

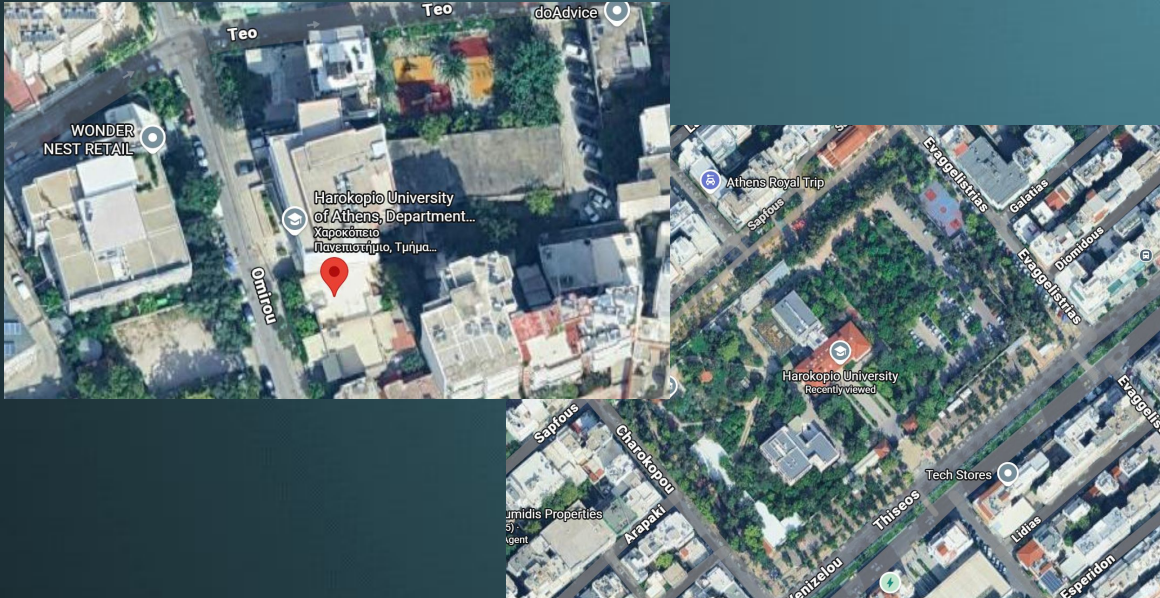
Application of IoT Technologies in a University Context

The case of Harokopio University Sustainable Campus

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HUA Campus Introduction



Harokopio University of Athens (HUA)

 **Academic Center:** Located in Kallithea, Athens, hosting 4 specialized departments

Economics and Sustainable Development
Informatics & Telematics
Geography
Nutrition and Dietetics

 **Microcosm Model:** Mix of dense urban environment and park.

-  **Distributed Environment:** Deployment spans three campus buildings

PART I

Strategic Vision & Goals

How it came about...

"Luck is what happens when preparation meets opportunity"

Vision of Internal IoT Testbed

Based on a previous procurement of mainstream DIY nodes, a main testbed to act as an IoT Ecosystem Backbone. Problem: time limitations of internal personnel

Recovery Fund

Massive funding available at the beginning of 2025. Problem: short notice availability and with tight timing constraints

Design Requirements

During Design Time, a number of requirements were set:

1. Technology Variations

Need to extend to multiple sensor technologies, wireless technologies etc. for student demonstration purposes. Turn key solution needed, from sensor to IoT platform

2. Return of Investment

What we design and implement needs to have the potential to attract funding, either from a research or application point of view

3. Sensor Data Scope

Core Data need to be usable by other Departments in the University, either for operational or for research goals, and involve end-users (i.e. students)

Exploitation Aspects

Smart Cities investments are expensive. How can we exploit them across more than one directions?



1. Campus Operations

Real-time information, facility capacity management, maintenance optimization, data analytics.



2. Pedagogical Support

Optimizing classroom conditions to directly enhance cognitive performance and actively engage students



3. Research Testbed

Open-data platform acting as an active laboratory context for postgraduate research, IoT applications prototyping, sustainable computing.

Sick Building Syndrome (SBS)

Environmental Conditions Affect Cognitive Processes

Inadequately ventilated classrooms act as direct barriers to education.

CO2 accumulation triggers headaches, fatigue, dizziness, and cognitive drop-offs in both students and instructors.

ASHRAE Standards recommend that indoor CO2 levels are below **1,000 ppm** to support ideal brain health and memory processes during learning.

Critical IAQ Indicators To Be Used



CO2 (PPM): Primary measure of ventilation quality.



TVOCs (PPB): Monitoring chemical contaminants.



Particulate Matter: Checking levels of PM1.0, PM2.5, PM10.



Thermal Comfort: Dynamic balance between room temp and relative humidity.

PART II

Physical Infrastructure and Platform

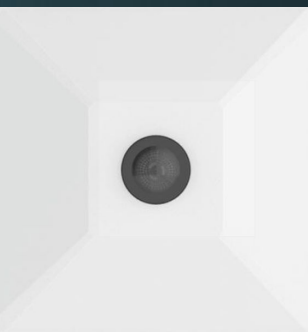
Main Sensor Scope Selection

- Based on the previous technical and non technical requirements
 - Environmental Monitoring (especially indoor) covers SBS
 - End user comfort levels through indoor air quality (IAQ)
 - People presence
 - Facility Management and Information to be combined with CO2 levels management
 - Openings (Windows/Doors) State Monitoring



Technology Variations

- Campus-wide deployment and technology variation
 - LoRaWAN Backbone
- People presence detection variations
 - Infrared Seat detector
 - most accurate, most expensive
 - selected for small labs (up to 35 seats)
 - Ceiling infrared detector
 - less accurate
 - selected for large auditoriums
 - Optical sensor detector
 - Limited area
 - selected for restaurant queue monitoring

