Thermal Grace - VHUB Comfort-as-a-Service IoT System

Intermediate Stage Progress Report

Artur Kraskov
Semester 7
ICT & OL, Delta
Fontys 2025-2026

Contents

Introduction

Within the scope of VHUB Comfort-as-a-Service system development a prototype was realized. The current document reports the path to the current stage, decision-making process and the technical and architectural specifications.

Demo

Video: https://youtu.be/vrhQb1QjbCg
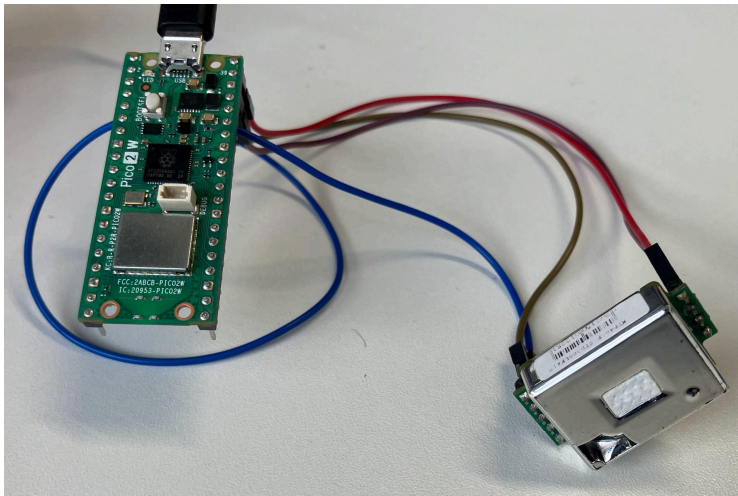
Prototype v.1

Image 1: Raspberry Pi Pico 2 w and CO2 NDIR sensor, powered from a charger with a micro USB cable, streaming sensor data over MQTT to the server
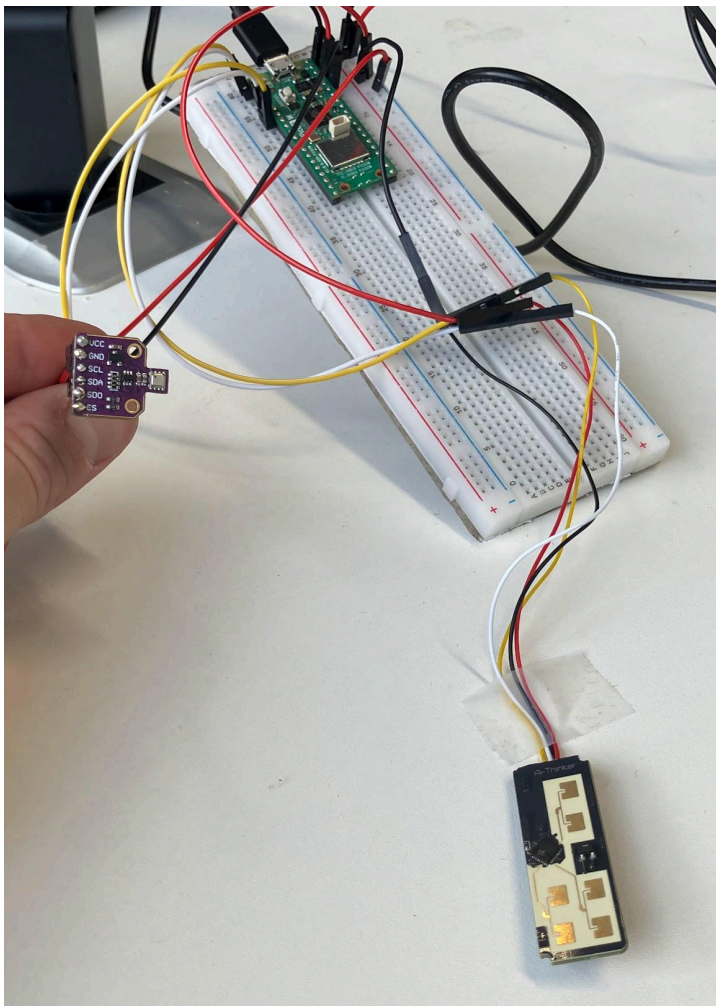

