Leveraging System Architecture Models for Diagnosis of High-Tech Systems

Capella Days 2024

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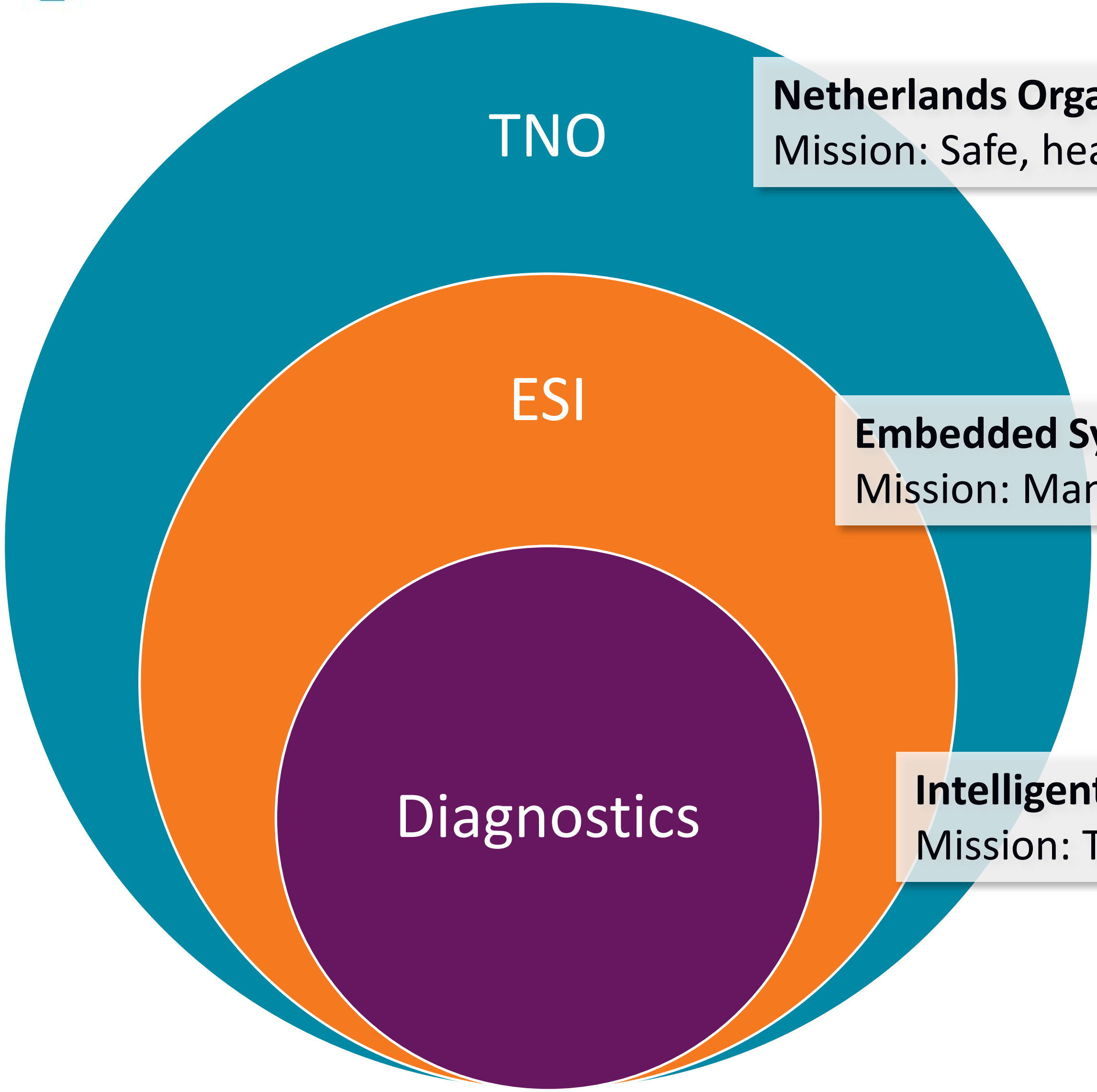
TNO ESI
Powered by industry and academia



Netherlands Organisation for Applied Scientific Research
Mission: Safe, healthy, sustainable, and digital society

4000

Embedded Systems Innovation
Mission: Managing complexity in high-tech systems

70

Intelligent Diagnostics
Mission: Towards zero unscheduled downtime

10

ESI at a glance

Mission: Embedding cutting-edge methodologies into the Dutch high-tech systems industry in order to cope with the ever-increasing complexity of their products.

Synopsis

- Foundation ESI started in 2002
- ESI acquired by TNO per January 2013
- ~70 staff members (end 2024), many with extensive industrial experience
- 8 Part-time Professors
- Working at industry locations
- From embedded systems innovation to embedding innovation

Focus

Managing complexity of high-tech systems

through

- system architecting,
- system reasoning and
- model-driven engineering

delivering

- methodologies validated in cutting-edge industrial practice

Partner Board(s)

ASML, itec, PHILIPS, Canon CANON PRODUCTION PRINTING, THALES, VANDERLANDE, Radboud University Nijmegen, UNIVERSITY OF AMSTERDAM, TU Delft Delft University of Technology, TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY, UNIVERSITY OF TWENTE., TNO

