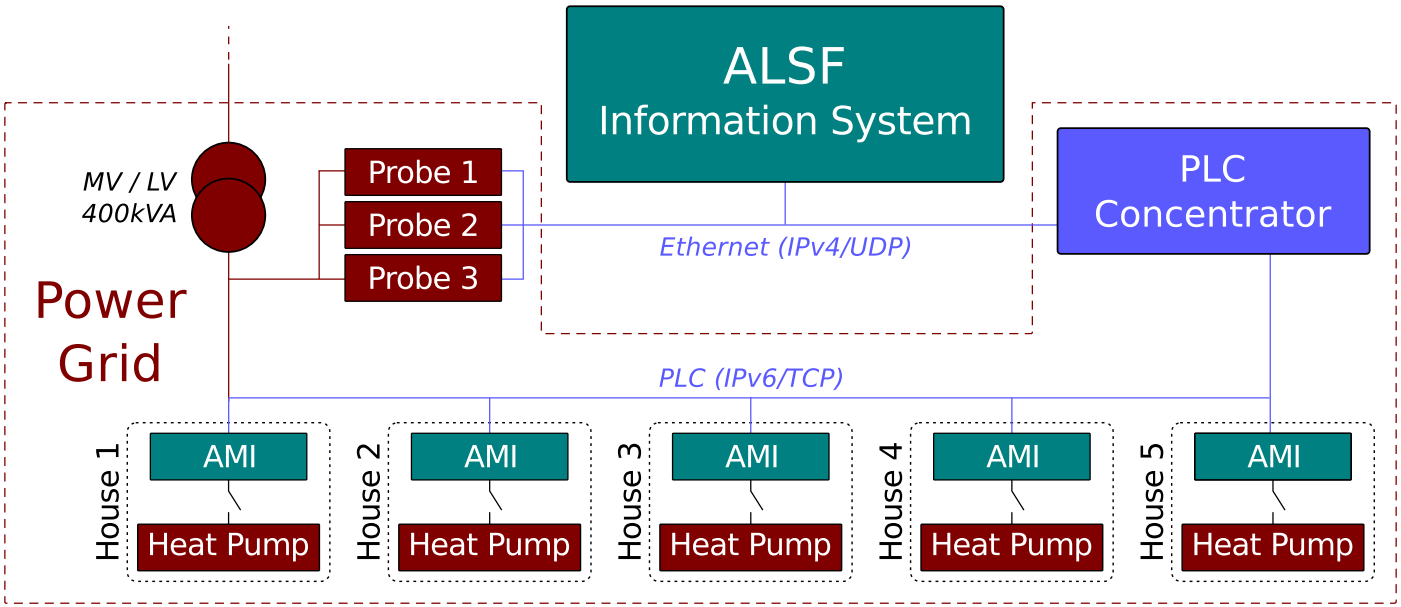

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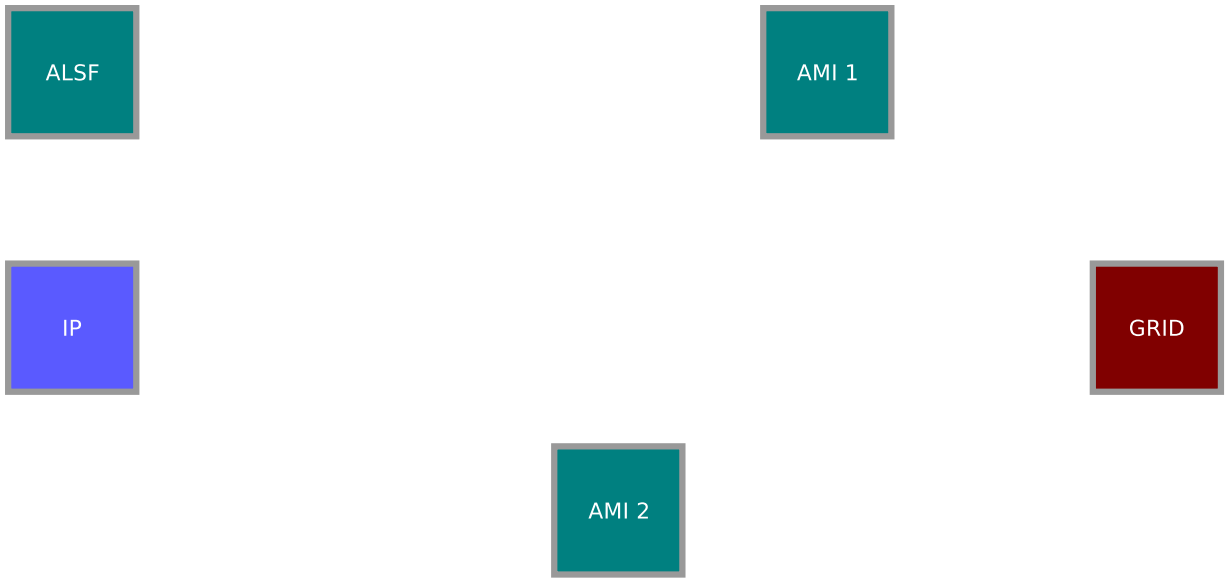
Goals

Goals: Reusability Support



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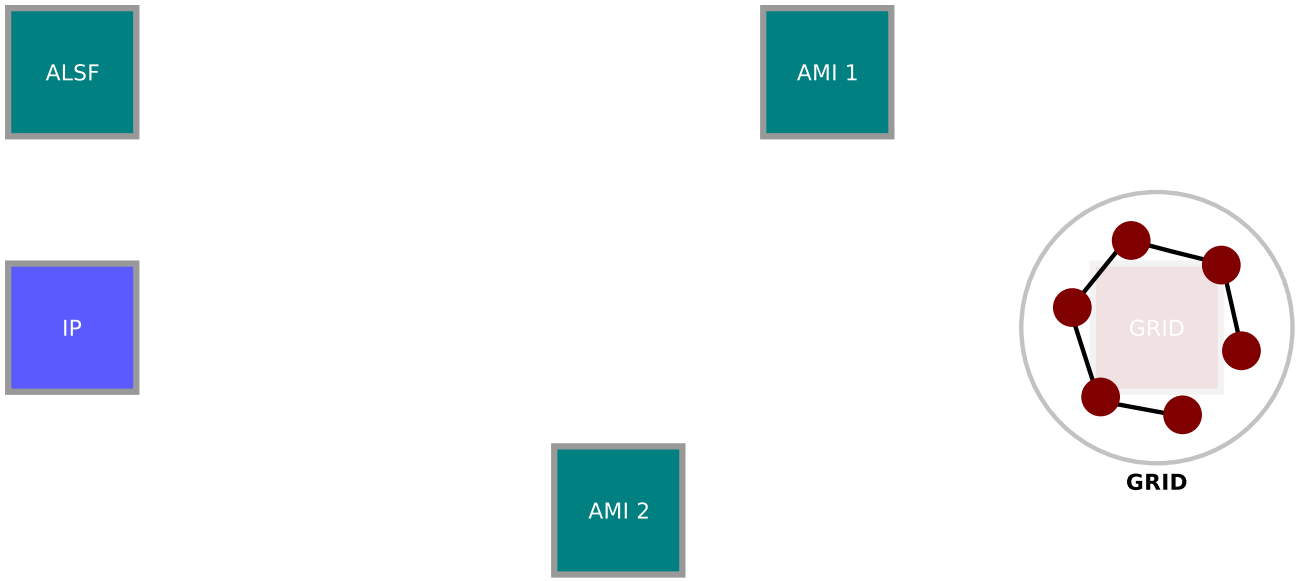

