

# Using Smart Devices for System-Level Management and Control in the Smart Grid



Student: Emre Can Kara, CEE, CMU

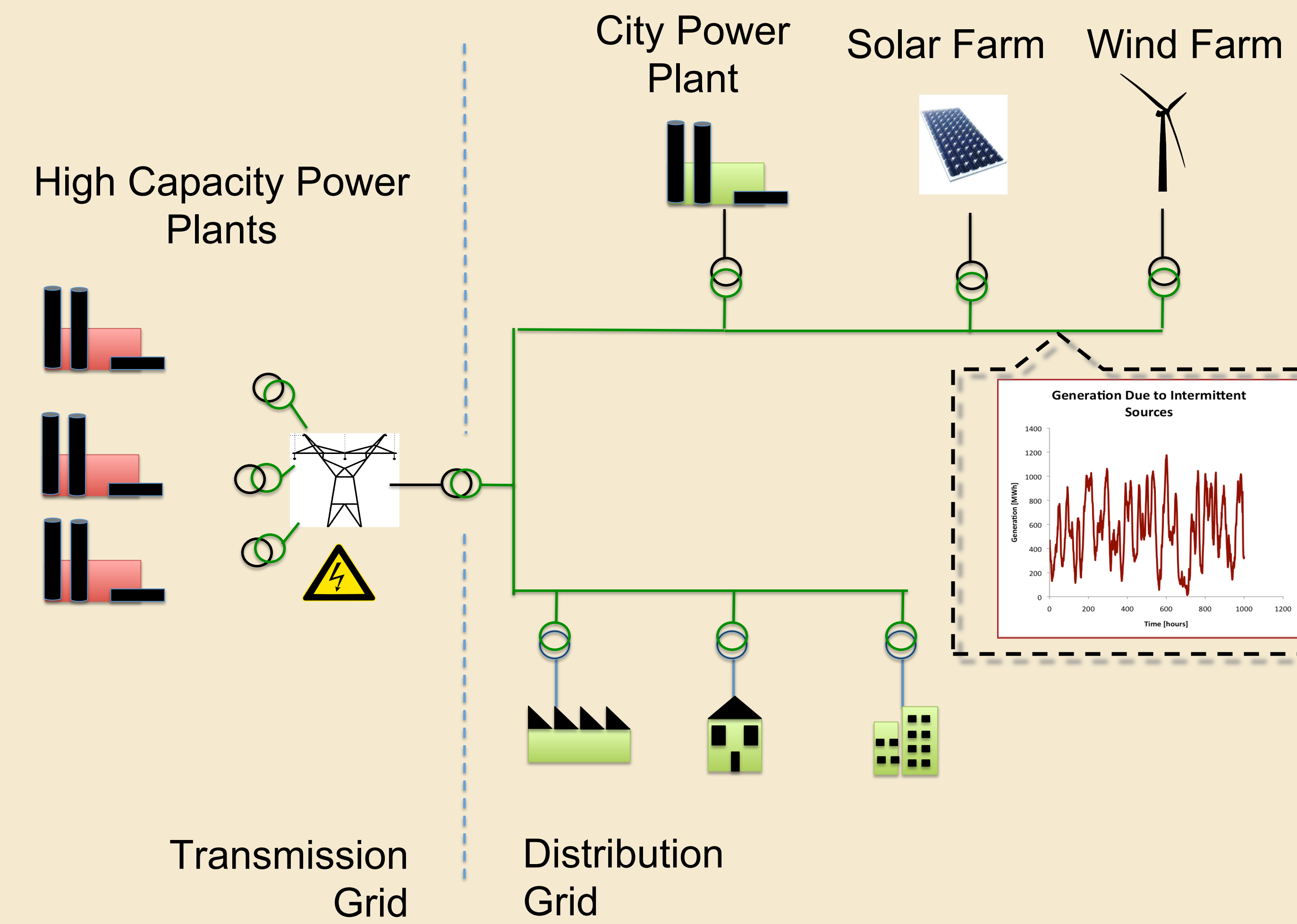
Advisors: Mario Bergés, CEE, CMU. Bruce Krogh, ECE, CMU. Soumya Kar, ECE, CMU.



## Problem Statement

Energy infrastructure is being rapidly populated with smart devices that can monitor and control individual end-use loads, opening the door for a wide variety of applications and a re-thinking of the traditional power distribution system. The typical use cases for these smart devices relate to the reduction of energy consumption through a number of mechanisms ranging from load shedding during peak demand hours (*demand response*), to occupancy-controlled heating, ventilation and air conditioning (HVAC) and lighting systems, to simply providing real-time energy consumption information to end-users in order to encourage more energy-efficient behavior. However, more dynamic mechanisms are possible through distributed fine-grained control of small loads, which is the focus of this research.