Capgemini engineering, ICT GROUP Strypes

Outline

Model-based systems engineering for model-based diagnostics

Our methodology

Demo

Conclusions and future work

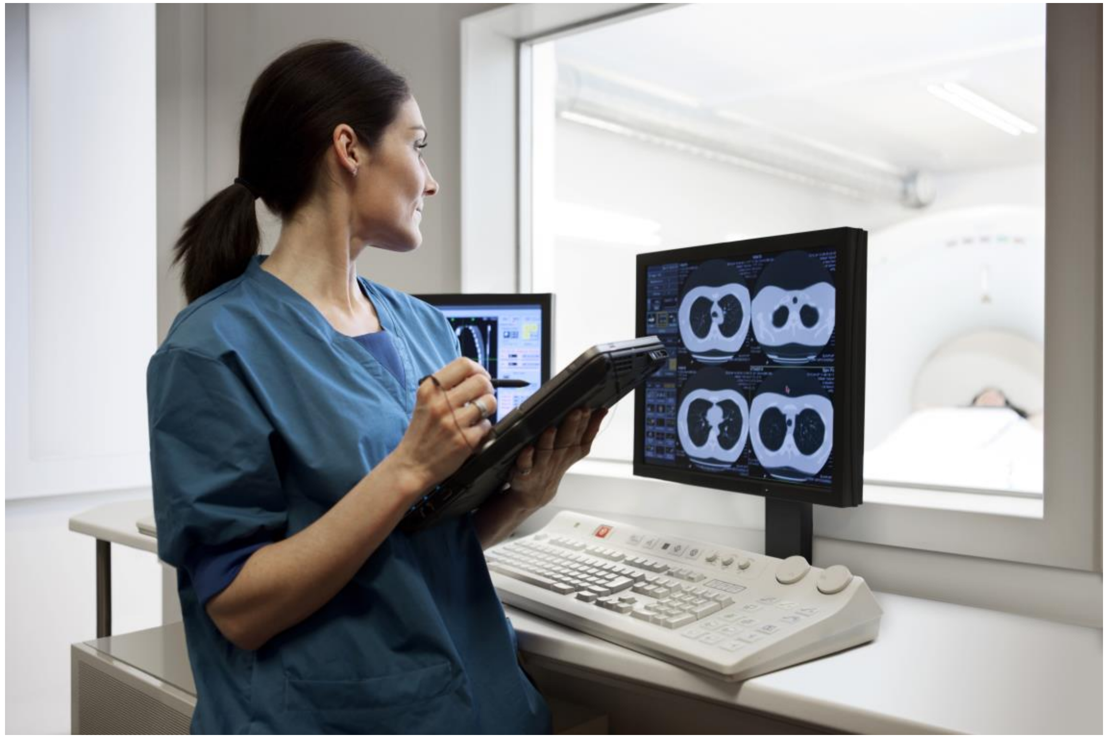
Model-Based Diagnostics

The use of formal models to compute diagnoses for a set of observations

Original ideas stem from the 1980s in the medical domain

Available formalisms for these models include logic, probabilistic models and neural networks

Our approaches use probabilistic graphical models, such as Bayesian/Markov Networks

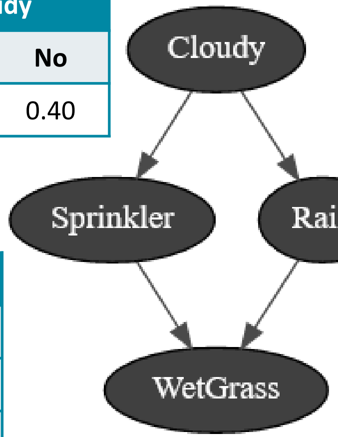


Bayesian networks

A Bayesian Network (BN) represents a set of variables and their conditional dependencies

Conditional dependencies are given by conditional probability tables (CPTs)

Cloudy	
Yes	No
0.60	0.40



	Rain	
Cloudy	Yes	No
Yes	0.70	0.30
No	0.10	0.90

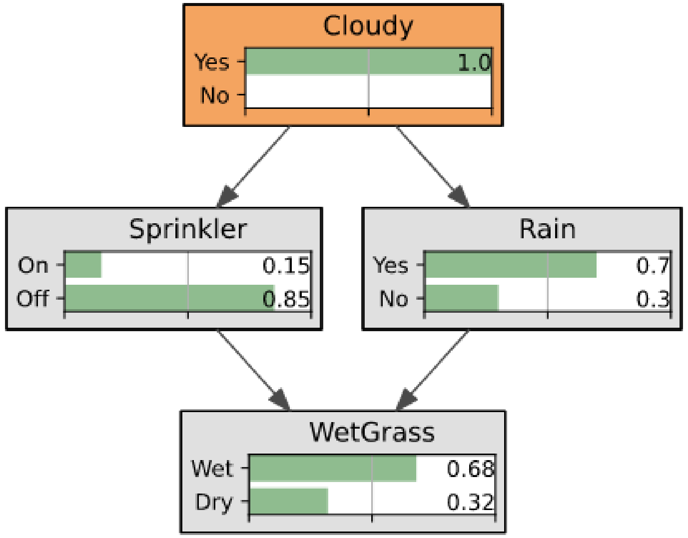
	Sprinkler	
Cloudy	On	Off
Yes	0.15	0.85
No	0.50	0.50

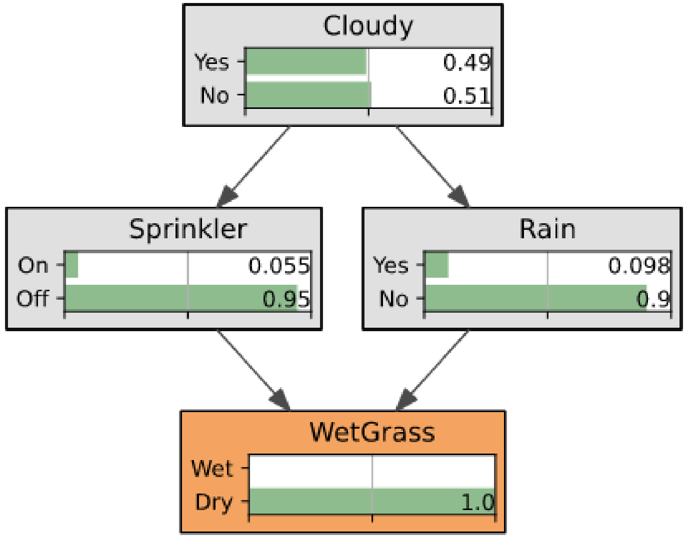
		WetGrass	
Rain	Sprinkler	Wet	Dry
Yes	On	0.99	0.01
	Off	0.90	0.10
No	On	0.90	0.10
	Off	0.00	1.00

Computing diagnoses

When inserting evidence, the posterior probabilities will be recomputed

Evidence can be either something you know or an assumption





Model-Based Diagnostics for High-Tech Equipment

High-tech equipment contains 1000s of components and observables

Challenging to create a diagnostic model at this scale

How and where to get the required information?