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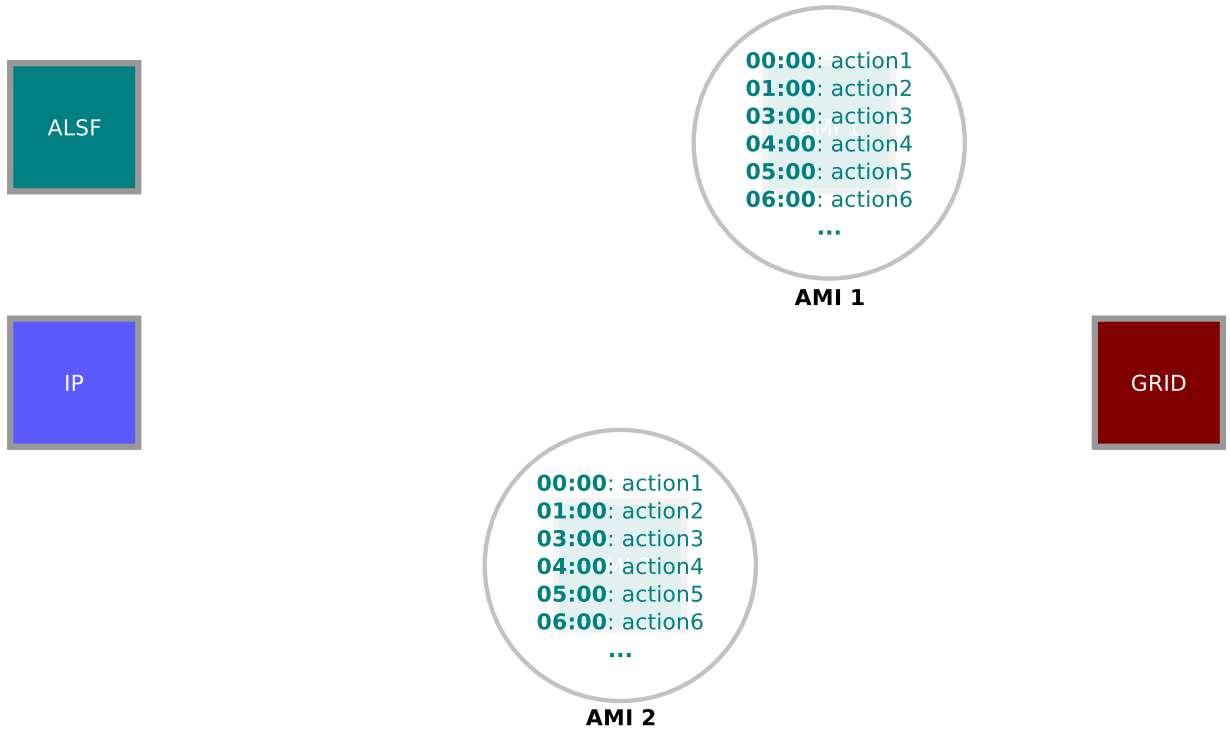

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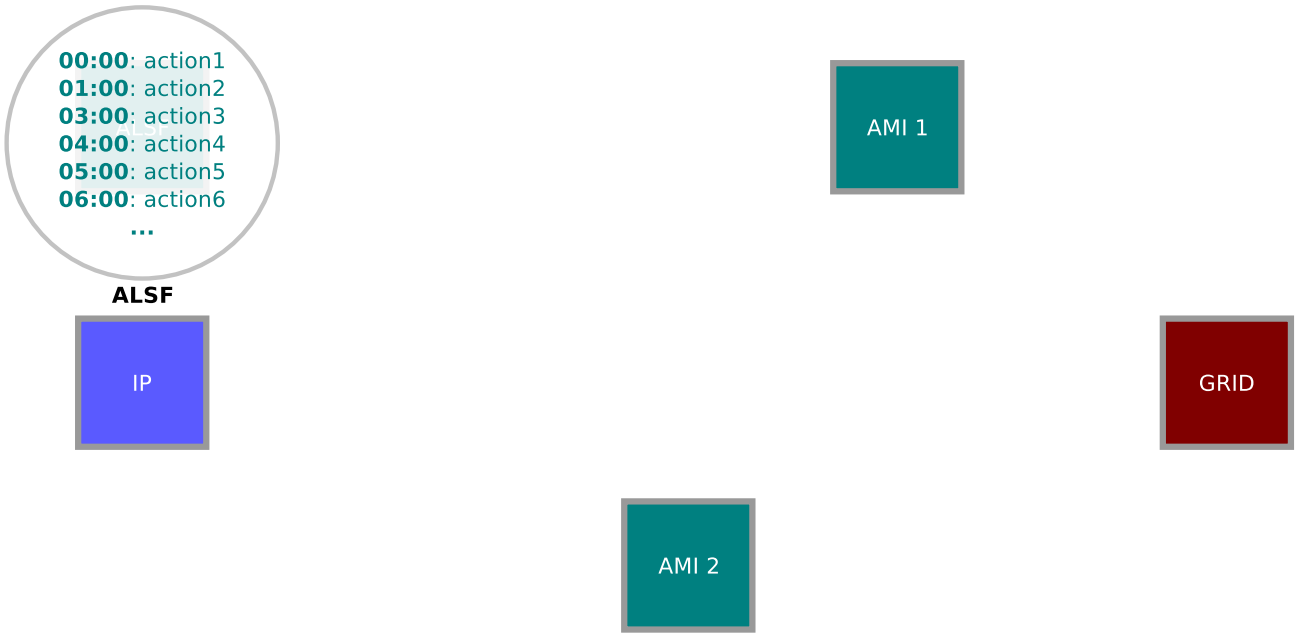

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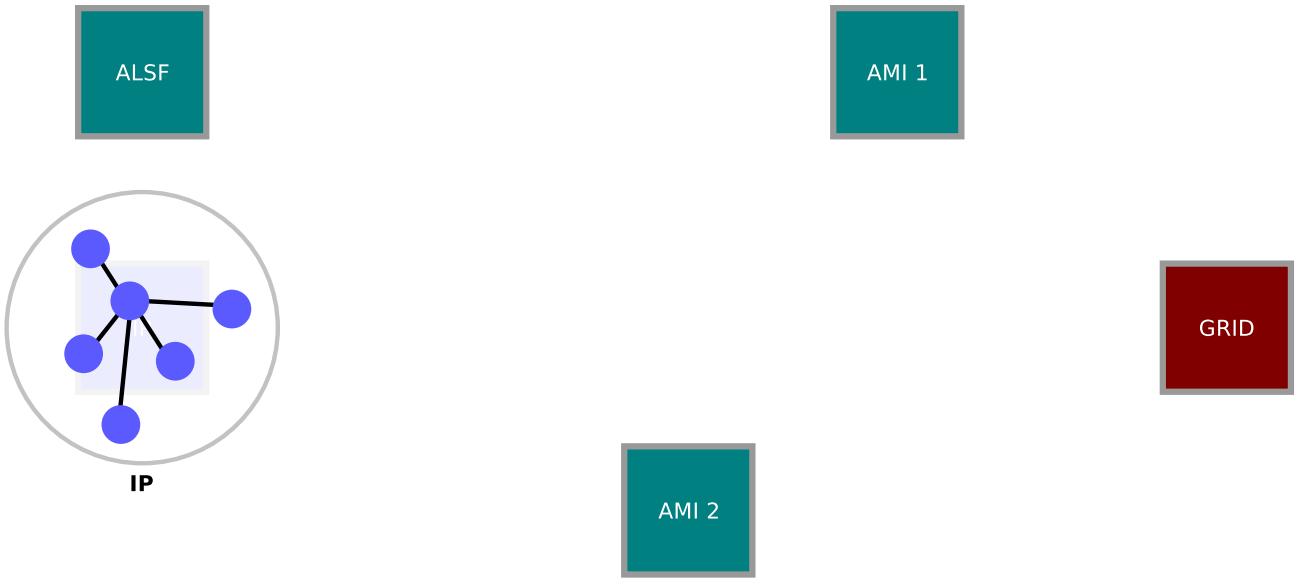