Image 2: Second Raspberry Pi Pico 2 w with BME 680 sensor (Temperature, Humidity, Air Pressure, VOC level) and mmWave Radar sensor streaming environmental data and detected human location

Image 3: Raspberry Pi 5 Central Computer receiving data from remote sensor nodes and running Thermal Grace Dashboard Streamlit App and visualizations
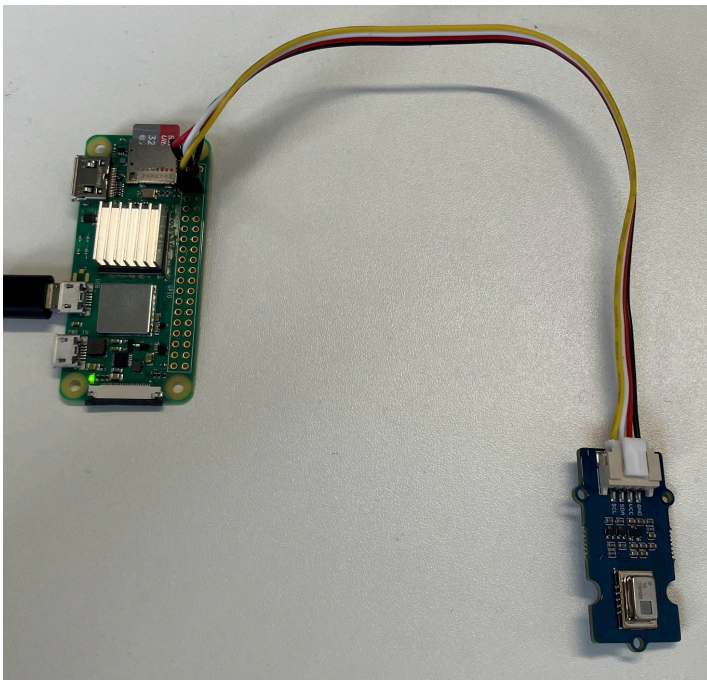

Image 4: Raspberry Pi Zero 2 w with a Thermal Temperature Sensor Array attached with I2C and streaming data to the central server over MQTT

Development process

Preliminary phase

1. UX research interview (S6, Spring–Summer 2025) explored fitting 3Beam AIoT LED Blackboard into VHUB; vision aligned, highlighting modularity, easy mounting, sensor kit, and a centralized dashboard [1].
2. Summer stakeholder talks secured a collaboration agreement and validated relevance, but no specific use case was chosen, so the project offered opportunities for use-case prototyping and integration.
3. Semester 7 at Fontys ICT & OL (Delta) began with a pitch; no student team formed, one full-stack developer continued the work [2].
4. Collaboration with 3Beam ended for internal reasons; the project pivoted to "Beets" (modular wireless components), then iterated after feedback due to missing V-model structure and user stories [3].
5. New project plan and requirements documents were compiled [4-5].

Current stage

Table 1: current implementation reasoning and motivation

#	Key Issue	What was done	Reasoning
1	Use case formulation	The feedback on Beets also put emphasis on perceived thermal comfort sensing and prediction. And it became the main use-case for the system.	The use case was actual for Vitality HUB stakeholder and for Fontys, which also had issues with thermal comfort at TQ. More research is needed to validate the relevance for the industry, but it is out of scope for the semester.
2	Team	One more Delta student joined the team.	Delta & OL projects must be a group work.
3	Literature study	Perceived thermal comfort systems literature study was done. The outcomes allowed us to understand existing approaches, required sensors and parameters, algorithms and models for comfort level calculation.	TUe, Delft and other academic institutions conducted the research and published their reports. They demonstrated the use of sensors, user data and code implementations.
4	MVP sensors	The minimum amount of sensors was derived after exploring research papers and aligning them with examples from PyThermalComfort library.	Various research approaches spanned from using little to many sensors, including wearables and external API data. After exploring PyThermalComfort library a perspective on MVP was formed.