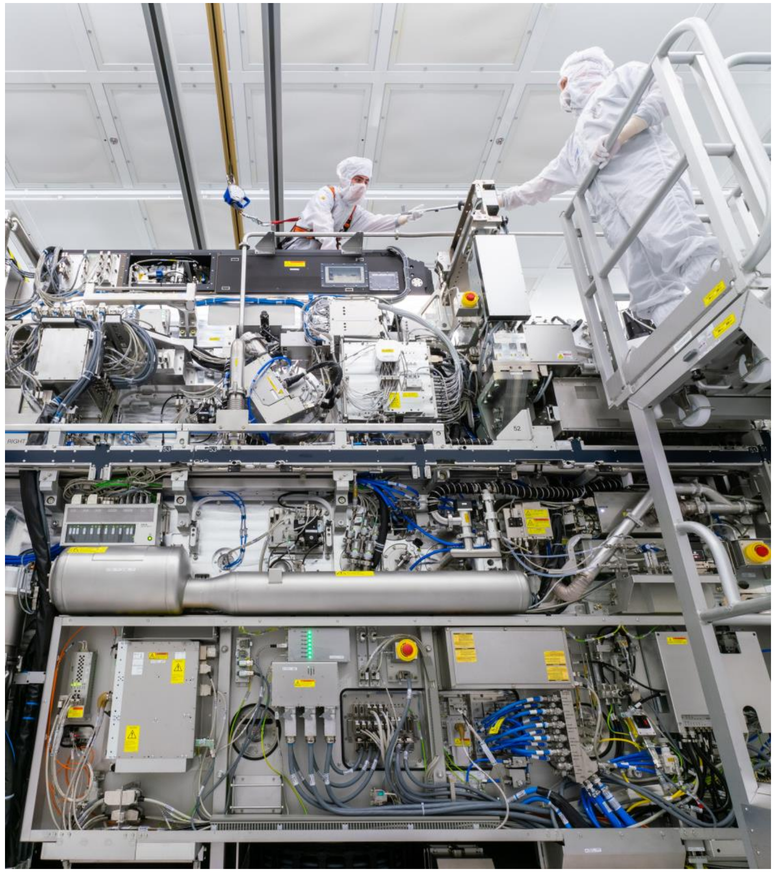
Probabilistic models may be learnt from data

This requires a huge amount of data, which is not always available

If insufficient data is available, experts should make the models

Few experts on probabilistic modelling

Why not try to leverage already available structured information?



Model-Based Systems Engineering for diagnostics

High-tech industry is gradually adopting model-based approaches for several reasons

- Requirement management, unified language, code generation, configuration management, virtual prototyping, …

Capella is one of the tools being used for this transition

Many of the ingredients needed for diagnostics are present in a Capella model

- Functional decomposition, hardware decomposition
- Functional dependencies
- Functional deployment on hardware

Let’s try to tap into this body of knowledge to create diagnostic models!