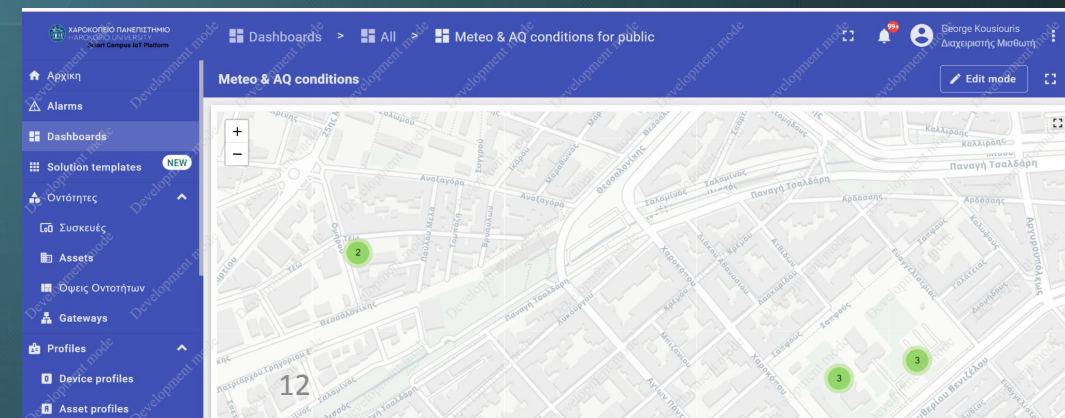
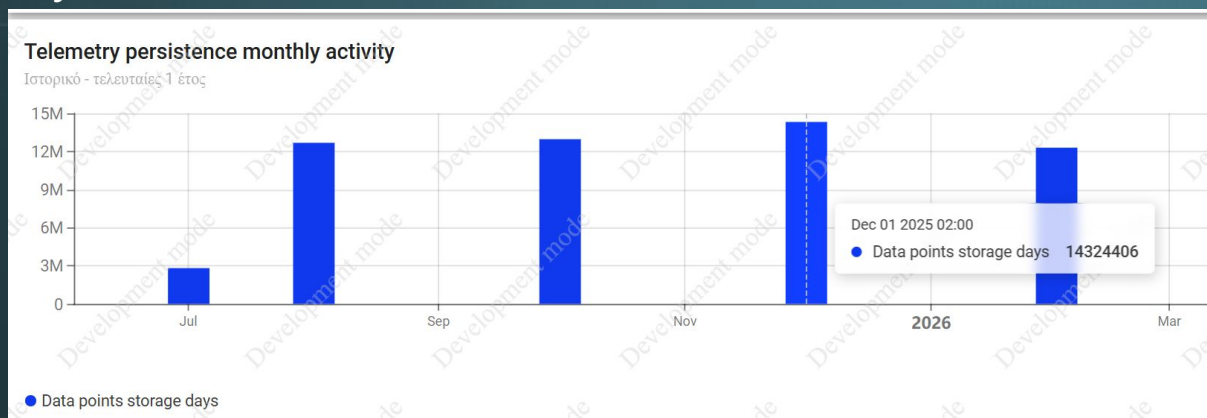
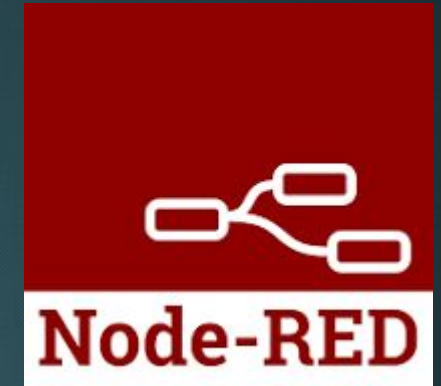


Total Sensors Acquired (203 devices in total)

Device Category	Quantity Deployed	Measured Physical Parameters
Internal Air Quality (IAQ)	65 Units	CO2, humidity, ambient light, movement, PM10, PM2.5, TVOC
Desk Occupancy (Infrared)	50 Units	Per-seat infrared thermal presence tracking
Magnetic Contact Sensors	30 Units	Boolean open/closed status for classroom doors and windows
Energy Smart Meters	12 Units	Active power, energy consumption rate, voltage levels, $\cos\Phi$
Room Sound Noise Monitors	12 Units	Real-time decibel level (instantaneous max and historical average)
Entrance People Counters	11 Units	Vertical infrared line-of-crossing direction counters (In/Out)
Critical Equipment Freezers	10 Units	Deep freezer ambient temperature for bio-chemical specimen safety
Workplace Occupancy (Area Visual Recognition)	2 Units	Region (area) people count, dwell time, maximum people count, accumulated line-cross counters, People flow analysis
Weather Station	1 Unit	Air temperature, atmospheric pressure, lightning strike count, precipitation, solar radiation, wind direction, wind speed, east wind speed, north wind speed
UVE	1 Unit	UV Index
CO2 Outdoor	2 Units	CO2, humidity, pressure, temperature
Outdoor Particulate Matter	4	Outdoor humidity, pm10, pm2_5, pressure, temperature, pm1_0
TH Outdoor	3	Humidity, temperature

Software Stack Selection

- Edge (Gateway) ability for processing
 - Node-RED enabled Gateways
- MQTT Messaging
 - Between Gateways and Platform
- Main Private Cloud Platform including device management, link to external systems, readymade mobile app, platform based analytics engine, dashboards etc,
 - Thingsboard self hosted version
- Approximately 600.000 key value pairs of data collected daily



ThingsBoard Self Hosted Platform

The screenshot displays the ThingsBoard Self Hosted Platform interface. The top navigation bar includes 'Dashboards', 'All', and 'Meteo & AQ conditions for public'. The main dashboard area shows a map titled 'Meteo & AQ conditions' with several green circular markers indicating data points. The left sidebar contains a menu with options like 'Alarms', 'Dashboards', 'Solution templates', 'On-site devices', 'Assets', 'Device profiles', and 'Asset profiles'. Below the map, the 'Root Rule Chain' is visible, showing a flowchart with nodes such as 'Input', 'message type filter', 'entity type filter', 'device profile switch', and 'message type switch'. A search bar and a filter dropdown are also present on the left side of the rule chain view.