The main problem we seek to address in this project is how to leverage end-use electrical loads to provide ancillary services (particularly balancing generation to load through frequency regulation) in the power grid. In particular we would like to shed light on the system-level properties that can be influenced through coordinated (centralized or otherwise) control of a large collection of *smart* loads, where we use the term *smart* to denote their ability to react to measurements or signals.



## Research Questions

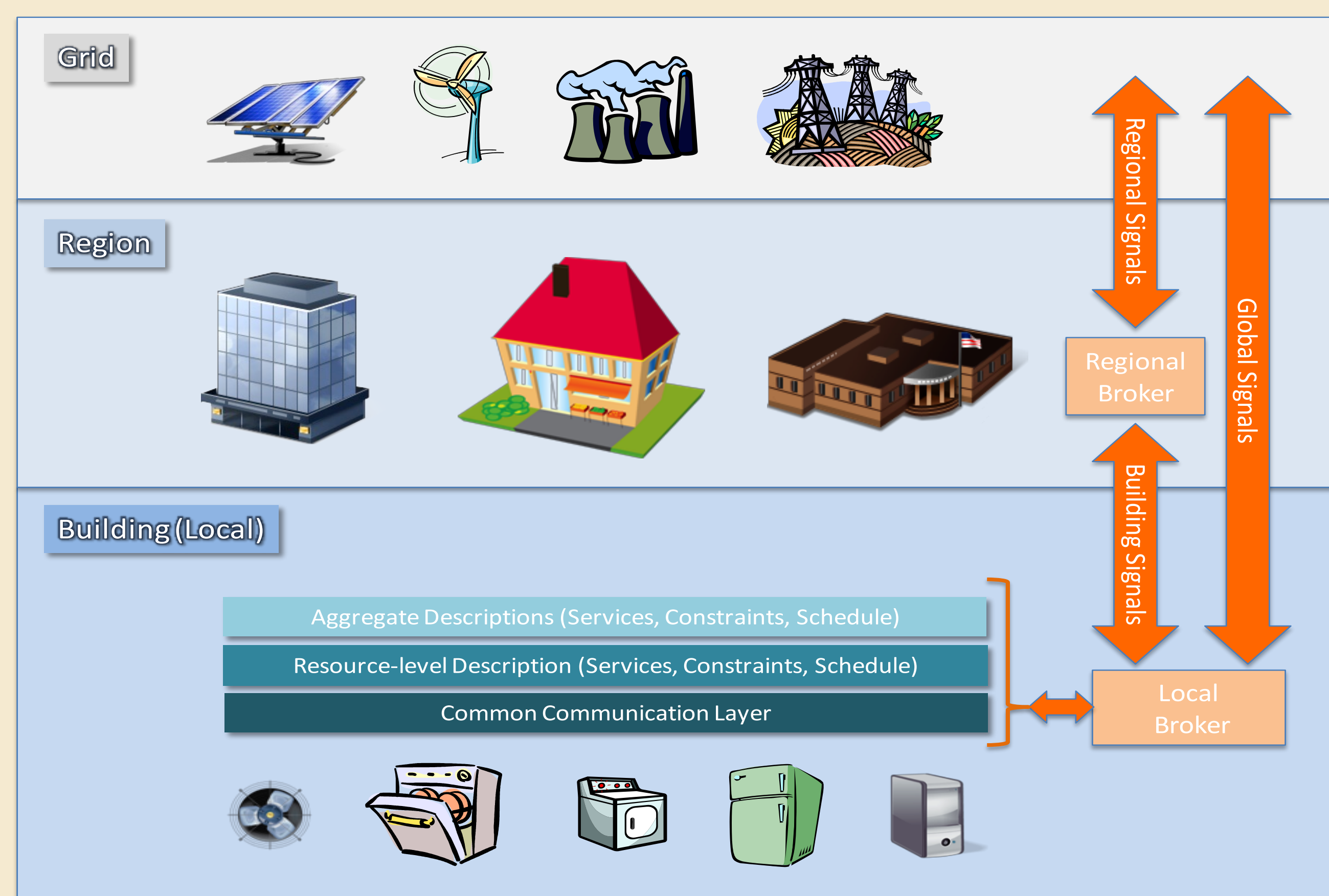
- What is the optimum control strategy for different types of appliances/ building types?
- What are desirable communication protocols for distinct combinations of control strategy and the appliance type?
- Can contextual information on buildings help develop better demand side management techniques?
- Can sensor fusion and machine learning techniques be used to develop solutions that leverage the existing infrastructure?