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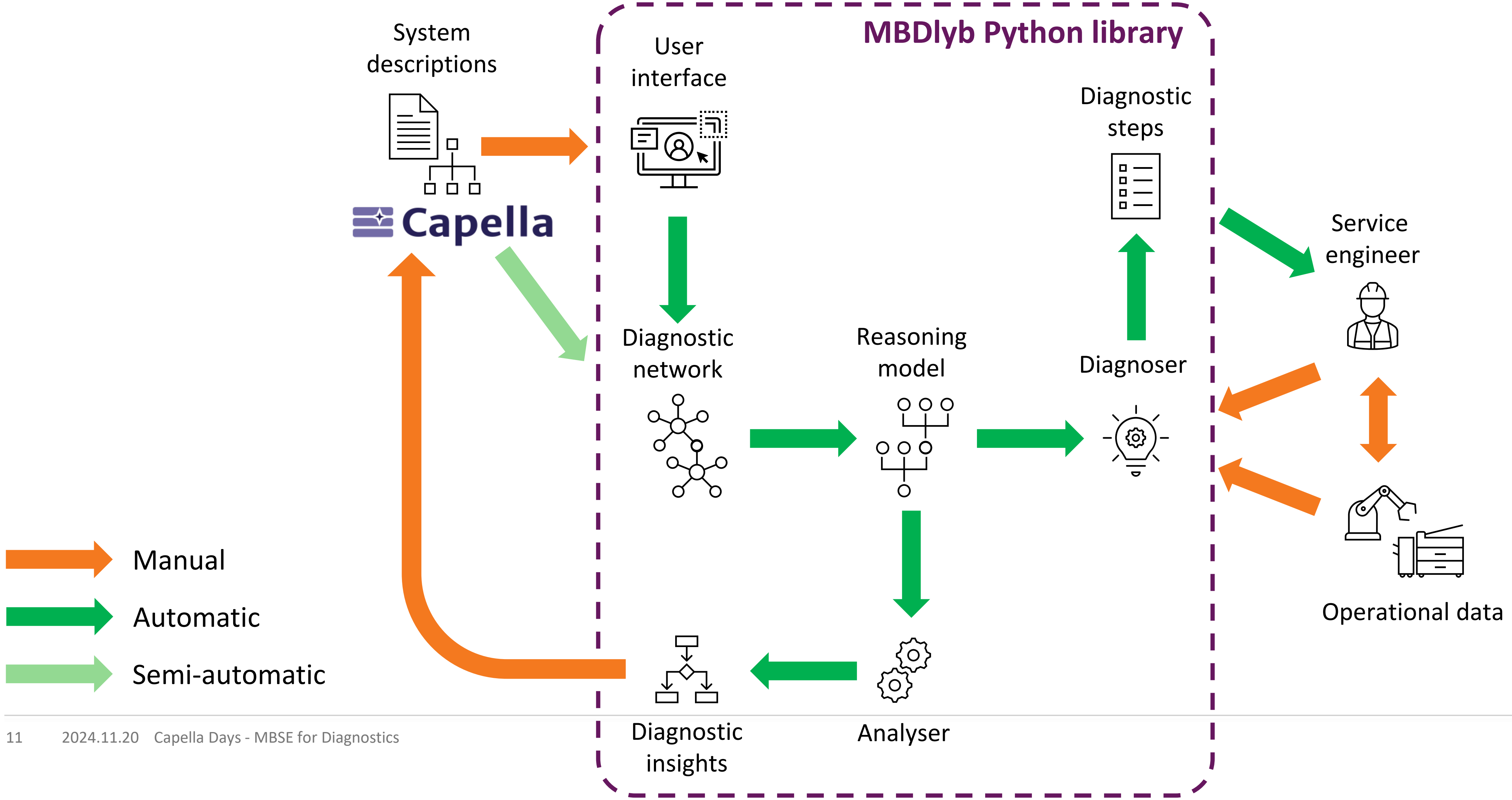
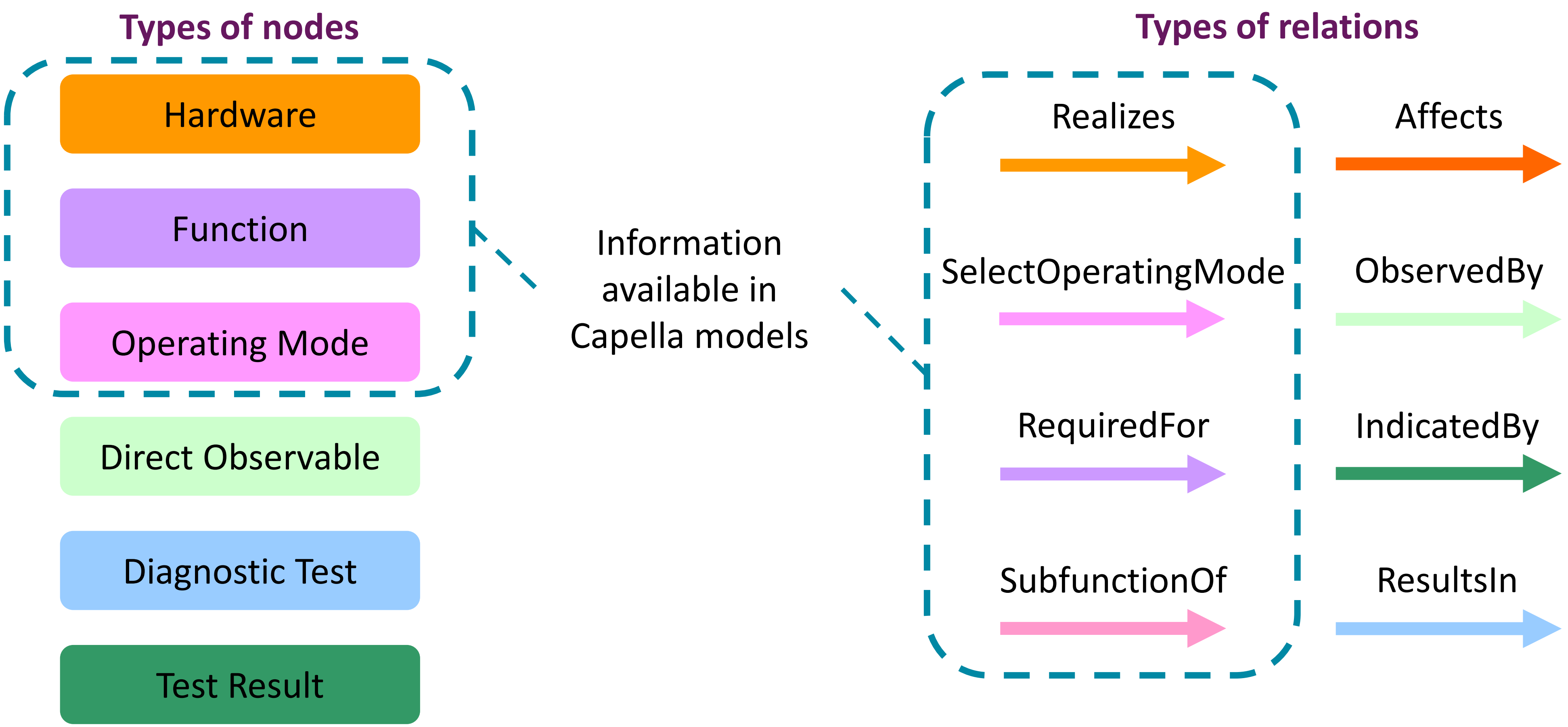
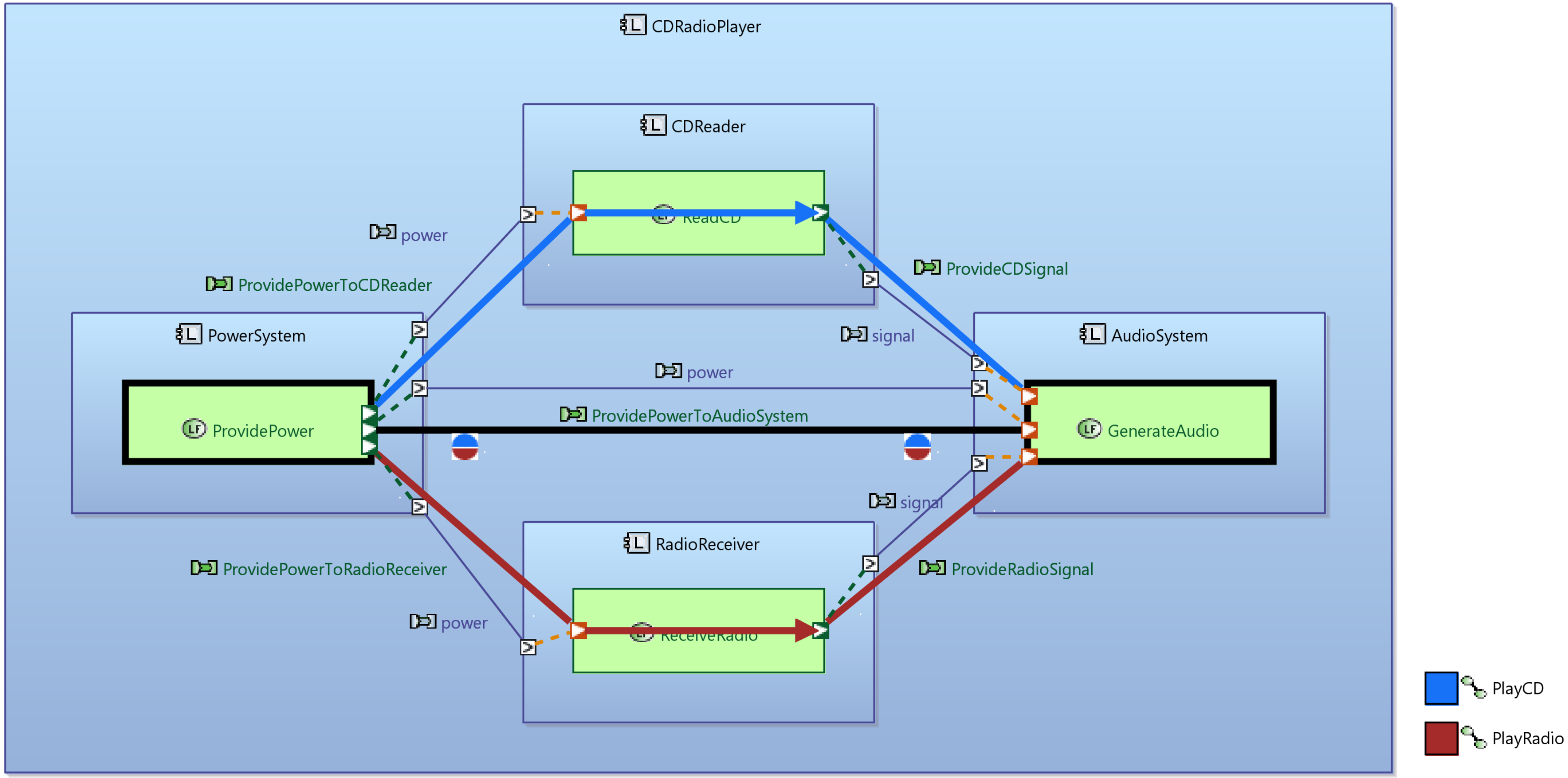
Methodology architecture