Orchestrating Raw Telemetry, Visualizations and Analytics



ThingsBoard Portal: Self-hosted secure platform storing and displaying continuous sensor metrics. Ability for Dashboard Creation, Rules and Analytics Engine



Role-Based Access: Segmented credentials mapping out system admins, faculty members, and students.



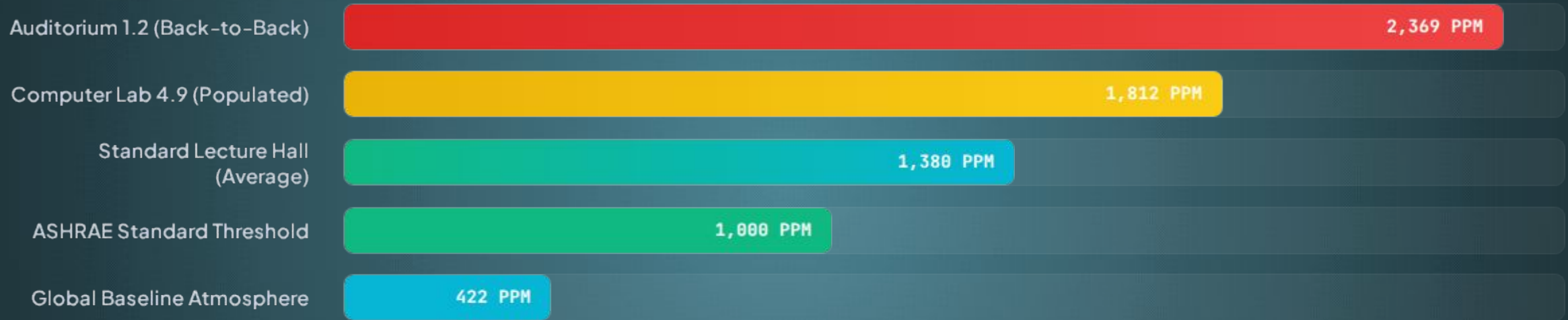
API Accessibility: Fast REST and telemetry endpoints allow student software to plug directly into live feeds.

The screenshot shows the Swagger UI for the ThingsBoard REST API. The page title is 'ThingsBoard REST API' with a version of 4.5.10. The API is described as 'ThingsBoard Professional Edition IoT platform REST API documentation'. The 'Servers' section shows a base URL of 'https://smarthdata.hua.gr'. The 'API Explorer' section lists several endpoints under the 'admin-controller' namespace, including 'GET /api/admin/autocommitSettings', 'POST /api/admin/autocommitSettings', and 'DELETE /api/admin/autocommitSettings'. The 'POST' endpoint is highlighted, showing its description: 'Create or update the auto commit settings (saveAutoCommitSettings)'.

PART III

Use Cases & Insights

Indicative CO2 Concentrations



Real-world metrics gathered over the initial 6-month operational period revealed dramatic threshold breaches, particularly during high-occupancy classes scheduled back-to-back.

