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Tech Note: Smart Home – Modeling the Internet-of-Things with SysML

Part 5 Design, Simulation and System Architecture

Contents

Abstract

This is the fifth and final in a series of technical notes describing the application of Model-Based Systems Engineering (MBSE) and Model-Based Engineering (MBE) to the specification, design, procurement and evaluation of an Internet-of-Things (IoT) system. The concept of an "Internet-of-Tools" is illustrated with two examples. In the first, the SmartHome SysML model is linked with a CAD model to share room volume data for coupled design and analysis. In the second, the SysML model is used to generate a Simulink block structure for higher fidelity simulation, with persistent connections between the models allowing for ongoing comparison and harmonization.

Introduction

The normal context for an IoT engineer, like any engineer, is a diverse, multi-vendor tool environment where system data is stored and managed in a variety of models and repositories. The engineer must be able to find and access the necessary data wherever it sits. This reality is driving the adoption of Model-Based Engineering (MBE), which is not just the use of models in engineering. It is an extension of MBSE where the creation, management and use of connections between models in different tools takes the “single source of truth” concept to a higher level.

In previous TechNotes in this series, we have made use of MBE techniques, employing Syndeia to access a database for component catalog data (Part 2) and to generate a PLM bill-of-materials from SysML (Part 3). In this final part, we will look at two new use cases:

- Using CAD data from an architectural model of the home to estimate HVAC energy use
- Mirroring the SysML IBD of the SmartHome with an equivalent Simulink block structure for higher fidelity simulation

Our objective, as previously, is to expand the thinking about IoT engineering. It is not a narrow discipline with a specialized toolset, but an extension of our normal engineering processes to take advantage of new smart, connected devices. It may be that the Internet-of-Things requires a second IoT, the Internet-of-Tools, the network of smart, interconnected models shown in Figure 1 that accomplish things no individual tool can carry out alone.

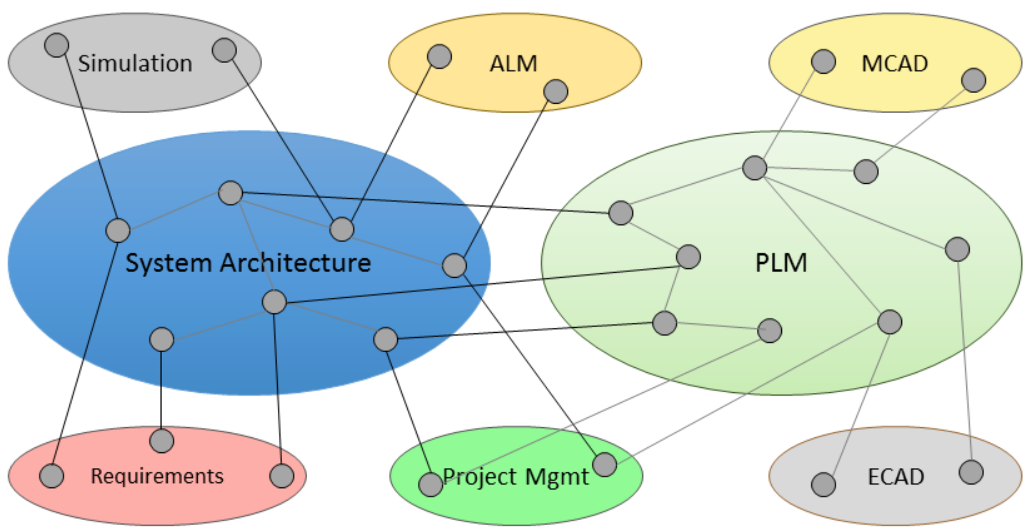

Figure 1 Graph network connecting models across tool boundaries in Model-Based Engineering

Connecting the System Architecture Model to CAD Models

In earlier parts of this series, we entered the heating and cooling efficiency values for each room as static values, determined exogenously by unknown means. They presumably are affected by the volume of the room, as well as other factors like the external wall exposure. Consider the power of a model where the system model is linked to an architectural CAD model, where the room dimensions are parameters of the design. Through tools like Syndeia, changes in dimension can update the parametric calculations in SysML and alternative designs can be readily evaluated from multiple perspectives.