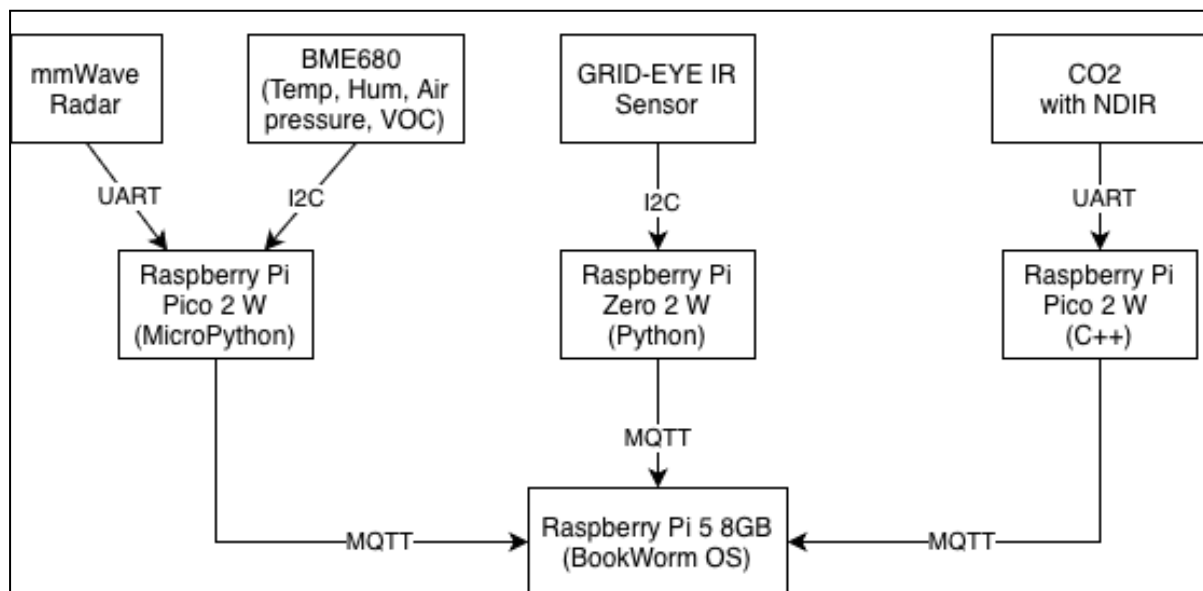| 5 | MVP software | Initially Home Assistant was planned as a main dashboard and an integration platform. It was substituted to a custom made Streamlit dashboard with a custom backend and a pipeline. | HA appeared to have the most features as the OS flashed into Raspberry Pi. While we need to develop on the PI and cannot use the OS. Container-based installation lacked certain add-ons. Adding custom UI required custom card creation with Javascript. Getting data out of HA also was indirect - required log parsing with all events in the dashboard. Streamlit appeared to be fast and intuitive, providing all necessary UI features with an easy integration with Python backend. The data can be forwarded to other dashboards or solutions like HA if needed. |
| 6 | MVP hardware | Available hardware stock was Raspberry Pi and ESP. Different Raspberry Pi devices were selected. | The available ESP32 didn't work with some sensors. While Raspberry Pi devices worked, everything was connected and stabilized faster reducing hours of debugging to minutes. Central Raspberry Pi 5 was capable of running the main application. |