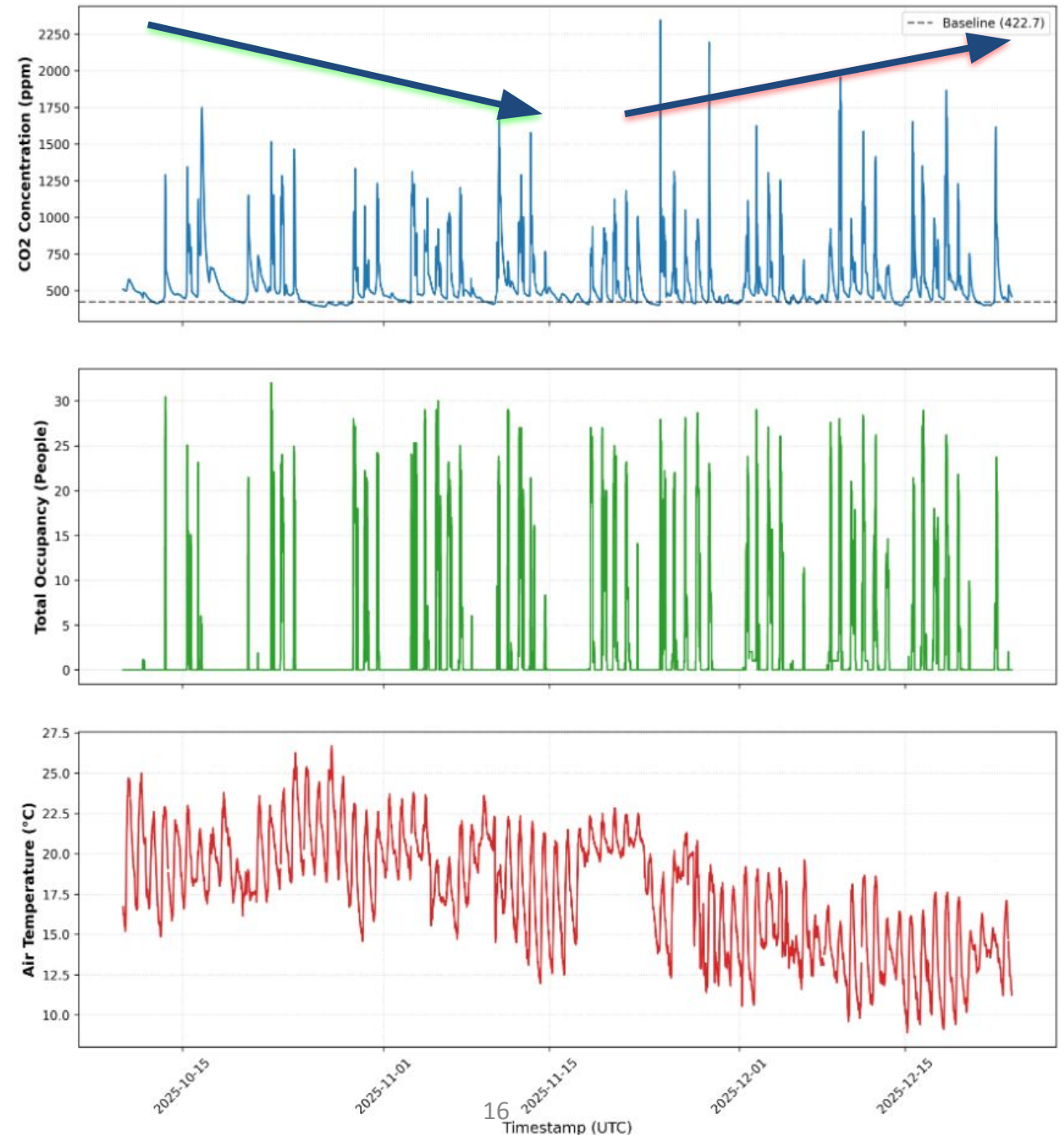
Long-Term IAQ Awareness Trends

Early Semester Reductions

During October and early November, exposing real-time sensor metrics to students and faculty generated high immediate awareness.

Winter Reluctance Spikes

As outdoor temperatures dropped below 15°C in late November, winter thermal discomfort took priority over fresh air quality.



Ventilation Analysis Based on Fused Sensor Data

Analysis Inputs

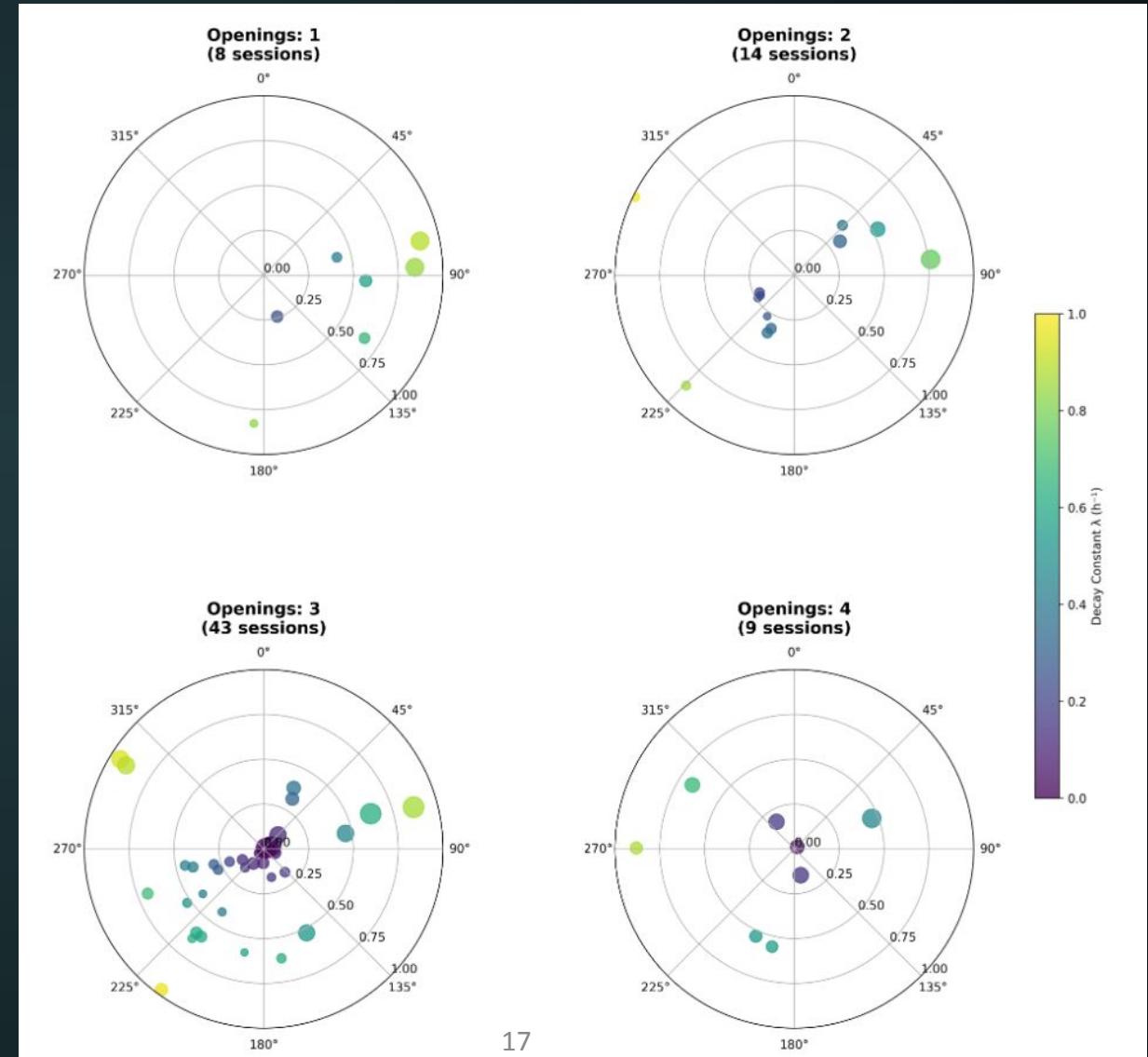
↑ People Counting

⇒ Wind Velocity & Direction

🚪 Openings Magnetic Contacts

We calculate the localized air change rate (expressed as decay constant λ) by fusing data across door/window state sensors, weather station, and occupancy counters:

$$\lambda = \frac{\ln(CO_{2start} - CO_{2bc}) - \ln(CO_{2end} - CO_{2bc})}{t_{end} - t_{start}}$$