As a simple example, we have created a CAD design of the 4 Room Home in Siemens NX, as shown in Figure 5. While NX is not primarily an architectural CAD tool, it serves to illustrate the possible use cases. The model has four cuboids as part features modeling the room.

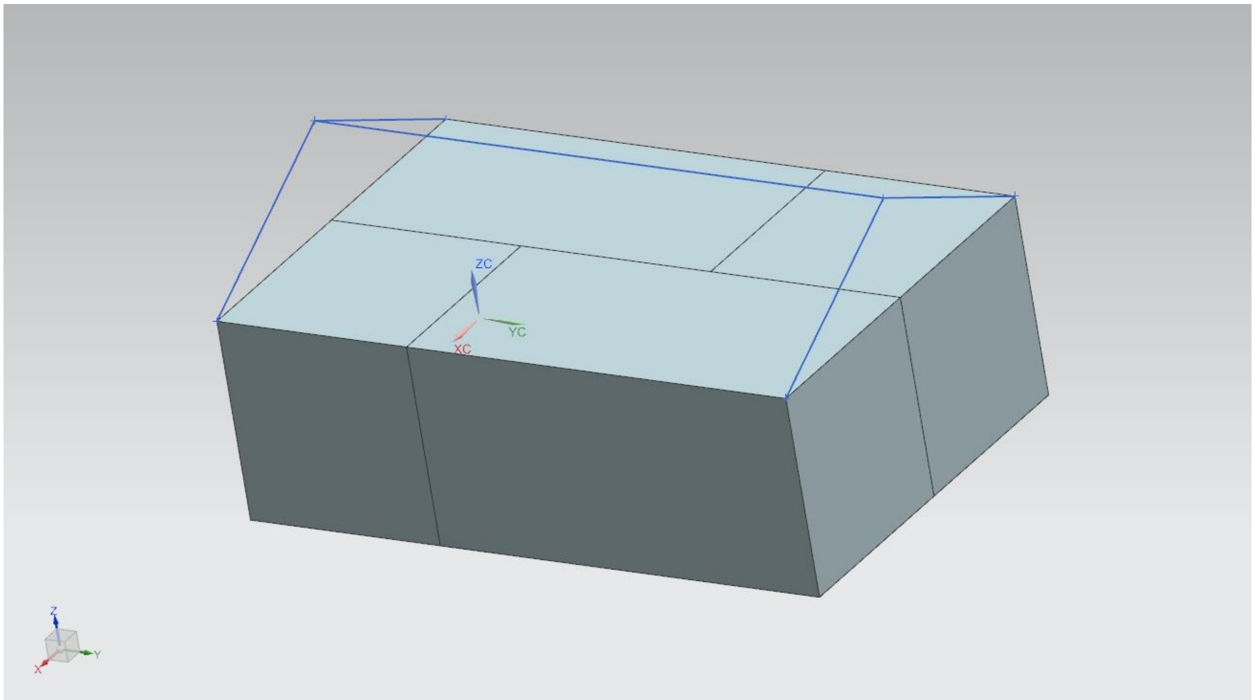

Figure 2 NX CAD model of the 4 Room Home

Using Syndeia, we drag the NX model into the existing SysML model. This generates a new block structure, shown on the right side of Figure 3, where the default values of the Length, Width and Height value properties reflect the room dimensions from the CAD model. In this BDD, we have mapped the Zones from the existing SysML model to the Rooms from the CAD model. The generalized Zone concept originally just represented a set of linked HVAC, security and audio components. Now we have specialized it to also represent the architectural divisions.