Hardware Architecture

Image 1: hardware architecture diagram

Complete review: 📕 Hardware architecture technical specification.pdf [6].
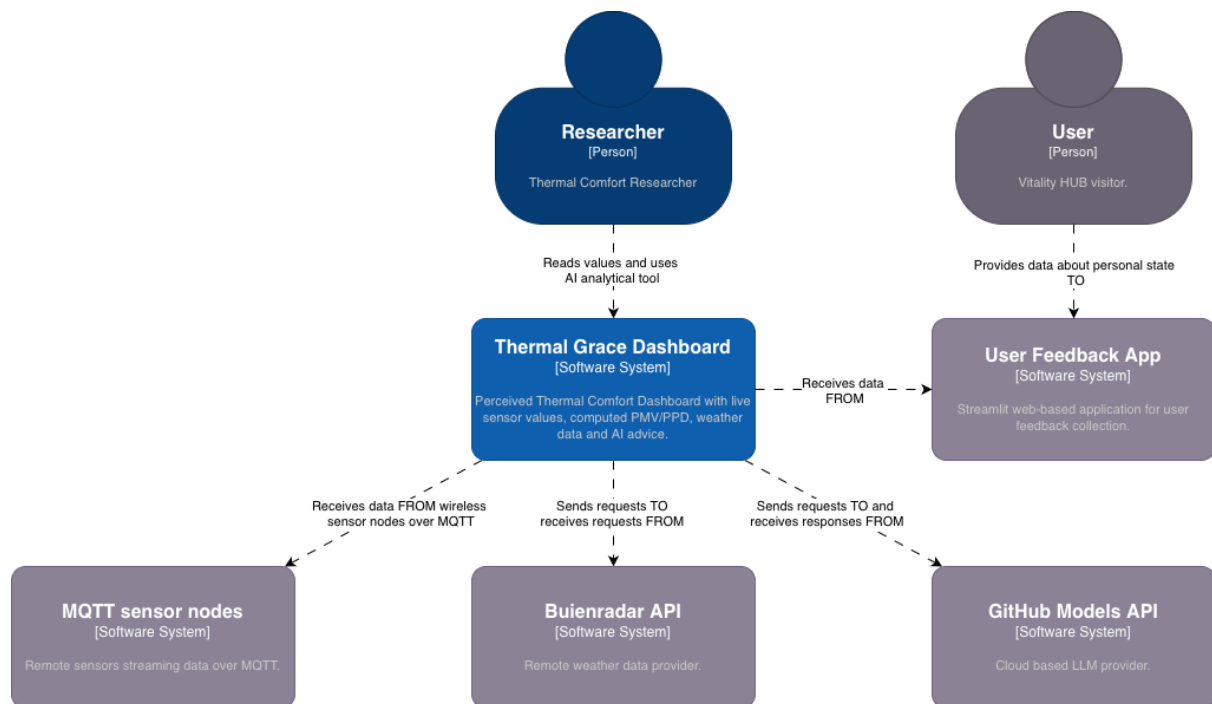
Software Architecture

Image 1: C4 diagram level 1 - context
High resolution: https://drive.google.com/file/d/1dxyRCSqdI8iYldqm1-Kn6hhx_9YyO0t3
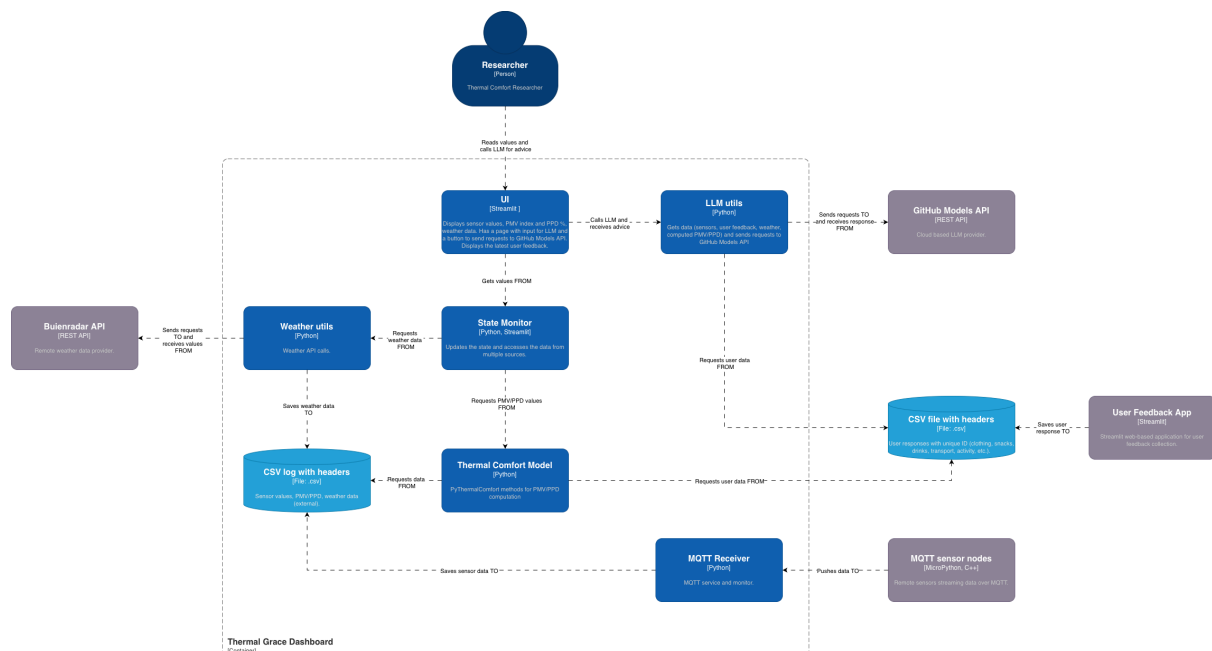