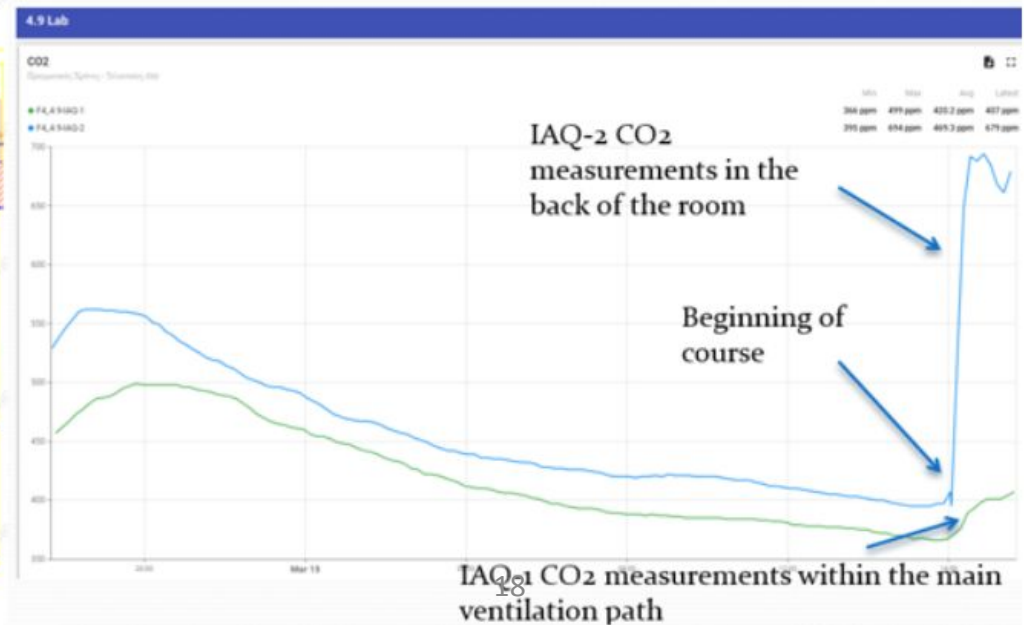
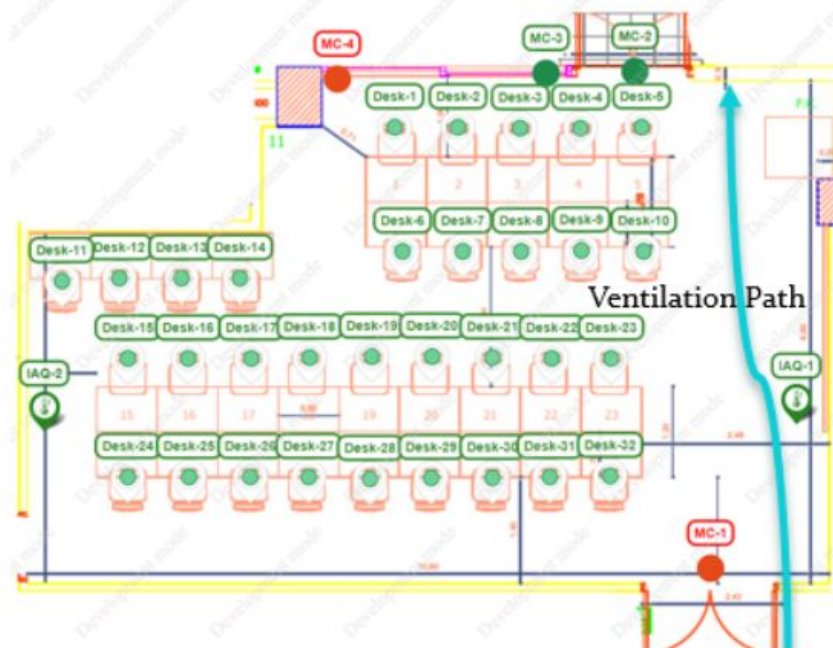
Front vs Back Row Dynamics

1. Ventilation Path Cleanliness

Front row seating blocks aligned with cross-room draft vectors (window-to-door paths) experience fresh air change and maintain sub-1,000 ppm averages. This is where active, engaged students usually seat themselves during normal lecture blocks.