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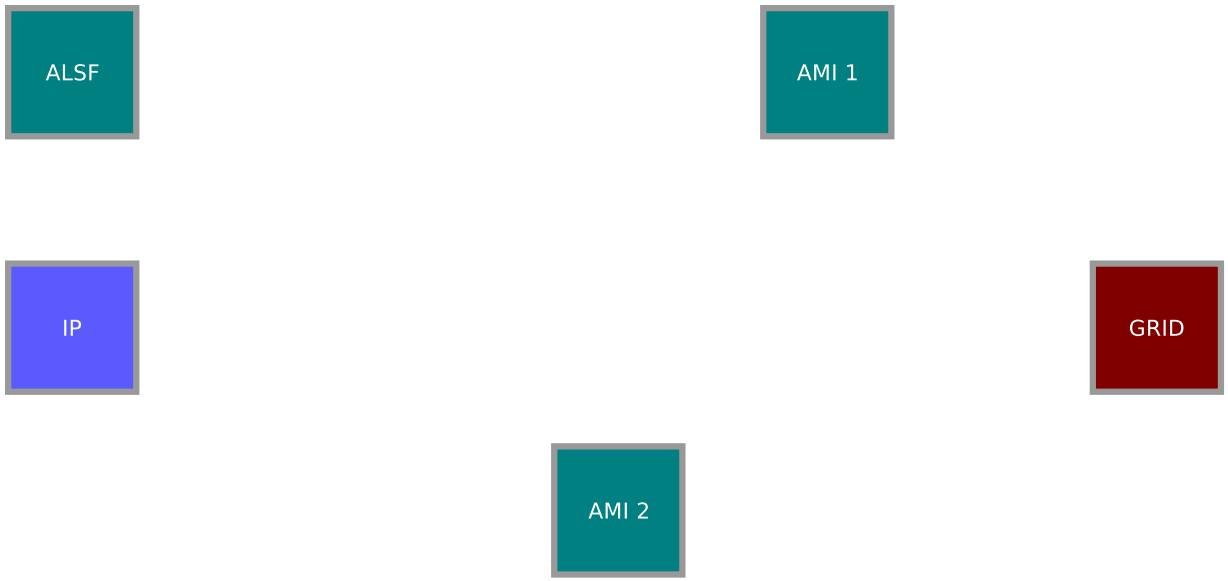
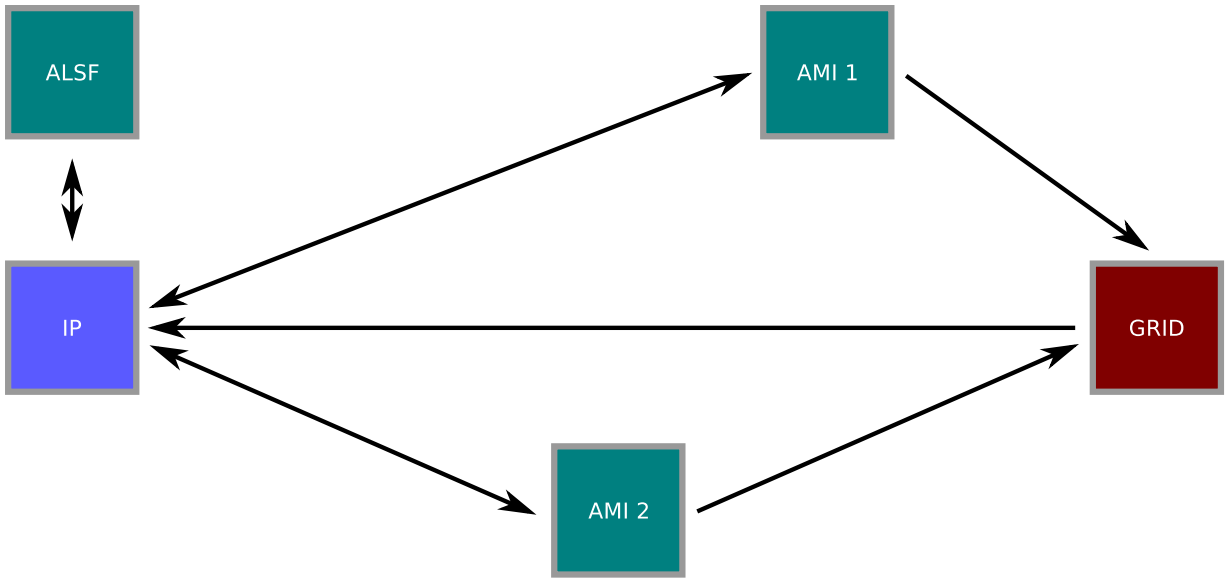


Various existing **well-tested, proven or industrial models** has to be reused

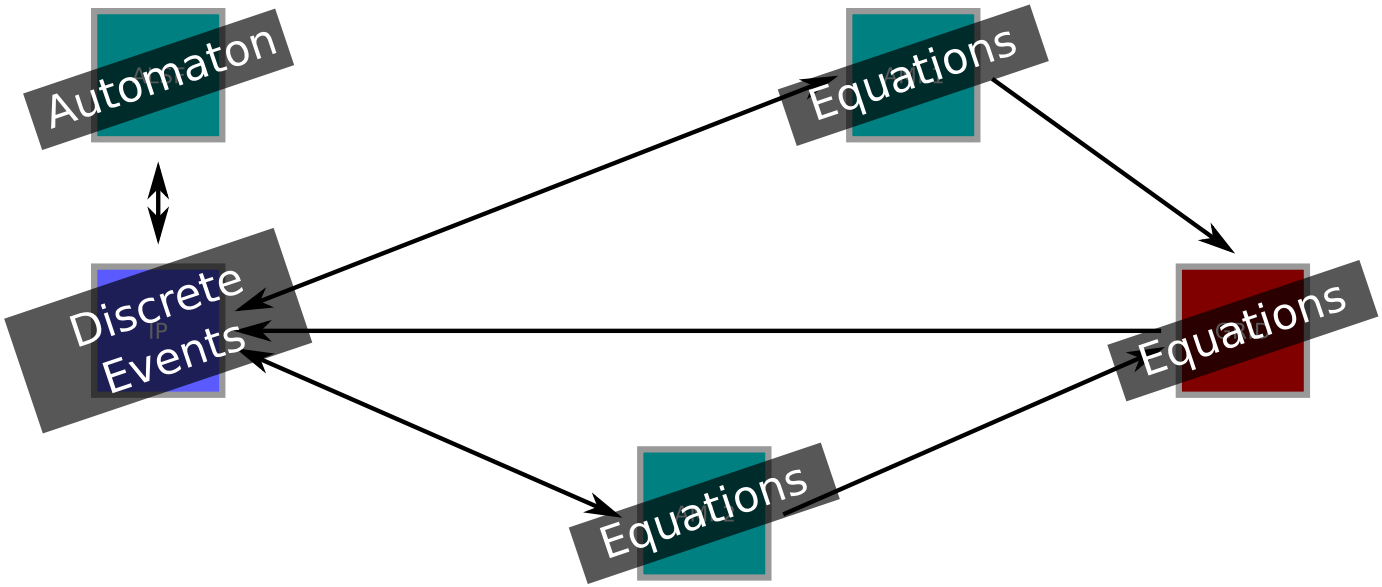
Goals: Interactions among models



Models have to be **connected and executed together** in a same **co-simulation**