Image 2: C4 diagram level 2 - container
High resolution: https://drive.google.com/file/d/1_d4d4YvSziXnISVNDAA3kGB_XrYcdbUx

Complete review: 📄 Software Architecture Design.pdf [7].

Conclusion

The current stage was achieved through multiple iterations on conceptualization and ideation sessions with stakeholders, collaborators and partners. Literature study on perceived thermal comfort research and V-model cycle finalized the use case. Hardware and software decisions were based on findings in research papers and modern available technologies. The prototype requires verification and validation according to the V-model cycle and the stakeholder requirements. Validation ensures the product meets the customer's needs and is suitable for its intended use (often involving external acceptance). Verification checks that the product conforms to specified requirements, regulations, or specifications (typically an internal compliance process).

Reference

1. Kraskov A., (2025), Interviews and demo sessions, 3Beam AIoT LED Black Board, ICT & OL, Delta, [Online], Available:
   https://drive.google.com/file/d/1SMBRVV_7rpr2lVS0C7f9PEobBwyvicy3
2. Kraskov et al., (2025), Cluster of Intelligent Sensing Boards With a Data-Driven Software, Centralized Control dashboard, ICT & OL, Delta, [Online], Available:
   https://drive.google.com/file/d/1-3km-L-2MYYZmhuy5lyG5DwLxnj3O6m
3. Kraskov A., (2025), Beets - Modular AIoT Components for Smart offices and workplaces, ICT & Ol, Delta, [Online], Available:
   https://drive.google.com/file/d/1njBupd_SgNKH9ki1Ip_qf5zodBM_Wss6
4. Kraskov A., Kaszuba B., (2025), Vitality HUB Perceived Thermal Comfort Project Plan, Thermal Comfort-as-a-Service (CaaS) IoT system, ICT & OL, Delta, Fontys 2025-2026, [Online], Available:
   https://drive.google.com/file/d/1BXHXlD4_SPatpJrU1mDwF0ZKnESl2W_U
5. Kaszuba B., Kraskov A., (2025), Vitality HUB Perceived Thermal Comfort Requirements, Thermal Comfort-as-a-Service (CaaS) IoT system, ICT & OL, Delta, Fontys 2025-2026, [Online], Available:
   https://drive.google.com/file/d/1NooyuNM97BFz3jYOX2aPSRkbFZ7f5yJF
6. Kraskov A., (2025), Thermal Grace - VHUB, Comfort-as-a-Service IoT System, Hardware Architecture Design, ICT & OL, Delta, Fontys 2025-2026, [Online], Available:
   https://drive.google.com/file/d/1sWcylxS85DdrUbDKQ6F5CqS8aSHxkFRN
7. Kraskov A., (2025), Thermal Grace - VHUB, Comfort-as-a-Service IoT System, Software Architecture Design, ICT & OL, Delta, Fontys 2025-2026, [Online], Available: https://drive.google.com/file/d/1Te8GJlp8Rl33oFk_7jRtmwgHi9mpjRp1