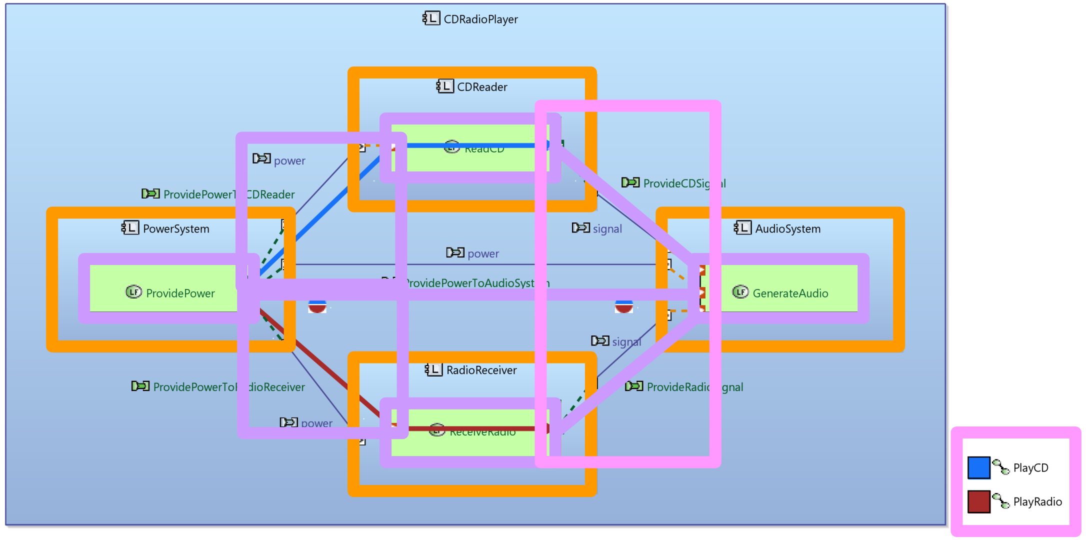
Diagnostic network's ontology

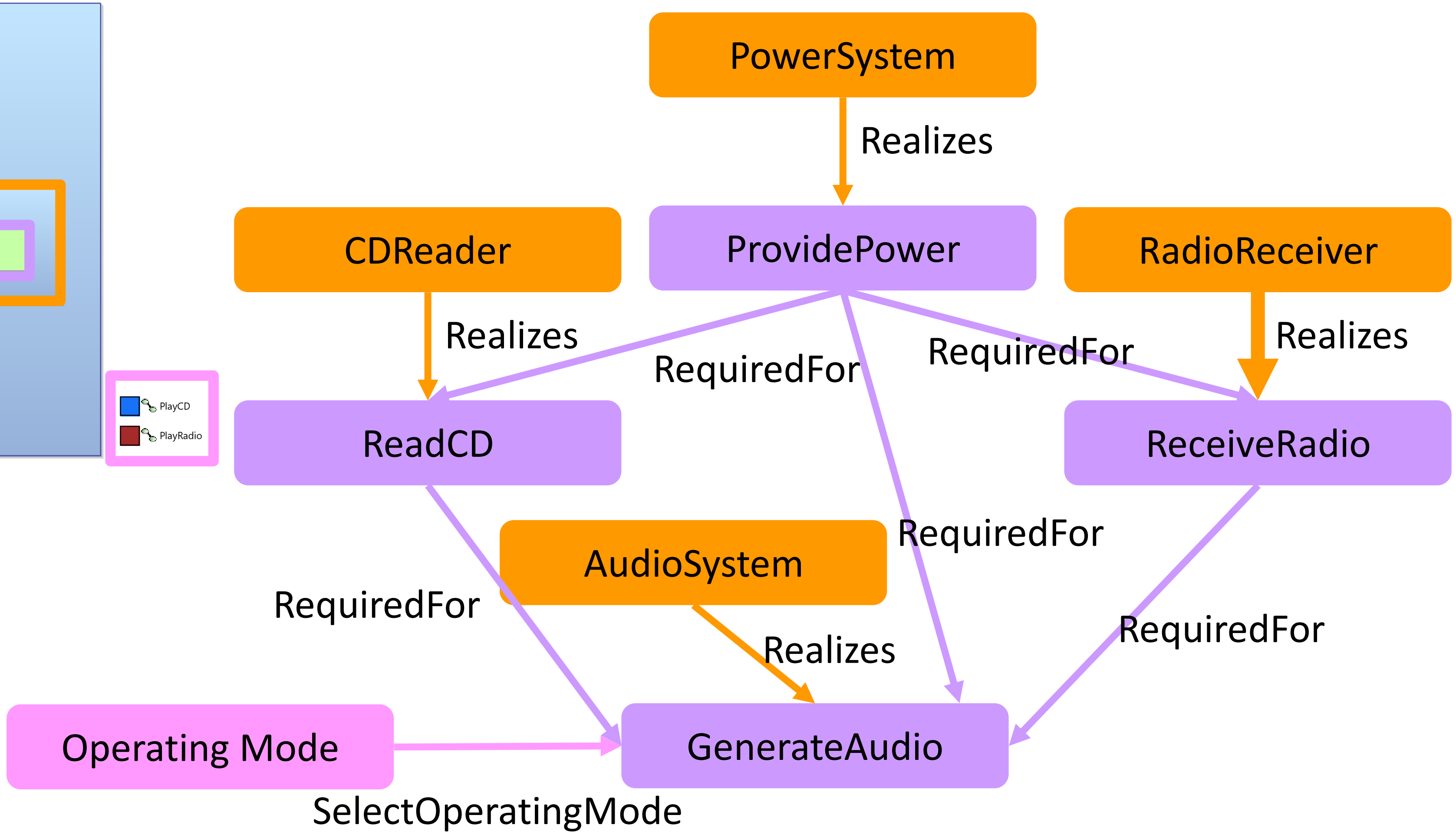


Transforming a simple CD-radio player



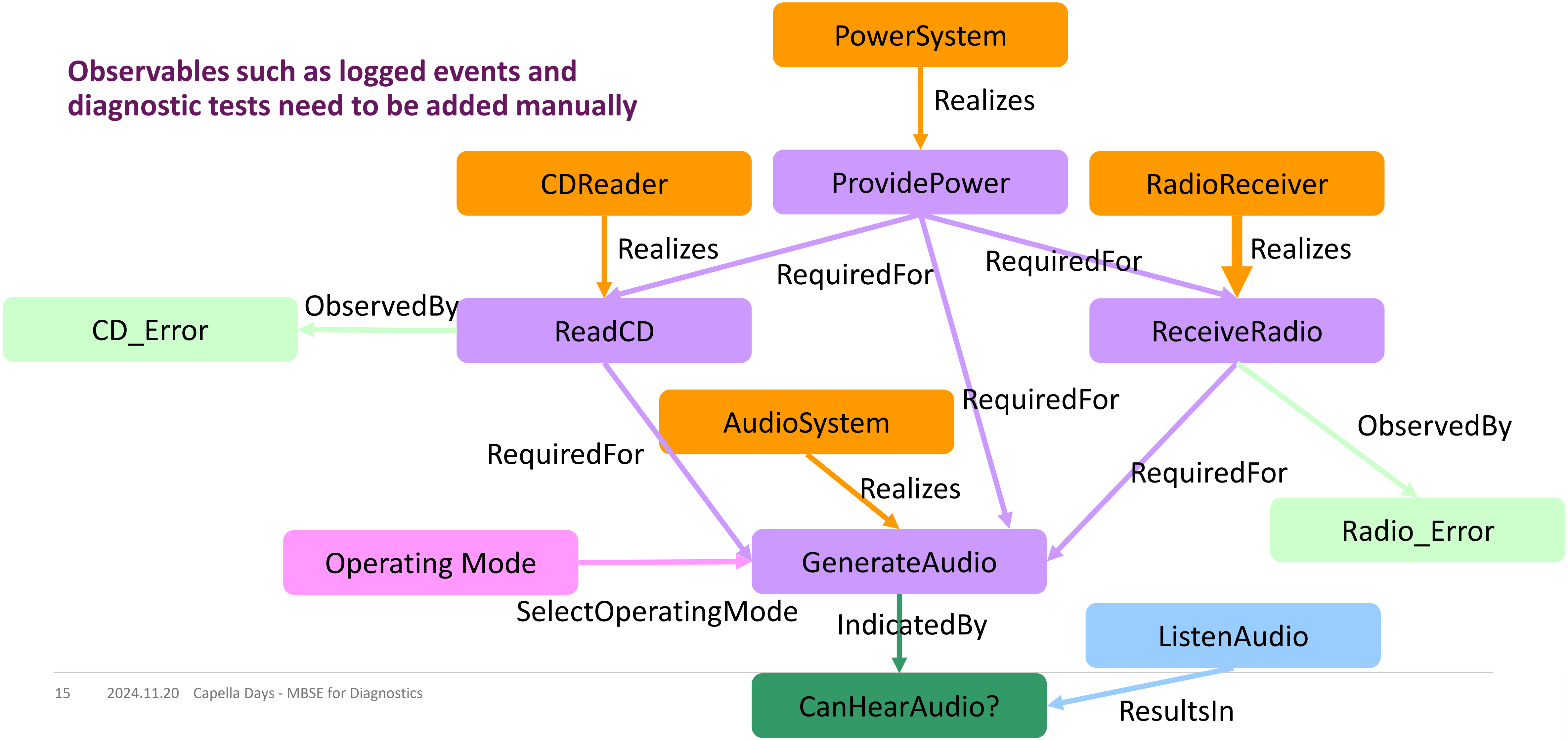