Each specialized Zone references a specific CAD part feature and uses those dimensions to calculate the room volume (Figure 4). The existing parametric models for energy use are slightly modified; the zone heating and cooling energy use parameters now include a scaling factor based on room volume. As room volume increases, energy use increases proportionately.

A simple path now exists to evaluate the impact of design changes on energy use. We can revise the CAD design to expand the bathroom dimensions, as shown in Figure 5 (who doesn't want a larger master bath?) and update the SysML model through Syndeia. We generate a second instance and compare the analyses using ParaMagic (Figure 6 and Figure 7). Under otherwise identical conditions, the revised design only leads to about a one percent increase in energy use. Of course, we may test the sensitivity of that conclusion to thermostat settings, outside temperature and other factors in the model.

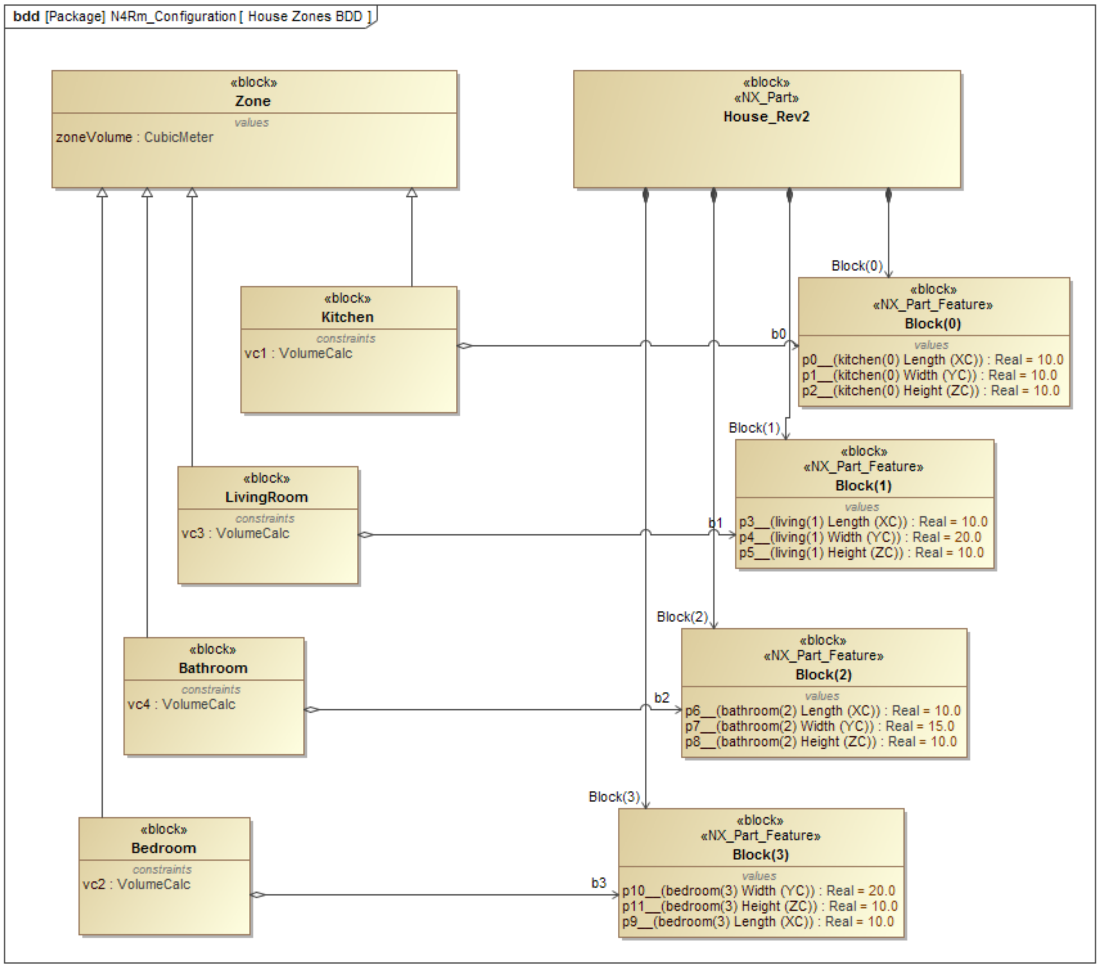

Figure 3 SysML Block Definition Diagram mapping rooms from CAD model to zones in system model

