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# Heating Control of Residential Building Apartments with IoT and Presence Estimation

**Abstract:** Heating is a major sink for energy consumption in the Nordic countries. To improve energy efficiency, home automation and smart radiator thermostats have been used to reduce unnecessary heating. However, the barrier to entry for this kind of automation can be high for older buildings where drastic new installations are not possible and the inhabitants may lack the technical know-how or motivation to operate home automation. Furthermore, even modern smart radiators may only use a rigid schedule to automate when to turn off the heat. In this paper, we examine how a heating automation system could be retrofitted into an apartment complex while requiring minimal new installations and low maintenance to upkeep. In addition, we attempt to further optimize energy use by using presence detection to further lower energy use when the apartments are empty. As a result, a wireless and batteryless home automation system was developed and tested for a month in three phases: control period, fixed schedule period, and finally a period with presence detection on top of the fixed schedule. Major energy savings minimum of 20 percent were gained using a fixed schedule compared to consumption during the control period. However, presence detection did not seem to improve the savings significantly compared to the fixed schedule.

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## 1 Introduction

Heating is a major sink for energy consumption in the Nordic countries. According to [1], in 2020 heating energy comprising roughly 64 percent of total yearly energy consumption in households in Finland. To improve energy efficiency, home automation through smart radiator thermostats has been used to lower heating when no one is at home or during the night when lower room temperatures are acceptable, even favorable for health reasons [2]. However, the barrier to entry for this kind of

automation can be high for older buildings where drastic new installations are not possible and the inhabitants may lack the know-how or motivation to operate home automation. Furthermore, even modern smart radiators may use only a rigid schedule to automate when to turn off the heat, meaning any spontaneous absence from home still wastes heating energy.

In this paper, we examine how a heating automation system could be retrofitted into an apartment complex while requiring minimal new installations and low maintenance to upkeep. In addition, we attempt to further optimize energy use by using a camera facing the entrance and a machine learning algorithm to detect whether anyone is home or not and adjust the heating accordingly.

## 2 Proposed solution and system setup

A wireless and batteryless home automation system was developed and is illustrated in Figure 1. Raspberry Pi 3 was used as the main hub. Due to the strict requirements set on the thermostats, Micropelt's MVA 005 thermostats was seen as the only viable candidate to act as a controller for the radiators providing the heat. The thermostat harvests heat energy from the radiator to power itself to remain batteryless and wireless, and could be controlled using EnOcean messages. Since Raspberry Pi 3 doesn't have inherent ability to communicate via EnOcean messages, USB300 component was installed into the hub to enable communication to the thermostats. Finally, to enable presence detection, a small camera was installed and connected to the hub. The camera would monitor the main entrance and send graphical data to the presence detection algorithm, which would finally give its evaluation whether anyone was in the apartment or not.

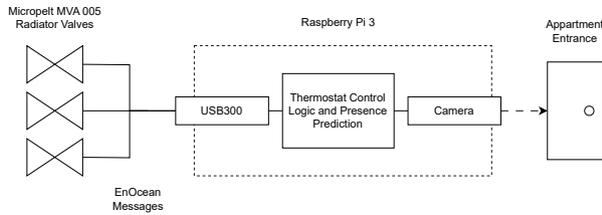


Fig. 1. Overview of the control system

### 3 Experiments and results

The developed system was tested for a month in three phases: control period, fixed schedule period, and finally use of presence detection on top of the fixed schedule. During the control period thermostats were set to 22°C to gauge the maximum energy consumption. In fixed schedule thermostats were set to 22°C during the day, but were instructed to lower the temperature to 18°C during the night, from 22:00 to 6:00. Finally during the last test period, thermostats received further instructions to lower or increase the temperature based on the presence prediction algorithm; temperature was kept at 22°C during the day, but adjusted to 18°C if the apartment was assumed empty.

The heating energy consumption measurements were compared to a baseline building of similar size, structure, and occupancy. During the baseline control period, the difference in median power input between the buildings was only 1.14% and 0.28% in terms of average power input, both being lower in the experimental building.

During the fixed schedule period, the baseline building had 21.29% higher median power input and 9.45% higher average power input than the experiment building. These results agree with the results made in other studies researching scheduled thermostats, such as [3] and [4]. However, the performance with presence detection did not drastically differ from the results gained from the fixed schedule. There may be multiple reasons for this, such as inaccuracies with the algorithm, inhabitants working remotely and not leaving their apartments, or the testing being done during early spring instead of the middle of winter. Furthermore, the test periods may have been too short to average out the variances caused by the human activity in the apartments.

Some thermostats lost connection to the database during the tests. Due to their low transmission strength, some may have been too obstructed by furniture, appliances or walls to reach the hub device. In addition, some thermostats were unable to harvest enough power from

the radiators for one reason or the other, which caused them to drain out and shut down. While the majority of the thermostats functioned correctly during the experiment, the reduced control over some of the radiators diminished the energy savings compared to the ideal performance.

### Acknowledgement

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