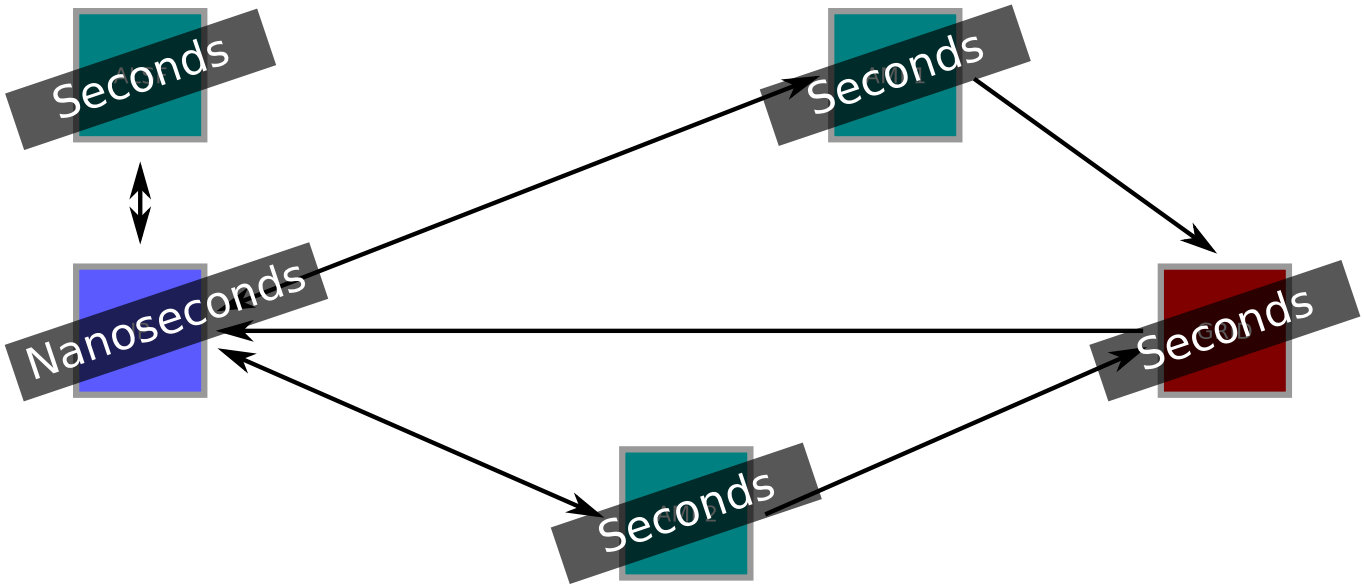
Challenges

Challenges: Formalisms Heterogeneity Integration



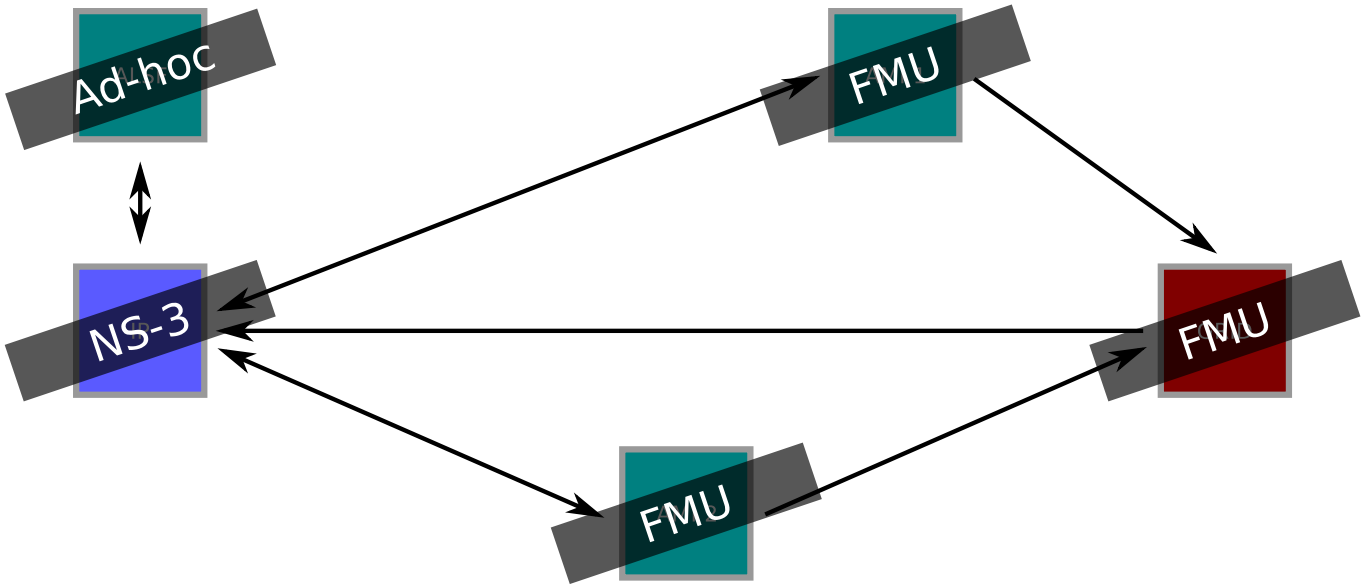
Different formalisms have to co-exist

Challenges: Representations Heterogeneity Integration



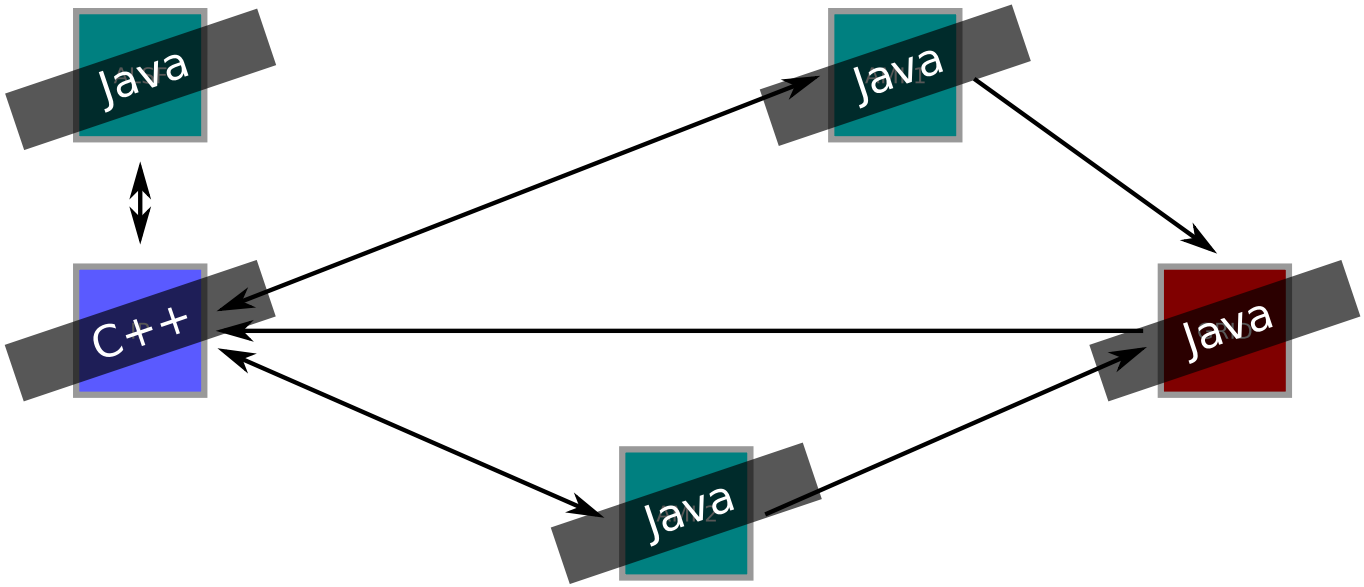
Simulated time and exchanged data can have
different representations

Challenges: Simulators Heterogeneity Integration



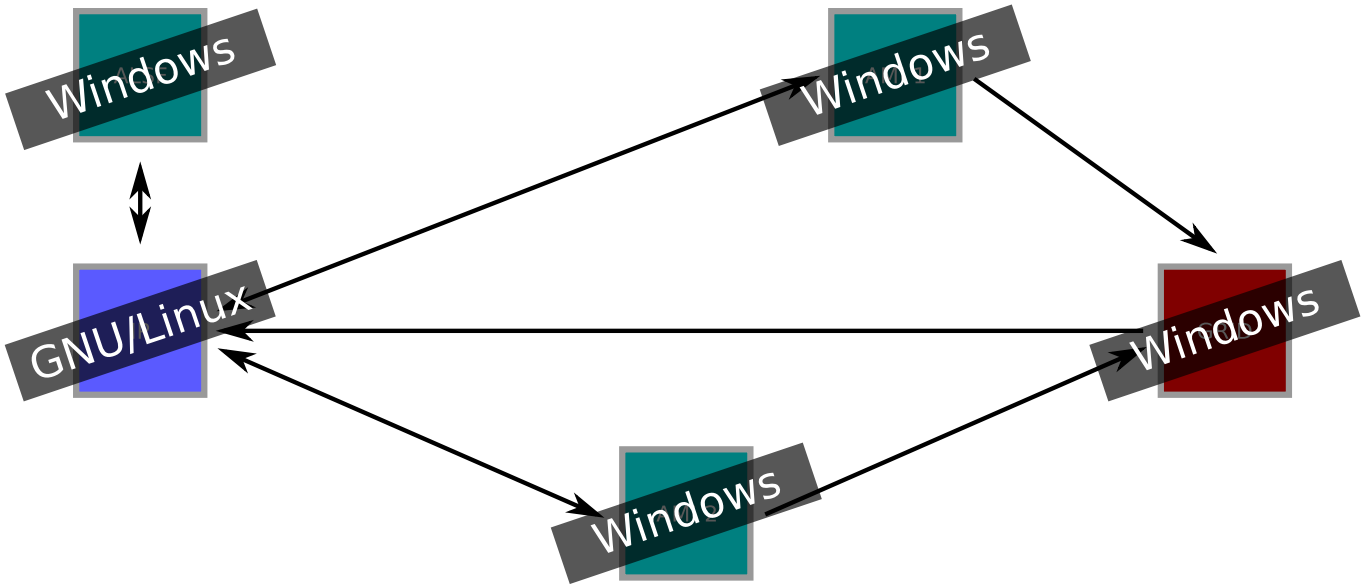
Models implementations are usable with **different simulators**
(often **not interoperable** together)