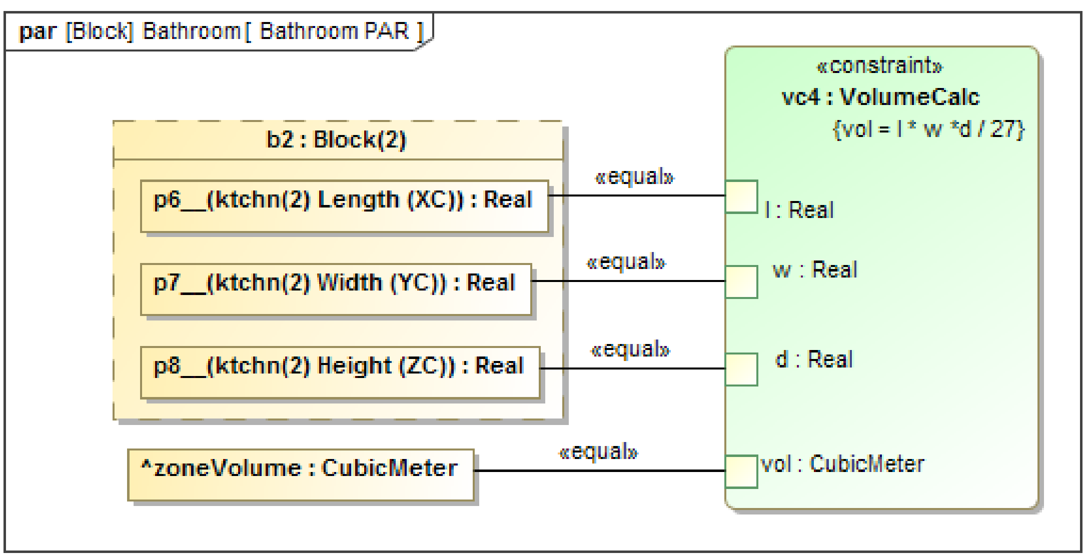

Figure 4 Parametric diagram for volume calculation

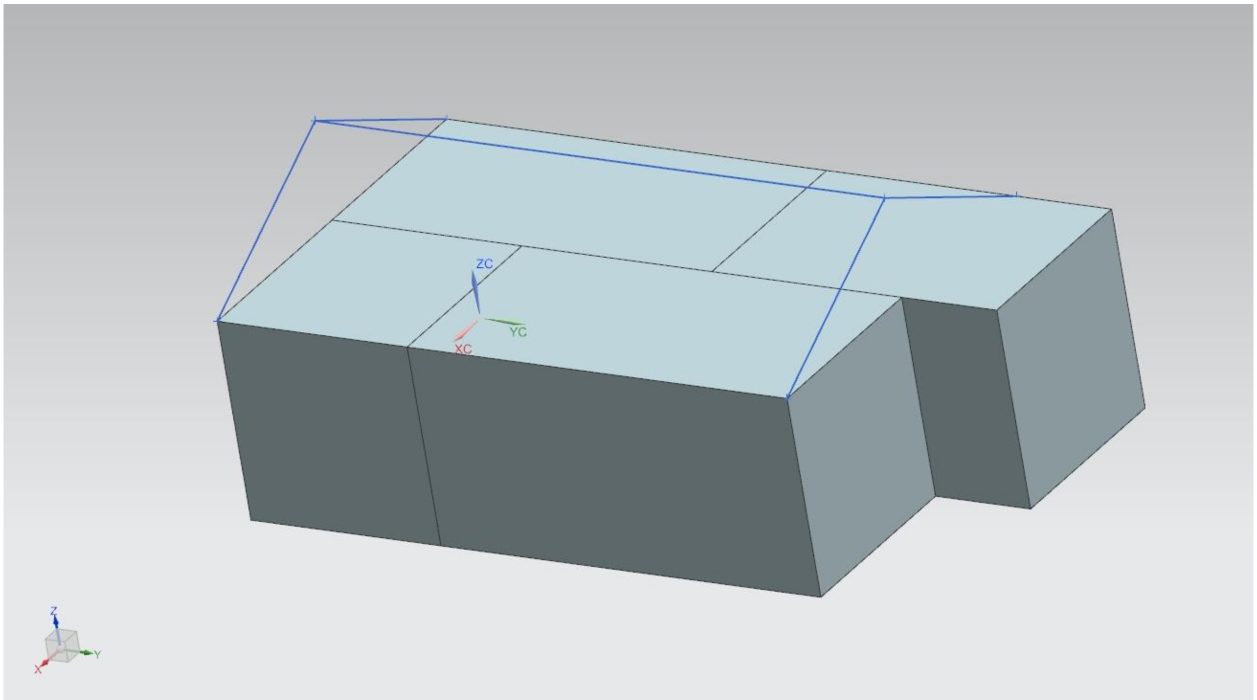

Figure 5 Revised Home CAD model with expanded bathroom

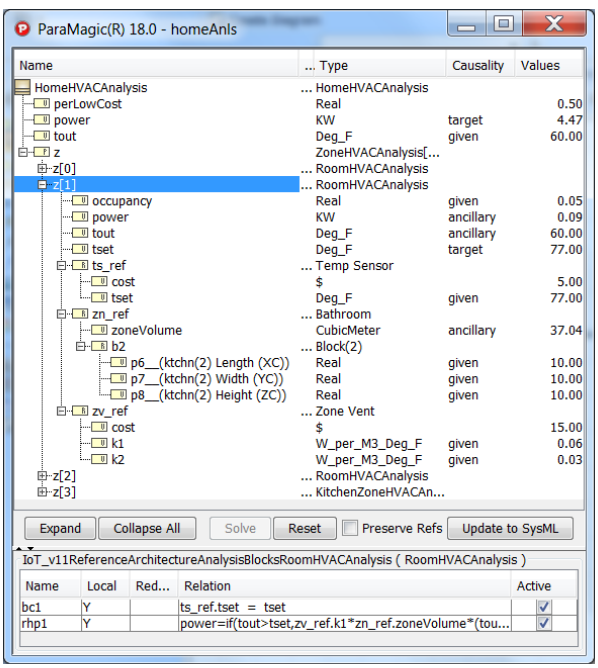

Figure 6 Energy Use Analysis, original home

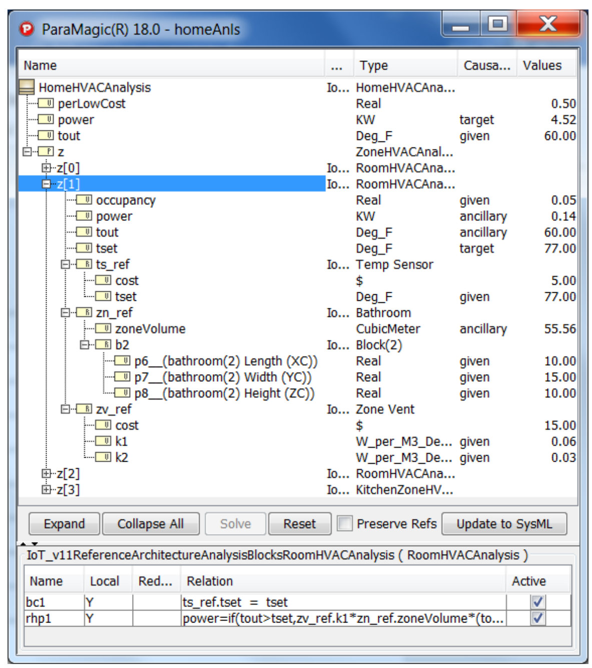

Figure 7 Energy Use Analysis, expanded bathroom

Using System Model to Generate Simulation Models

Our parametric model for energy use could certainly be described as simple and static. Higher fidelity simulation would take into account dynamic effects in heating and cooling, occupancy detection and other factors, and would preferably be done in specialized simulation tools. The difficulty arises in making sure the SysML and simulation models are consistent with each other, particularly as they evolve separately.

Using Syndeia, we can generate a Simulink model from a SysML model expressed in IBD or Activity diagrams, and the elements of the two models remained linked through the Syndeia-managed graph. This allows comparison between the two models at any point to identify differences in the block structure.