Transforming a simple CD-radio player



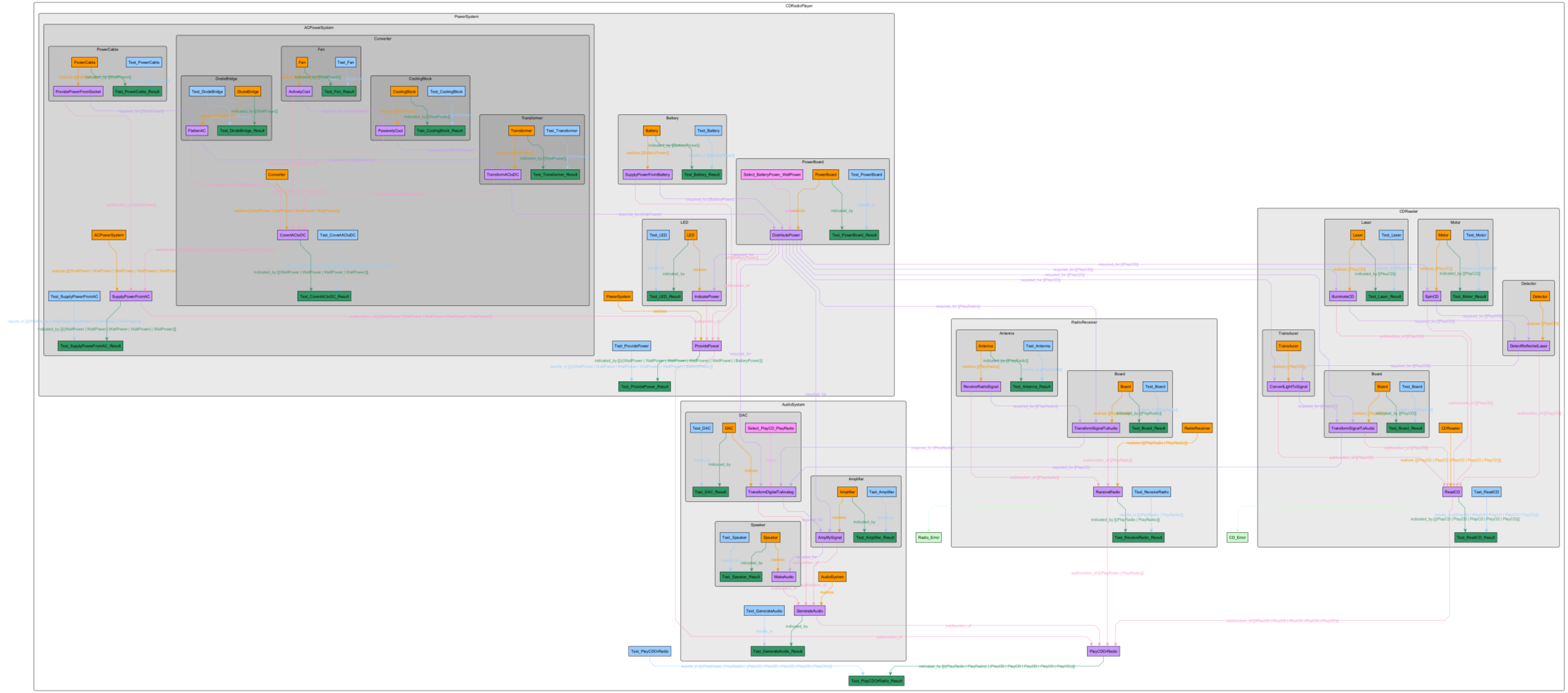


Adding observables

Observables such as logged events and diagnostic tests need to be added manually