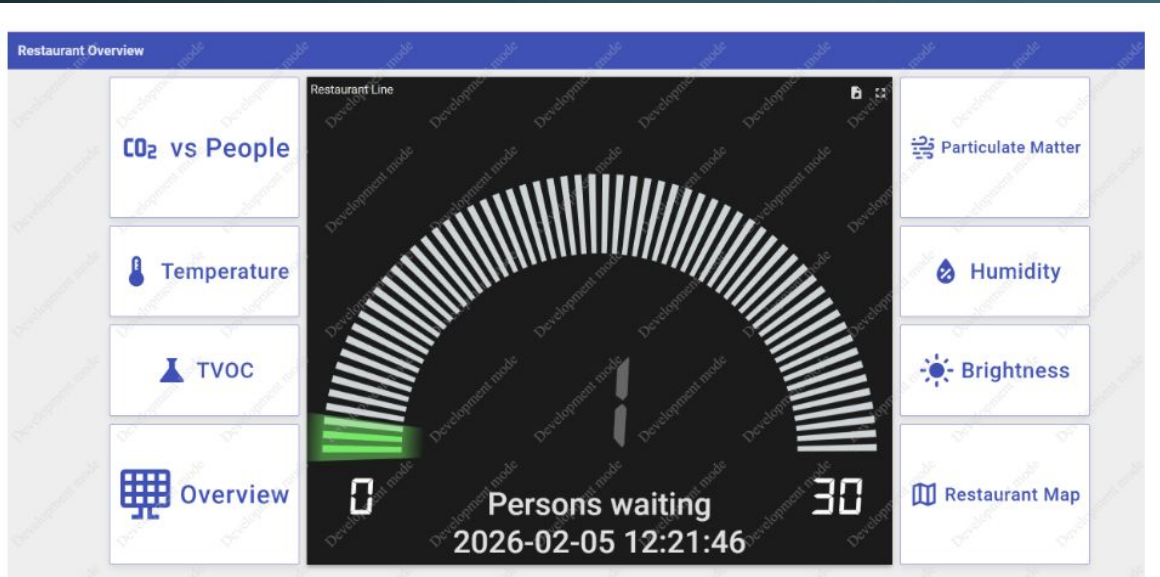
2. The Stagnant Back-Row Vicious Cycle

Rear-corner seats situated away from the central draft zone experience severe air stagnation. CO₂ rises rapidly shortly after lecture start. This forms a vicious cycle, forcing under-performing or distracted students to study under severe oxygen deficits.



IAQ-1 CO₂ measurements within the main ventilation path

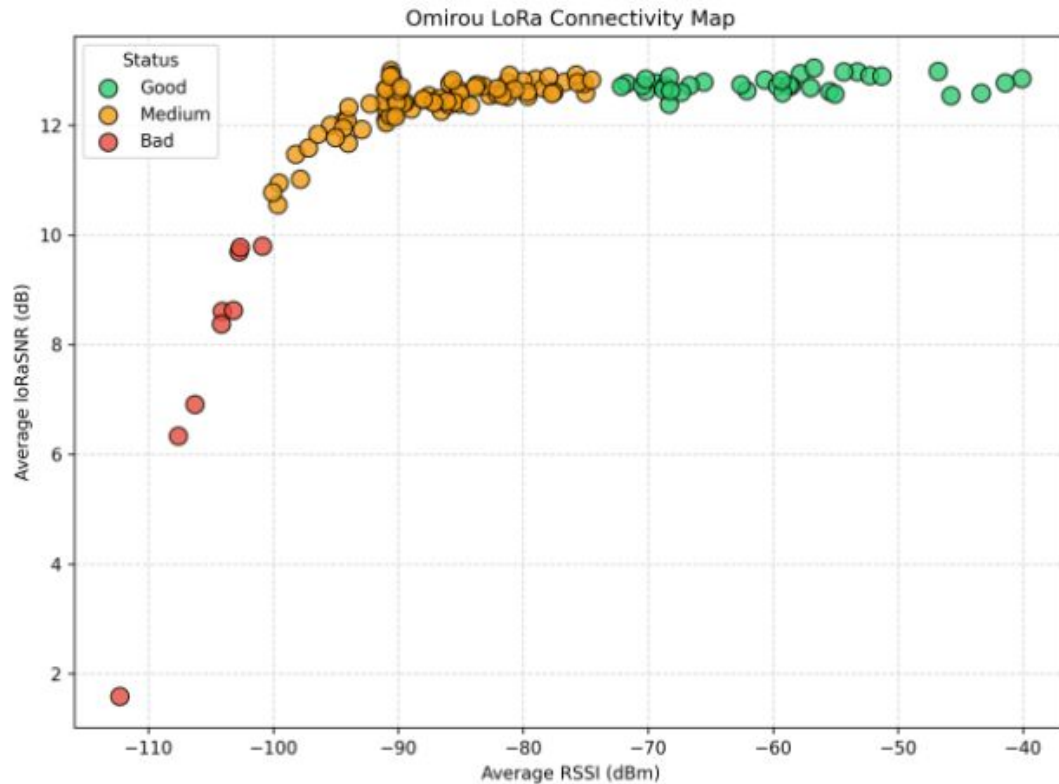
Restaurant Conditions Overview



AI-Powered Occupancy Tracking

- 🌐 **GDPR compliant Computer Vision People Counting:** Ceiling sensors use localized region interest models to count queue lengths.
- 🌐 **Live Waiting Gauges:** Publishes live wait counts on digital signage screens, helping balance campus lunch breaks. Includes other info (e.g. CO₂ vs People Graphs) in order to enhance awareness on the link between the two

LoRa-WAN Coverage Map



Signal Quality Analysis

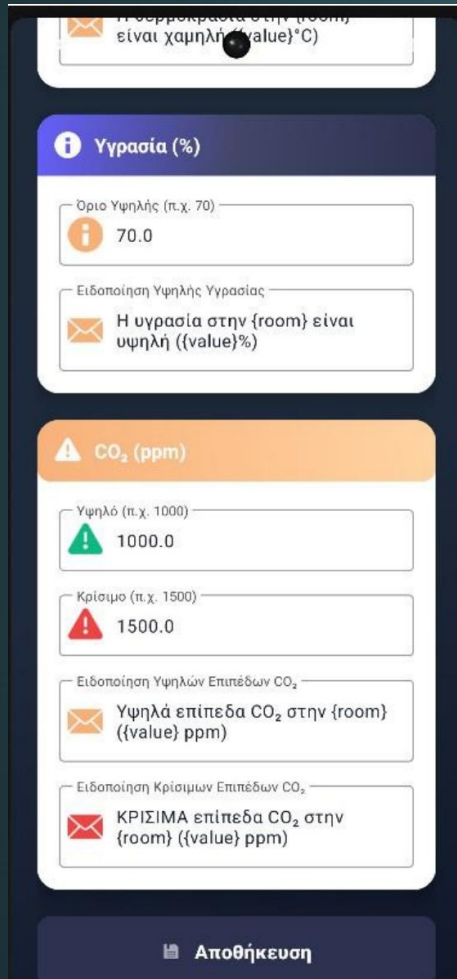
Clustering over three months of connectivity metrics, tracking Signal-to-Noise Ratio (SNR) and Received Signal Strength Indicator (RSSI) values.