Challenges: Languages Heterogeneity Integration



Simulator bindings are proposed with **different languages**

Challenges: Platforms Heterogeneity Integration



Simulators are available for **different platforms**

Challenges: Synthesis

Managing the **heterogeneity** of a multi-model:

1. **Models Issues**: integrating different **formalisms and representations**

2. **Software Issues**: ensuring the **simulators interoperability** for the models reusability

MECSYCO

Multi-agent Environment for Complex SYstems CO-simulation

MECSYCO: What is it?

MECSYCO is a **co-simulation platform**

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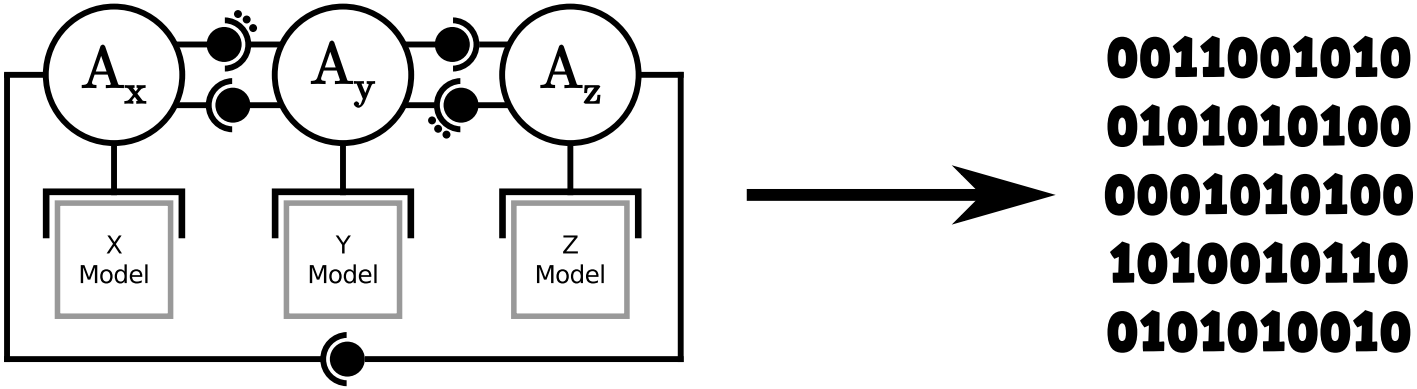
MECSYCO is a **co-simulation platform**



Meta-modeling approach: from an **intuitive graphic** to an **executable software**

MECSYCO: What is it?

Intuitive graphics are described
with the **Agents & Artifacts paradigm**

MECSYCO: What is it?

Intuitive graphics are described
with the **Agents & Artifacts paradigm**

- Agents correspond to models (**1 agent = 1 model**)
- **Artifacts** correspond to the **interactions**
- The **multi-agent dynamics** corresponds to the **multi-model execution**

MECSYCO: What is it?

Specifications are based on **the DEVS formalism**

MECSYCO: What is it?

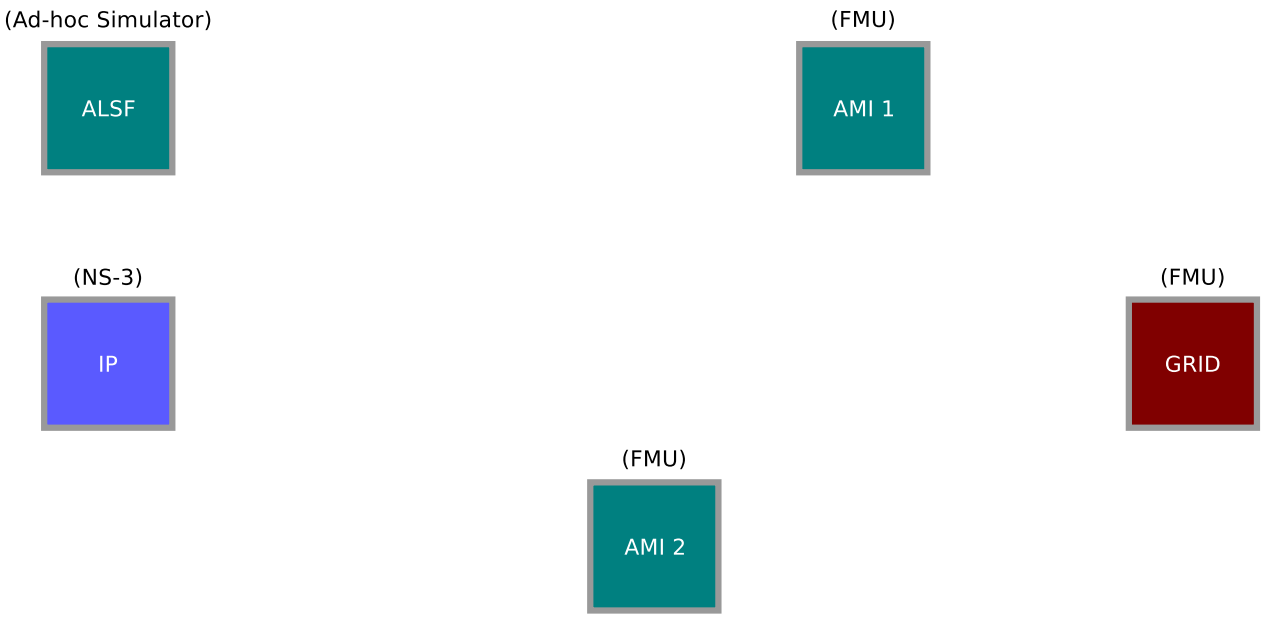
Specifications are based on **the DEVS formalism**

- **Any formalism can be mapped** in DEVS
- Agents' behavior is defined with the **Chandy-Misra-Bryant algorithm**