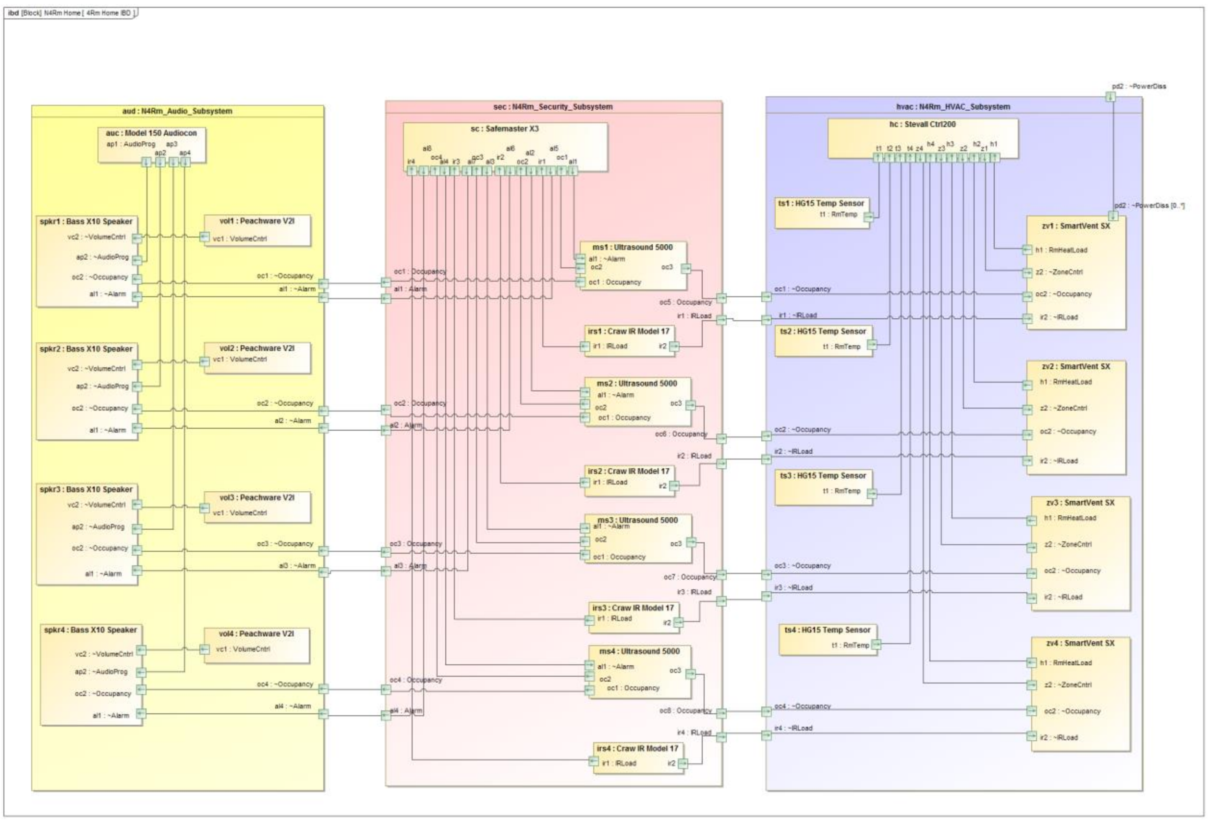

Figure 8 SysML 4 Room Home Internal Block Diagram

Despite superficial similarities, the two tools have significant differences in meta-models. This requires some changes to the SysML model in Figure 8 relative to its appearance in Part 3. For example, each proxy port can only support one inbound connector for the SysML model to map