Analysis groups devices into Good, Medium, and Bad clusters, highlighting weaker signal pockets across campus walls.

PART IV

Educational & Research Examples

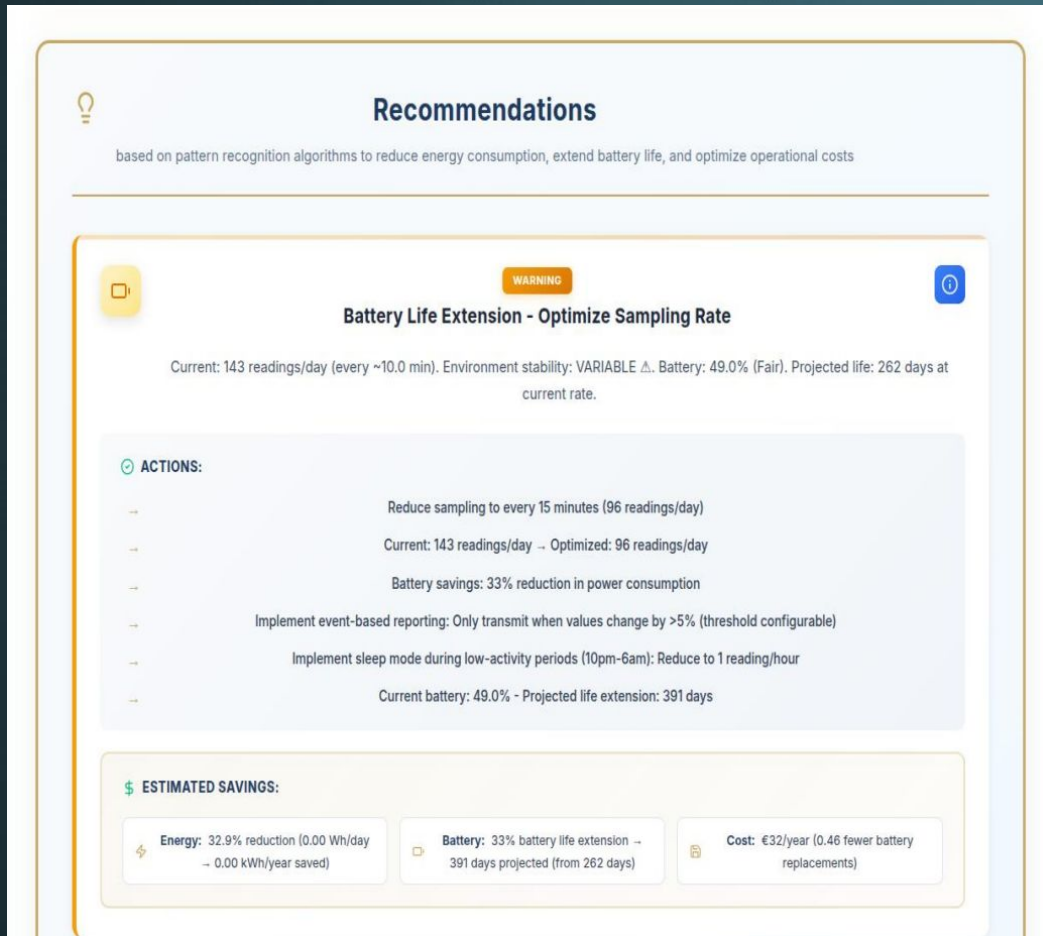
Smart Classroom Assistant BSc Thesis



-  **Smart Classroom Assistant:** Student-built Android app delivering live air alerts to lecturers.
-  **Automated Alerts:** Real-time prompts recommending window and door settings based on rules

<https://estia.hua.gr/entities/publication/188be8ed-875c-4ca7-a008-2d4166055985/full>

Sensor Battery Footprint Analytics(M.Sc. Thesis)– To be presented in this conference:



Smart Campus Context–Aware Policies for the Efficient Operation of Battery–Powered IoT Devices

Optimized battery tracking extended sensor battery life, significantly reducing university maintenance burden.