Co-Simulation Building Example

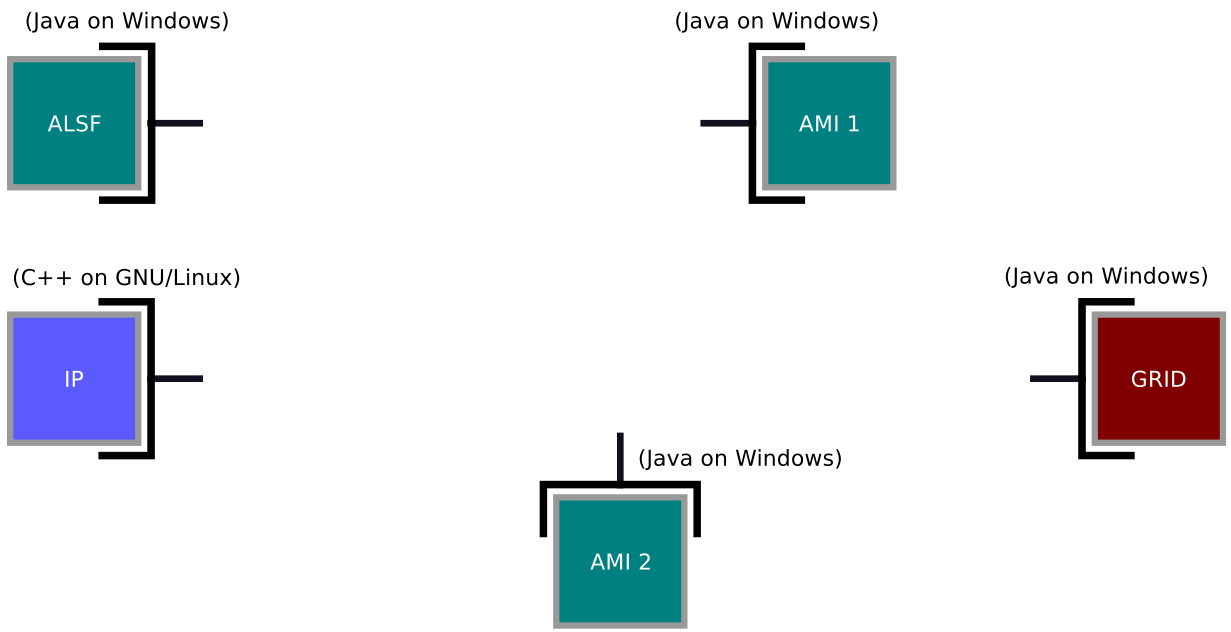
With MECSYCO

Building with MECSYCO: Existing



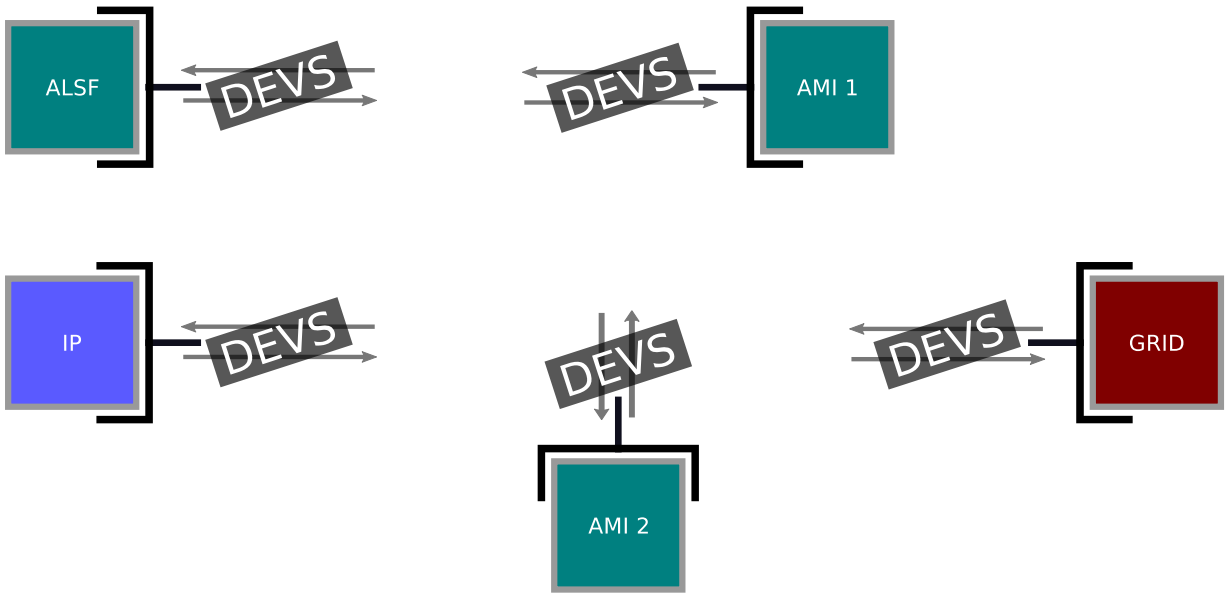
Existing **models and simulators** to use

Building with MECSYCO: Model Artifacts



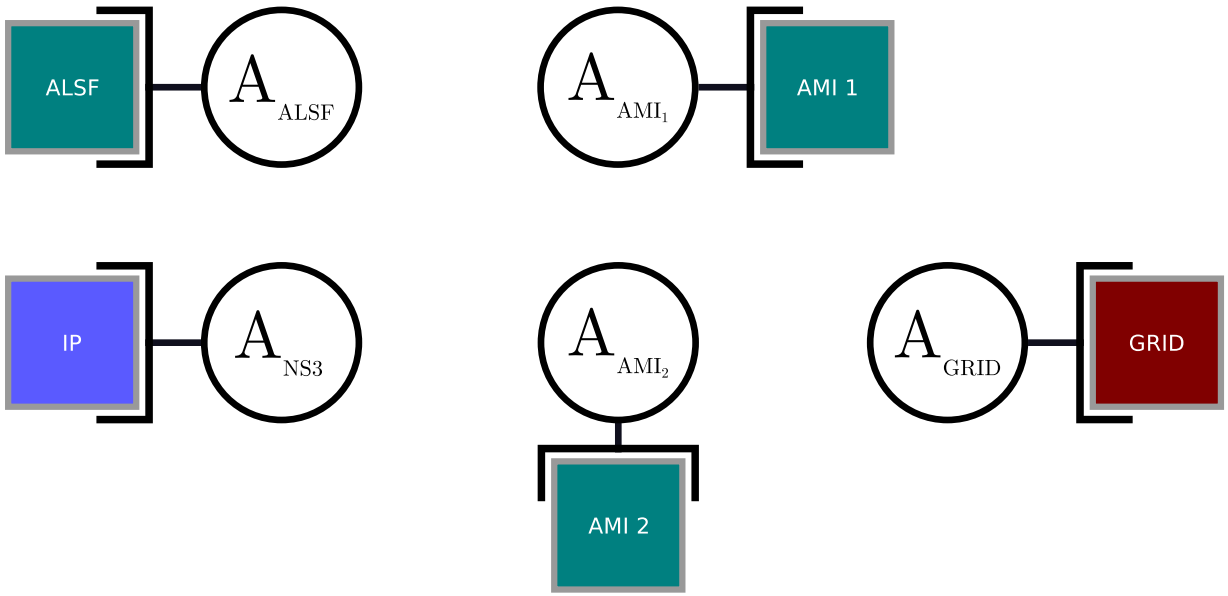
Model Artifacts: ensure software **interoperability** and manage **formalism** integration

Building with MECSYCO: Model Artifacts



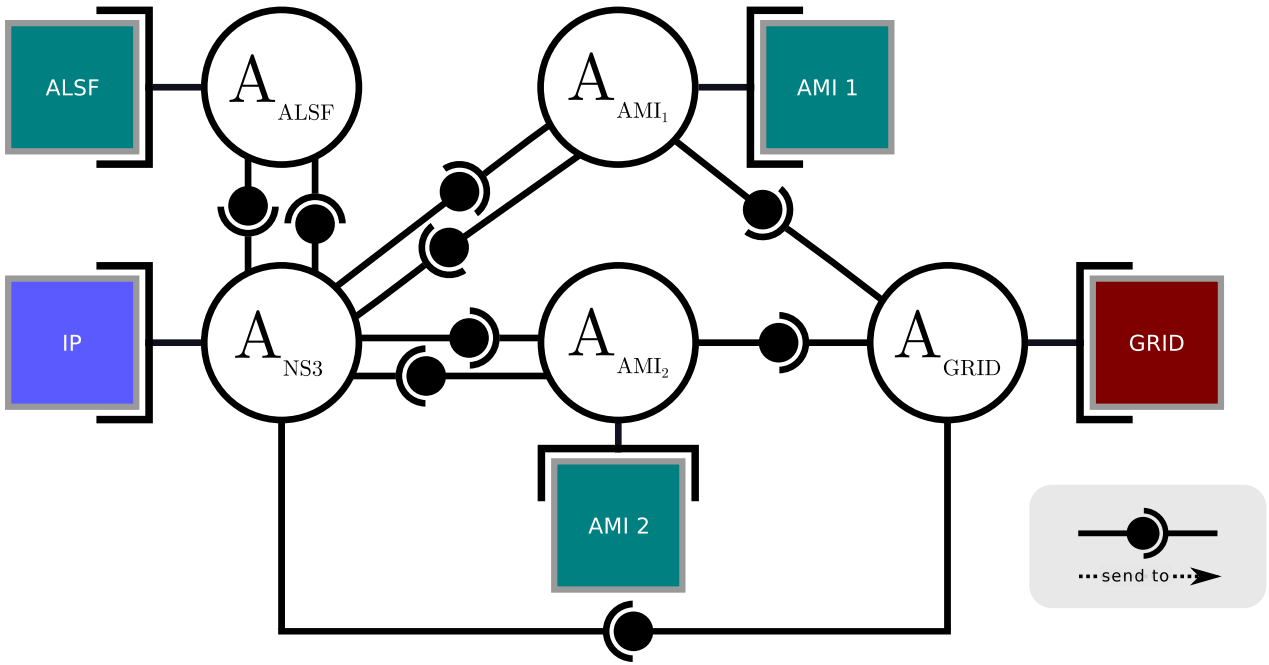
Model Artifacts act as **DEVS** wrappers