## Research Timeline

	Timeline		
	Year 1	Year 2	Year 3
Control Algorithm	Development of a local controller	Development of a centralized controller	Development of a distributed controller
Type of Load	Small TCLs*	Passive Loads, Small and Large TCLs	All Loads
Type of Facility	Laboratory, Residential	Commercial, Residential	Mixed
Number of Loads	Implementation: 10 <sup>1</sup> Simulation: 10 <sup>3</sup>	Implementation: 10 <sup>2</sup> Simulation: 10 <sup>4</sup>	Implementation: 10 <sup>2</sup> Simulation: 10 <sup>5</sup>

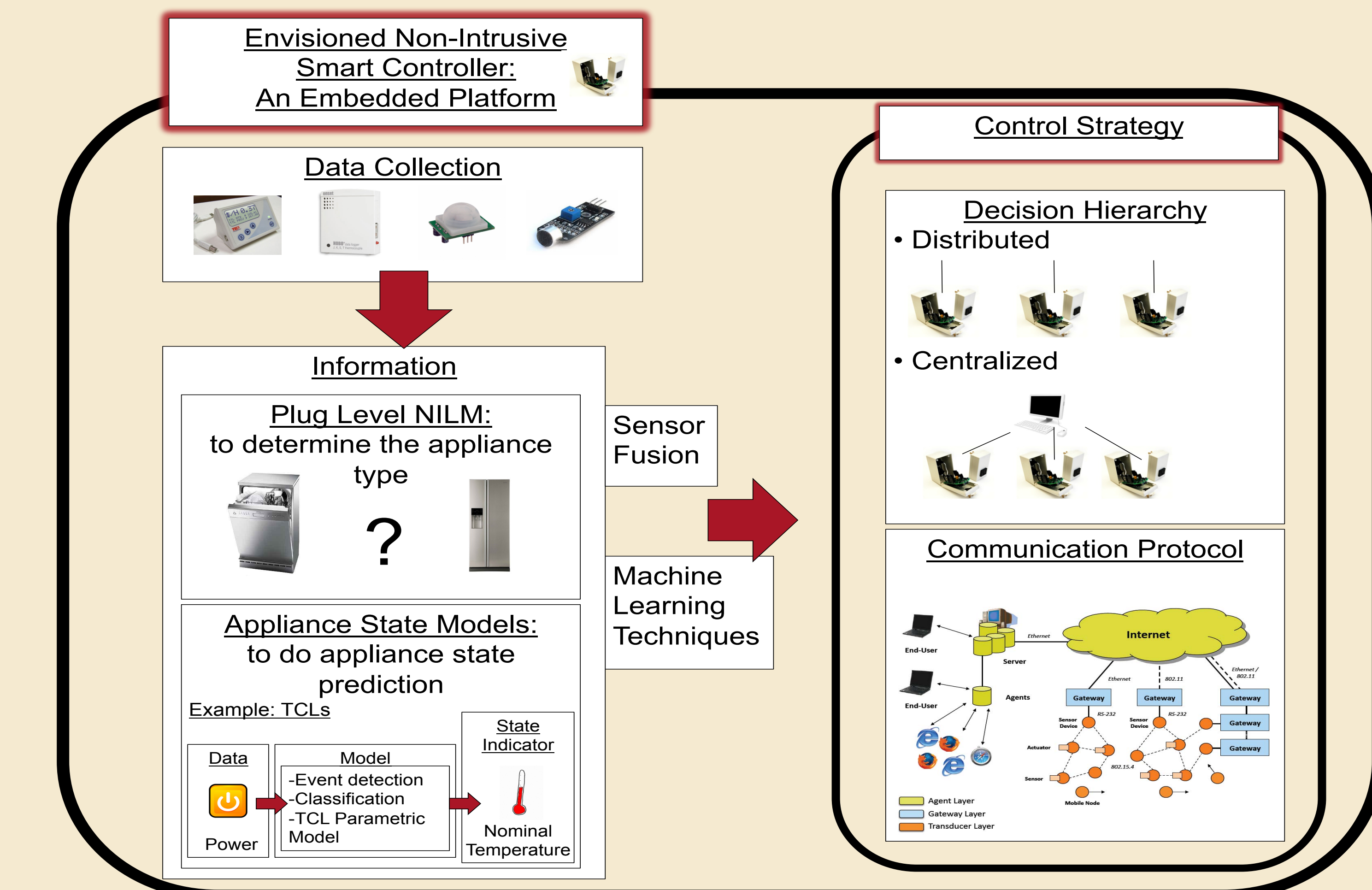
\*TCL: Thermostatically Controlled Loads