<https://estia.hua.gr/entities/publication/c055631c-1200-48f7-aba7-be45dfa968b>

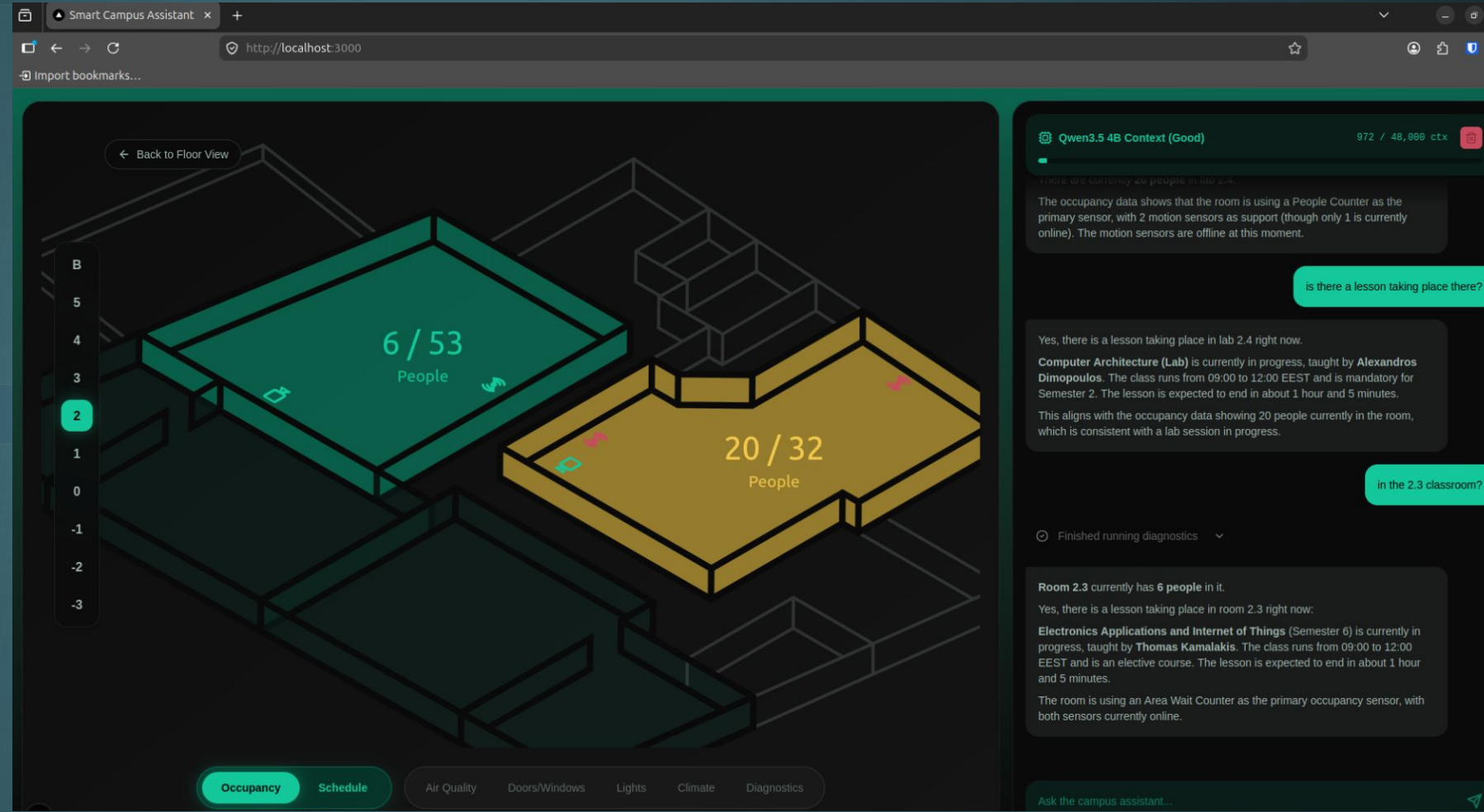
Smart Campus LLM Assistant (Ongoing– N. P. Rigas Thesis)

RAG & Agentic Architectures

Large Language Model (LLM) assistants, using Retrieval-Augmented Generation (RAG) to query sensor data via natural language. Direct Integration with the IoT Platform APIs

Empowering Non-IT Personnel

Natural language queries lower tech barriers, allowing all university staff to utilize data for daily decision-making.



Other ongoing works

- Recommender System for Conditions Improvement following Case Based Reasoning
 - Provides recommendations for window openings based on previous similar cases observed
- Window opening quantification
 - Angle calculation based on magnetometer measurements
- Facility Management
 - Seat reservation for limited spaces, including laboratory and office spaces

PART V

Takeaways, Challenges and Future Steps

Real Life Errors: It's a feature, not a bug

During Operation Time, a number of issues were encountered:

Sensor Errors in Occupancy Detection

Sensors are not perfect, one can observe negative values or residuals at the end of the day

Errors extend research scope

Modelling of errors based on back to back courses and size of these courses

Errors serve as example

Practical showcases of real life conditions for students and what to expect, how to filter

< F1_Ceremony-Hall-RD-PC		F1_Ceremony-Hall-LD-PC	F1_Ceremony-Hall-MD-PC	F3_3.9-PC
Timestamp ↓	line_1_period_in	line_1_period_out	line_1_total_in	line_1_total_out
2026-06-03 00:51:03	0	0	49	50
2026-06-03 00:41:04	0	0	49	50

Key Takeaways



1. Modular Extensibility

Platform and services must be inherently extensible, easily integrating custom student hardware and dynamic open APIs, from both ends (device input and data outputs)



2. Multi-Sensor Fusion

Fusing door states, outdoor wind, and interior carbon rates overcomes individual sensor limits, unlocking deeper analytics.



3. Living Lab Dynamics

Treating campus buildings as live sandboxes fuels student engagement, turning theoretical lessons into practical innovations. Enabling student extensions to become part of the ecosystem enhances creativity



4. Research Dynamics

Enablement of more roles in research grant acquisition (data provider, testbed provider, application provider, cognitive processes modelling)

Other challenges

- Ongoing maintenance of testbed depends on various factors
 - Parallel administration activities (e.g. window replacement)
- Ensure Ongoing support for student-delivered addons that are not part of the main platform
 - Challenging due to key people leaving
 - Could be constrained but we do not want to limit them
 - Balanced approach between creativity and deployment constraints

Future Steps

Dynamic HVAC Integration

HUA's next milestone is integrating ThingsBoard directly with building management systems (BMS).

Automated loops will balance room air quality with central heating, dynamically adjusting ventilation to preserve both cognitive health and energy efficiency.

Hackathons & Open Sandboxes

Organization of annual smart campus hackathons, encouraging students to build creative applications on top of HUA's data.

Integration of student-built solutions, extension to DIY and Edge Computing nodes, mobile sampling units etc.

Questions & Discussion

Thank you for your attention.



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