successfully to Simulink. However, if these guidelines are followed, the Simulink block structures in Figure 9, Figure 10 and Figure 11 can be generated in one step from the 4 Room configuration. The Simulink blocks are ready for the addition of the MATLAB code to support the new simulation.

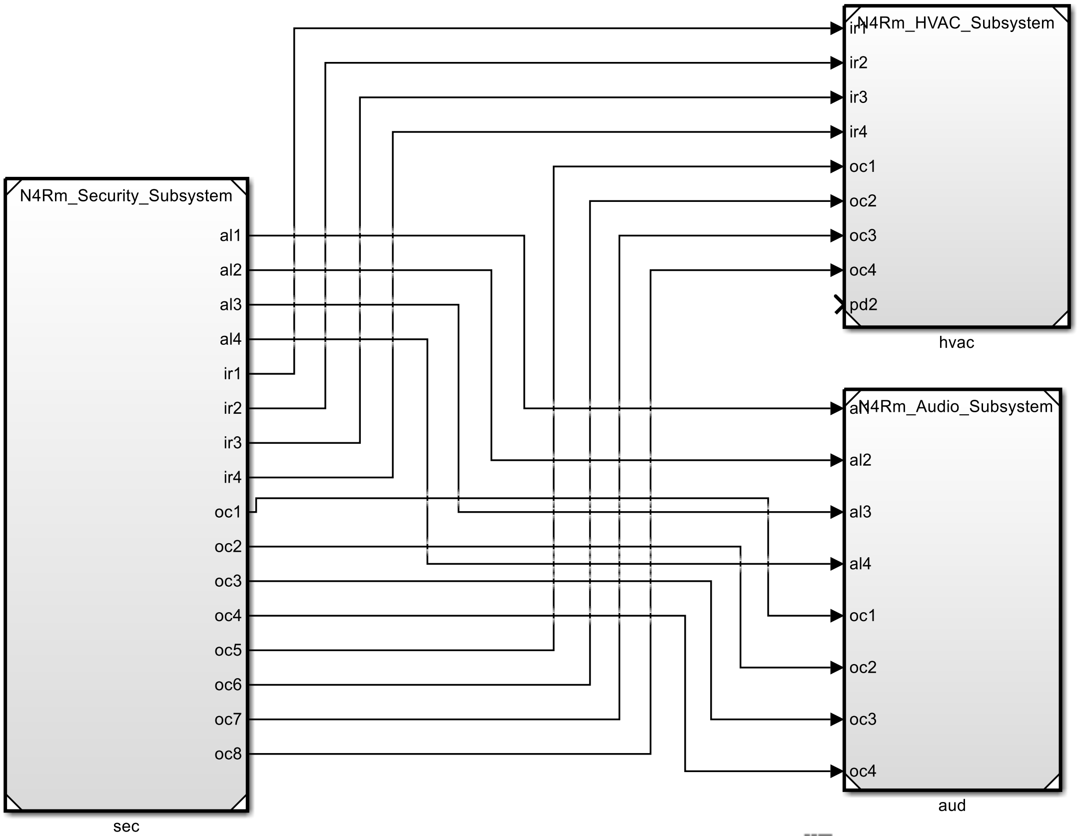

Figure 9 Simulink 4 Room Home Model (Top Level)