Final CD-radio player model



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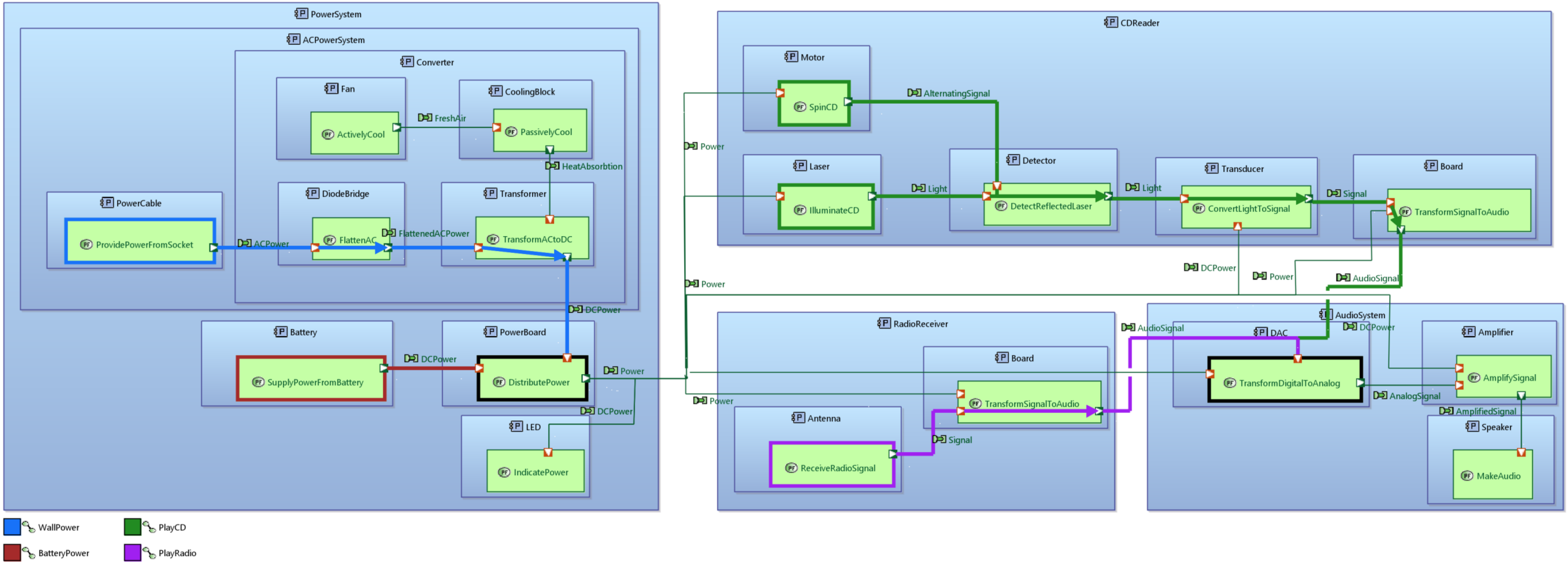
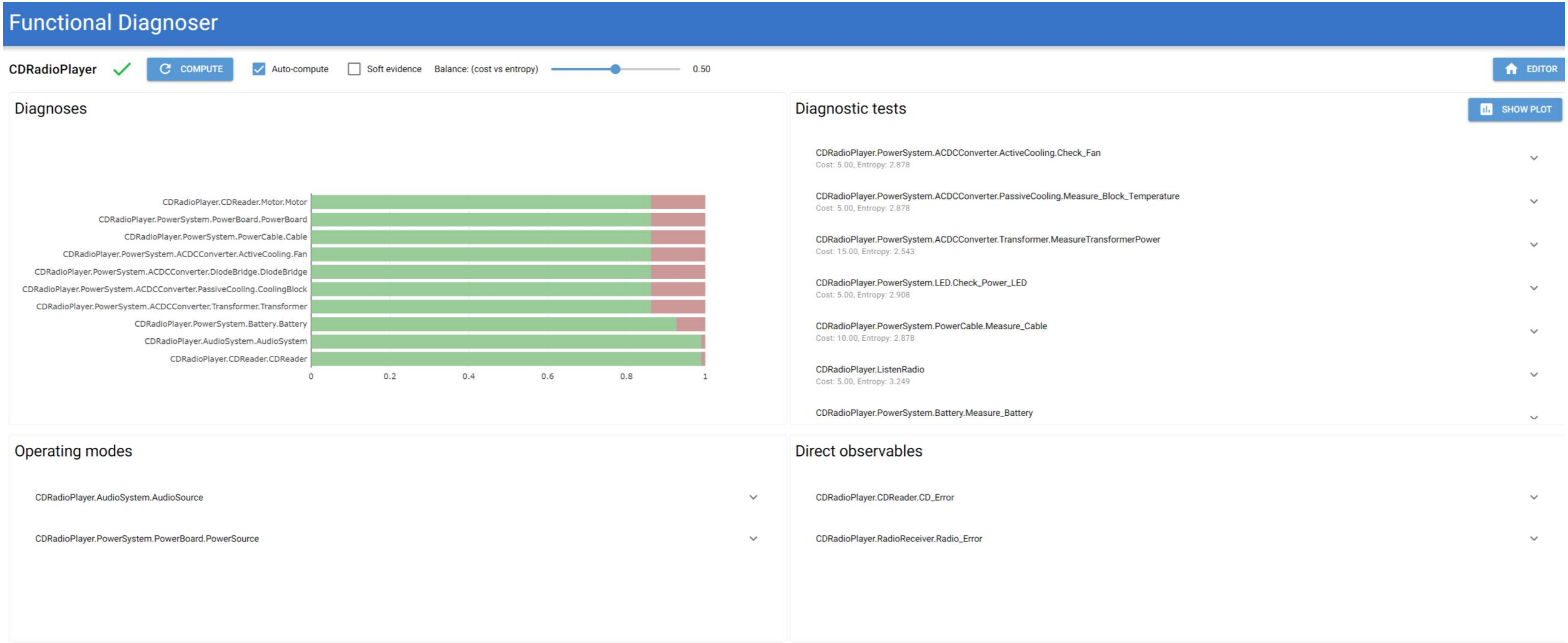
CDRadioPlayer: physical architecture