Building with MECSYCO: M-agents



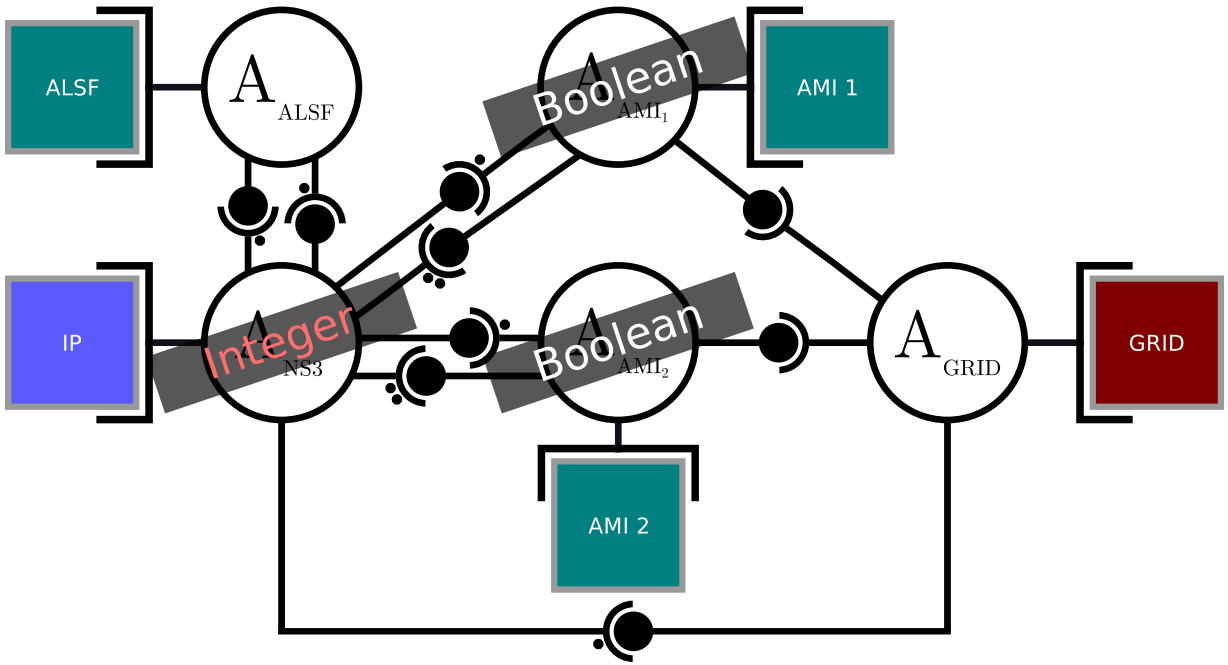
M-agents: execute the simulation (control the models and manage the **dynamics** of the co-simulation)

Building with MECSYCO: Coupling Artifacts



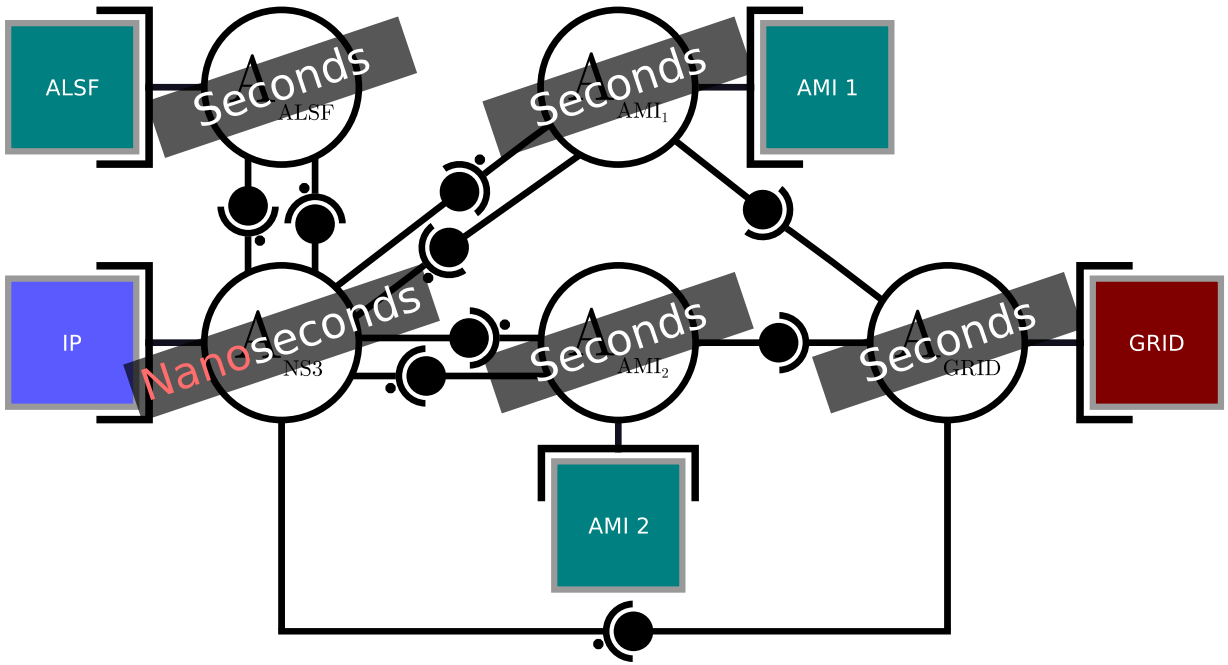
Coupling Artifacts: exchange events between m-agents