## Vision and Objectives

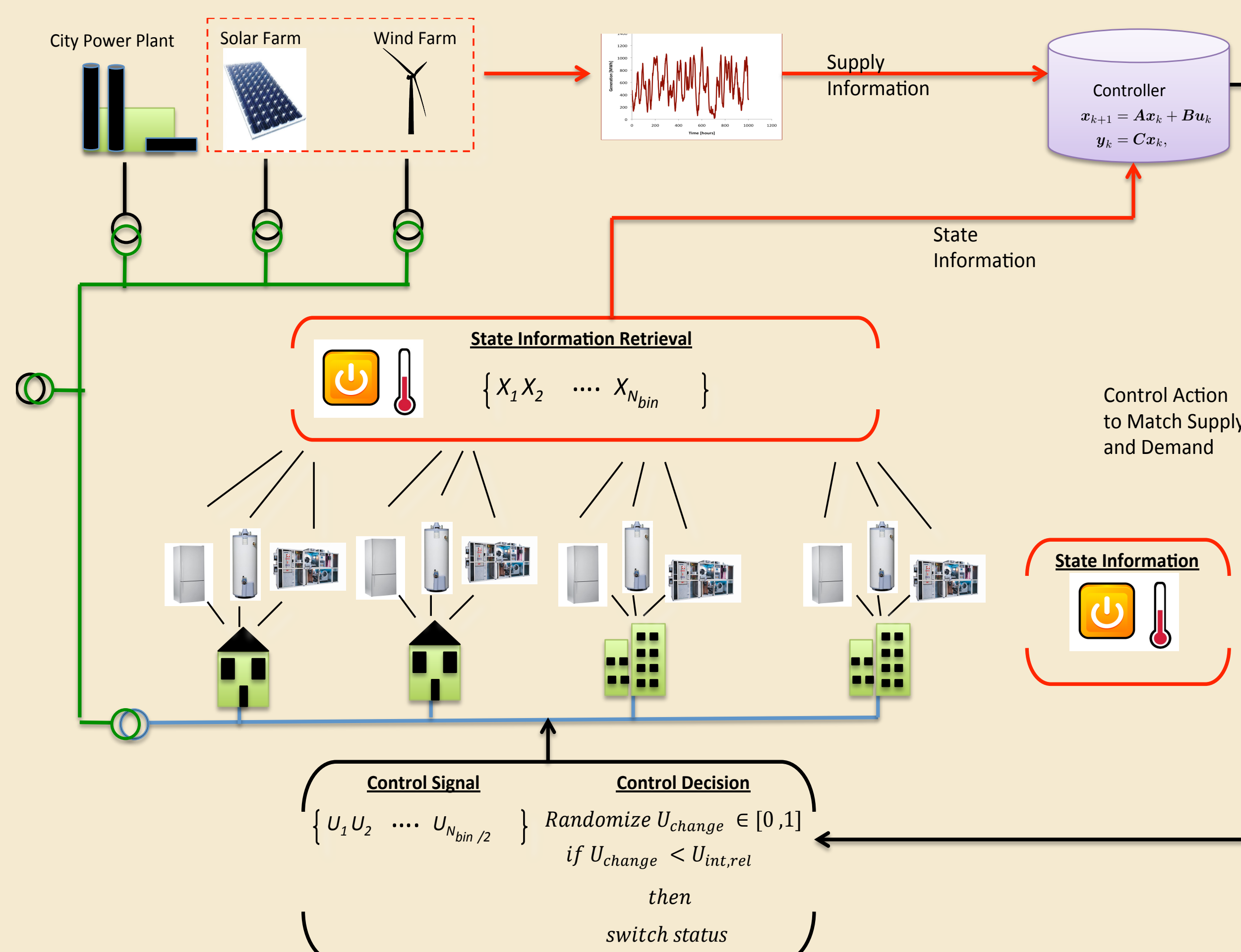


Our research method will involve a combination of theoretical analysis, simulations and real-life experiments to evaluate alternative methods for harnessing the coordinated responses of smart devices for system-level purposes. These methods will range from centralized strategies, where signals are introduced through the distribution system that trigger and coordinate the responses of individual devices, to highly distributed strategies, where each device is making decisions based entirely on local information, but these decisions are implemented so that the emergent behavior is the desired system-level control action.