Demo


Functional Diagnoser
CDRadioPlayer
COMPUTE
Auto-compute
Soft evidence
Balance: (cost vs entropy)
0.50
EDITOR
Diagnoses
CDRadioPlayer.CDReader.Motor.Motor
CDRadioPlayer.PowerSystem.PowerBoard.PowerBoard
CDRadioPlayer.PowerSystem.PowerCable.Cable
CDRadioPlayer.PowerSystem.ACDCConverter.ActiveCooling.Fan
CDRadioPlayer.PowerSystem.ACDCConverter.DiodeBridge.DiodeBridge
CDRadioPlayer.PowerSystem.ACDCConverter.PassiveCooling.CoolingBlock
CDRadioPlayer.PowerSystem.ACDCConverter.Transformer.Transformer
CDRadioPlayer.PowerSystem.Battery.Battery
CDRadioPlayer.AudioSystem.AudioSystem
CDRadioPlayer.CDReader.CDReader
0
0.2
0.4
0.6
0.8
1
Diagnostic tests
SHOW PLOT
CDRadioPlayer.PowerSystem.ACDCConverter.ActiveCooling.Check_Fan
Cost: 5.00, Entropy: 2.878
CDRadioPlayer.PowerSystem.ACDCConverter.PassiveCooling.Measure_Block_Temperature
Cost: 5.00, Entropy: 2.878
CDRadioPlayer.PowerSystem.ACDCConverter.Transformer.MeasureTransformerPower
Cost: 15.00, Entropy: 2.543
CDRadioPlayer.PowerSystem.LED.Check_Power_LED
Cost: 5.00, Entropy: 2.908
CDRadioPlayer.PowerSystem.PowerCable.Measure_Cable
Cost: 10.00, Entropy: 2.878
CDRadioPlayer.ListenRadio
Cost: 5.00, Entropy: 3.249
CDRadioPlayer.PowerSystem.Battery.Measure_Battery
Operating modes
CDRadioPlayer.AudioSystem.AudioSource
CDRadioPlayer.PowerSystem.PowerBoard.PowerSource
Direct observables
CDRadioPlayer.CDReader.CD_Error
CDRadioPlayer.RadioReceiver.Radio_Error

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Conclusions and future work

Successfully conducted three case studies with our partners

- One model could find satisfactory root cause on all case studies
- Positive reactions on given demos
- Concerns about model creation

Shown approach is promising for both operational diagnostics and design for diagnostics

- MBSE models – like Capella models – provide a lot of information needed for diagnostics

Where and how to combine the observability information?

- We are open to suggestions or experiences!

Need to build up experience with more MBSE models ‘in the wild’

- To what extent do those models adhere to our assumptions?

Thanks for your attention!

Are there any remaining questions?

Looking for more information? Download our report here.

Or reach out to me: thomas.nagele@tno.nl

The research is carried out as part of the SD2Act program under the responsibility of TNO-ESI in cooperation with ASML. The research activities are co-funded by Holland High Tech | TKI HSTM via the PPP Innovation Scheme (PPP-I) for public-private partnerships.

TNO ESI

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