Building with MECSYCO: Operations



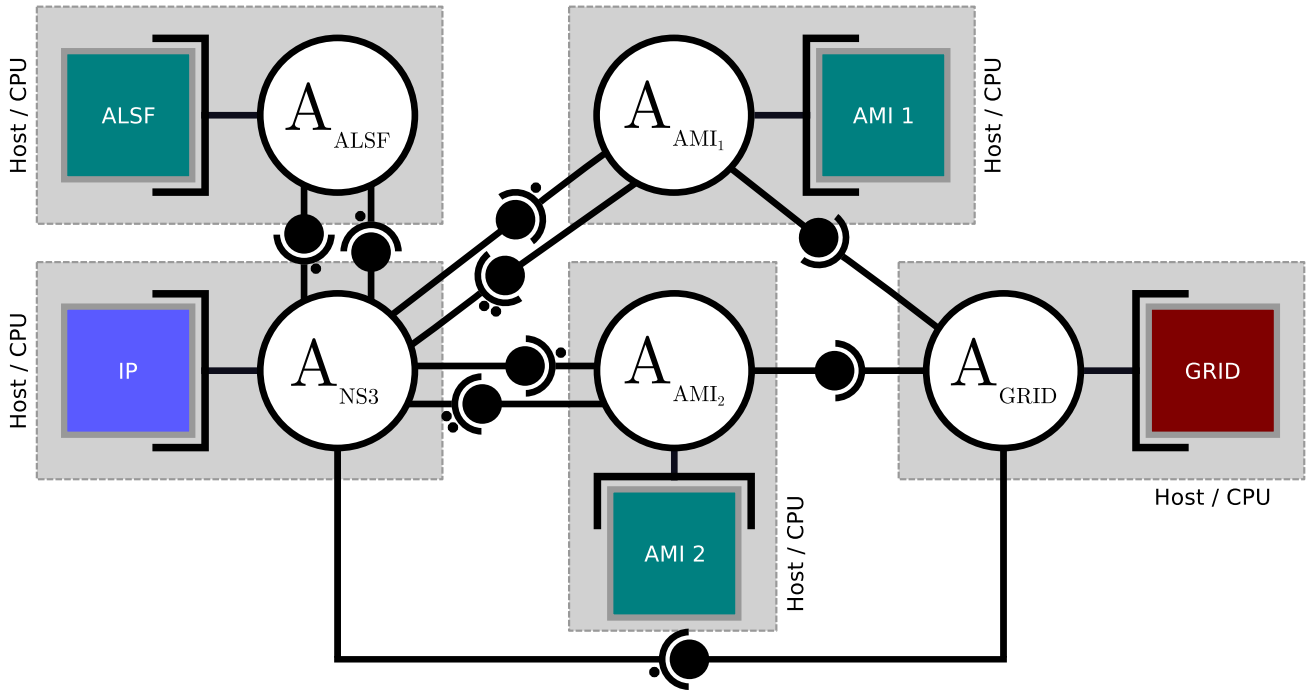
Operations: transform the events
(in this case, convert types)

Building with MECSYCO: Operations



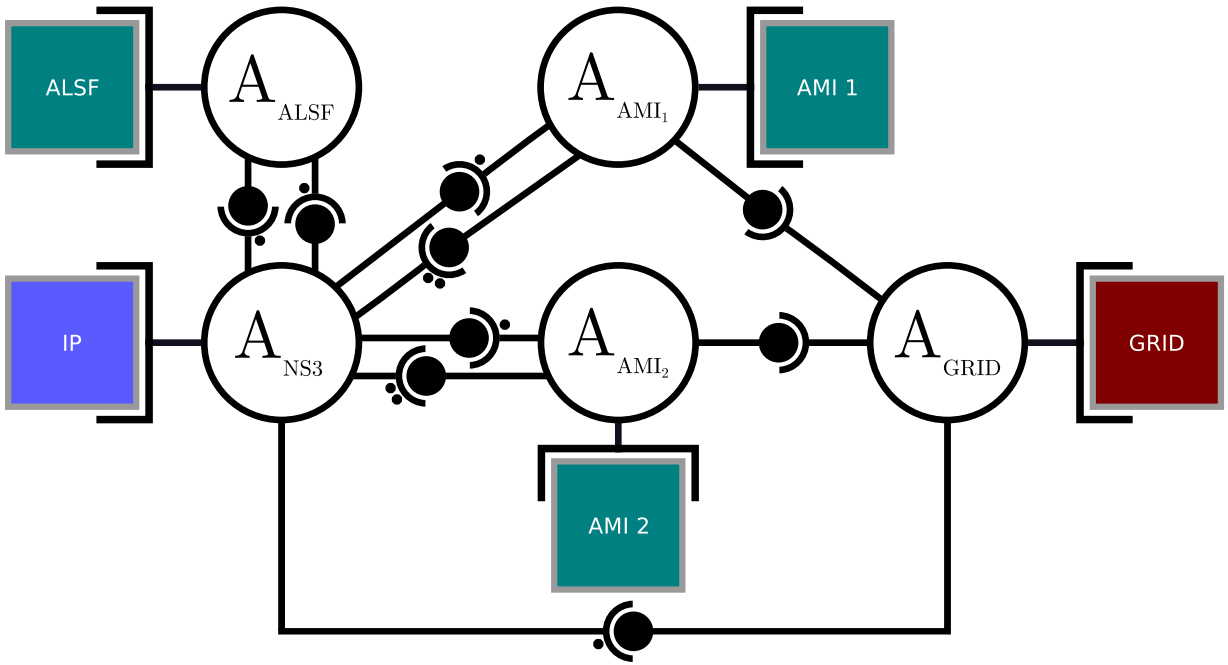
Operations: in this case, change **time scales**

Building with MECSYCO: Remote Communications



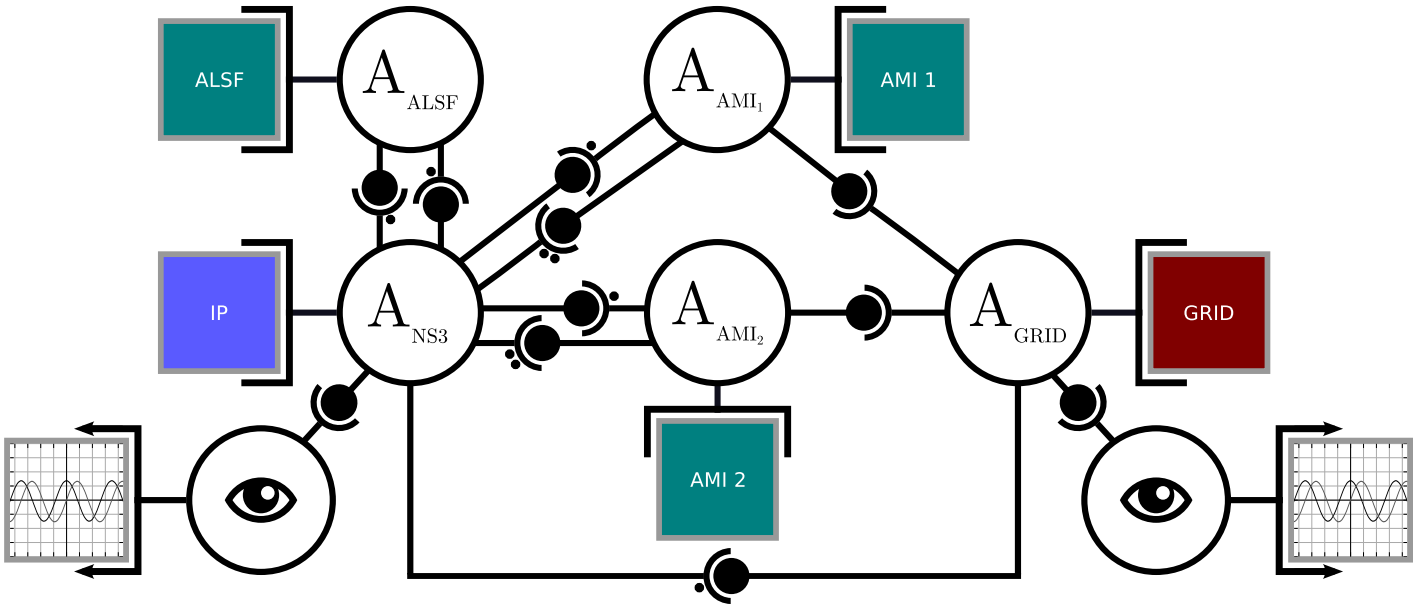
Each simulator instance can use a **dedicated thread or host**

Building with MECSYCO: Intuitive Graphic



This is the **intuitive graphic** corresponding to our use case

Building with MECSYCO: Observing Agents



The Agents & Artifacts paradigm allows us to add **observing m-agents** (plots, traces, etc.)

Building with MECSYCO: Results Visualization

The *European Institute For Energy Research* (EIFER) used our simulation results for building a **visualization software**

Conclusion

- **Executable co-simulation** created from a set of models, thanks to an **intuitive graphic**
- Integration of **several forms of heterogeneity** (formalism, representation, language, simulator and platform)
- **Simulation results** are directly usable

Conclusion

- Purely **decentralized** execution
- Developed in **Java and C++**
- Developement **framework** available (`mecsyco.com`)
  Free Software: AGPL 2.0

Perspectives

1. **Generating the physical domain** from CIM (*Common Information Model*)

2. Connecting more business tools to **visualize simulations**

3. Long Term: **Experimental Plans**

Questions?