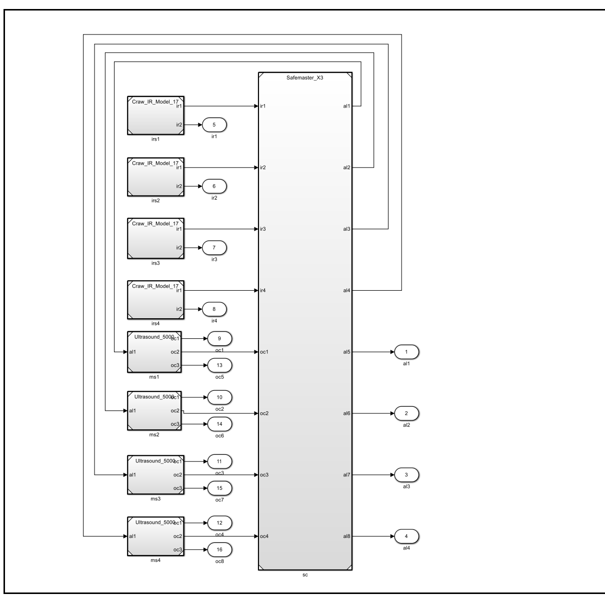

Figure 10 Simulink model, security subsystem

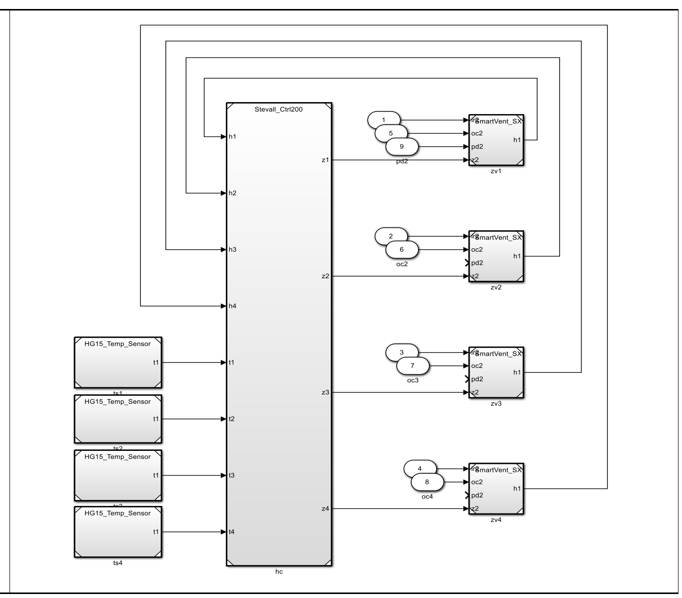

Figure 11 Simulink model, HVAC subsystem

Summary

As the IoT system development progresses, more and more specialized tools will enter the engineering process. The challenge becomes maintaining the central objective of a single, unified system model, a single source of truth from which project views and documentation can be generated and updated efficiently. In this part, we looked at two examples from the important domains of CAD and simulation. In the first, a CAD model was linked to structural blocks in the SysML model so that changes in the design can be transmitted to the SysML model and evaluated using existing SysML parametric analysis. In the second, the SysML model was used to generate a Simulink block structure, with a network of persistent connections that allow differencing and reconciliation as the models evolve.

In this series, we have attempted to show how SysML is an effective vehicle for IoT modeling and simulation, bringing the diverse perspectives of requirements, structure, behavior and parametrics into a common regime. In Parts 1-3, we used SysML to build a SmartHome model, then dropped it into a SmartGrid model in Part 4. We have also shown how new approaches to Model-Based Engineering allow those SysML models to be linked to databases, PLM, CAD and simulation tools to carry out important parts of the IoT engineering process. Fully realizing the benefits of an IoT-connected world will require equally connected tools and engineers engaged to new modes of systems engineering.

About the Author

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