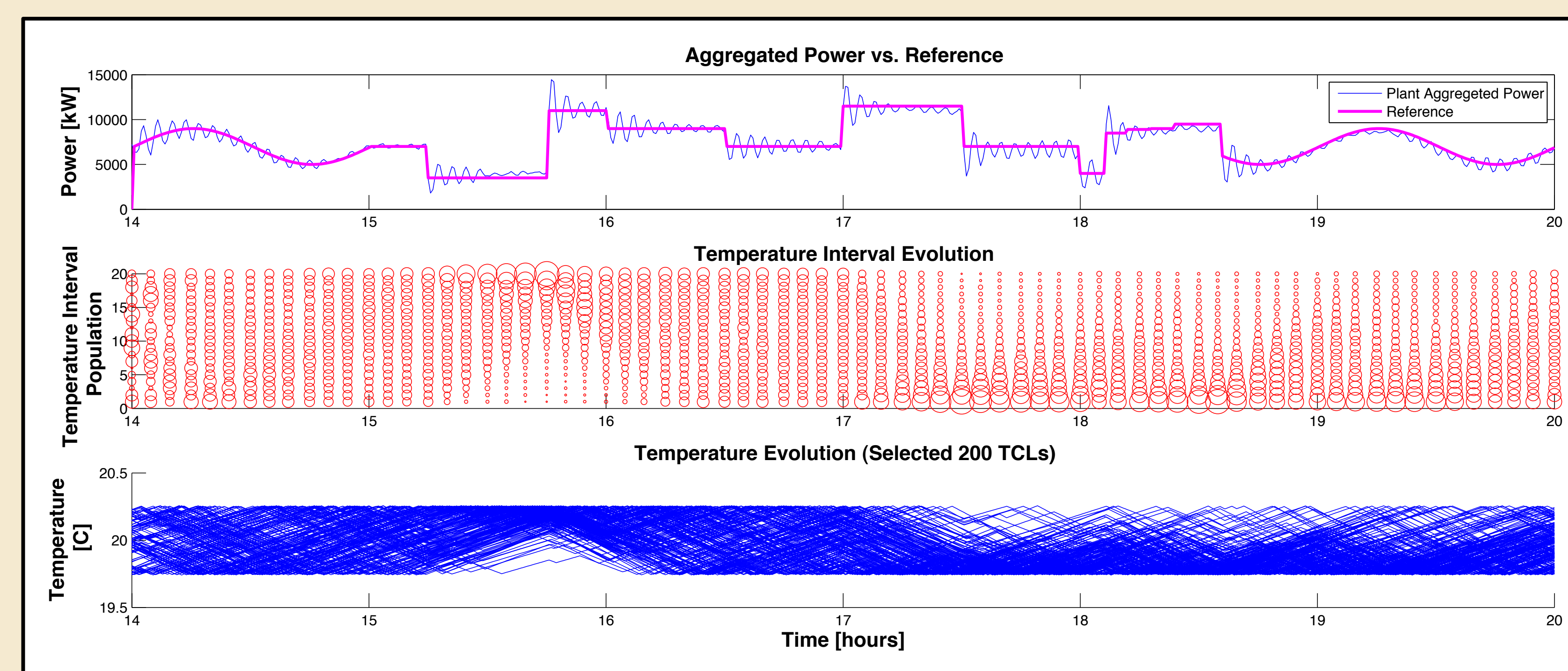
Our initial focus will be on the design of software for plug-level devices for controlling thermal loads such as refrigerators. Then we will focus on understanding the aggregate effect of smart devices. Adjusting their power consumption based on the need for ancillary services will depend upon several factors, including the duration of the ON-OFF periods, the total power change that can be effected by each device, the number of devices taking action in the system, and the relative phases of the control actions. Finally we will focus on different control strategies that leverage on the responsiveness of smart loads at the grid level. It is necessary to incorporate models of the load influenced by smart devices into system-level simulation studies.



## Motivating Case and Future Research Directions



Centralized control strategy with 1200 TCLs based on Callaway et. al., 2011



## Future Research

Currently we are working on formulating a Markov Decision Processes (MDP) based model to provide a more generic foundation to support various Reinforcement Learning techniques.

## Advantages

- A case with partially observable states can easily be formulated as POMDPs (Partially Observable Markov Decision Processes)
- Model-free approaches can yield to implementations with more realistic assumptions

## Challenges

- Relatively large state and decision spaces

## Acknowledgments

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