3rd Annual Buildsys 2025 Int'l Workshop on CPSIS
19 November 2025

大阪大学
THE UNIVERSITY OF OSAKA

LLM Driven Agent-Based Evaluation Framework for Occupant-Centric HVAC Control

Considering Individual Differences and Movement Behavior

Shinnosuke Sasaki, Nattaon Techasarntikul, Yuichi Ohsita, Hideyuki Shimonishi

Graduate School of Information Science and Technology, The University of Osaka

Background: Limitation of Conventional Evaluation

- **Building Performance Simulation (BPS)** is the tool to analyze and predict the environmental performance and energy consumption of a building during the design phase.

- **Performance gap** exists due to unmodeled occupant dynamics.

Cause of Performance Gap Between Prediction and Operation	
Fixed occupancy schedules	Population-average indices
Occupancy and behavior typically treated as exogenous and homogenous inputs.	Population-average metrics such as PMV/PPD, cannot adequately represent individual thermal preferences.

Building Performance Simulation (BPS) must internalize both individual thermal sensations and the behaviors they induce.

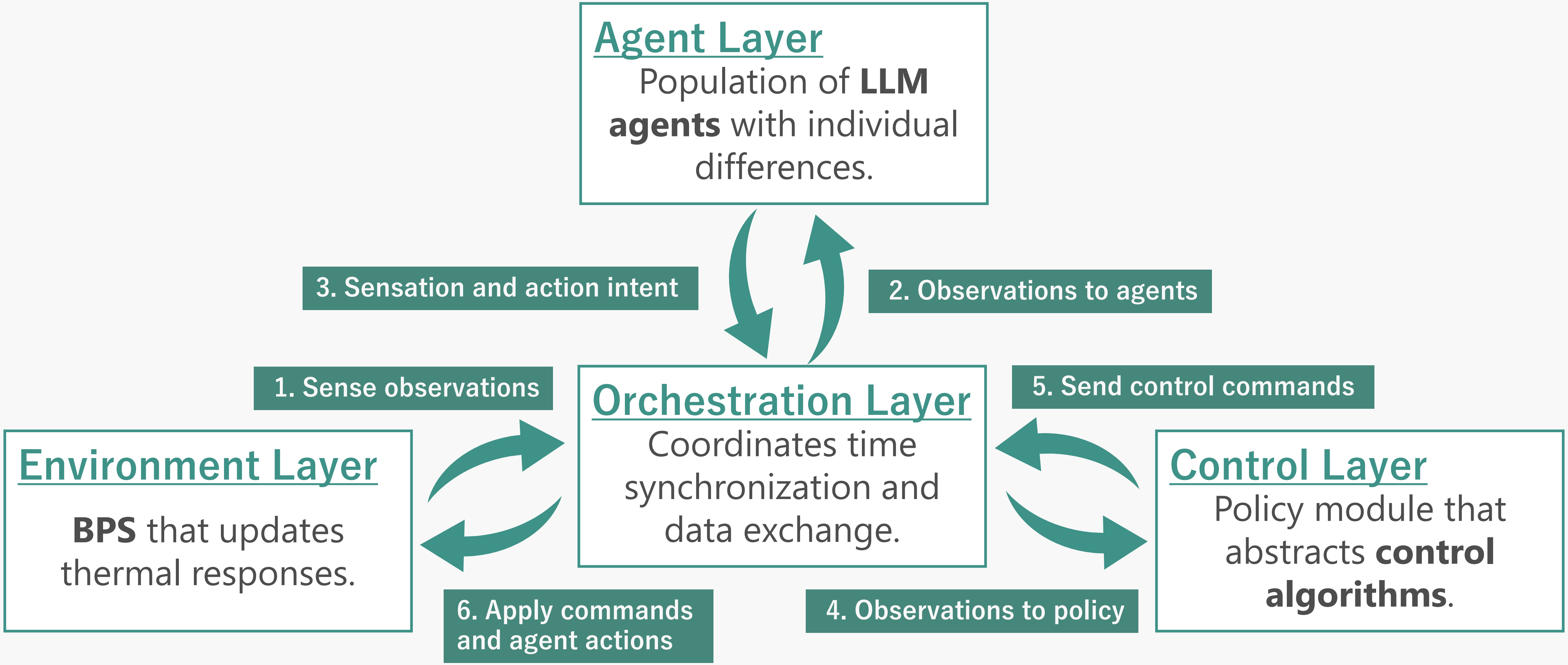
Conventional Solution: Agent-Based Modeling (ABM)

- ABM is computational approach that models explicit individual, autonomous agents.
- ABM can capture heterogeneity, decision making, and interactions.
- Achieving realistic, subjective sensation and context-dependent judgements is a challenge in traditional ABM.

Our Solution: Large Language Model (LLM) Driven ABM

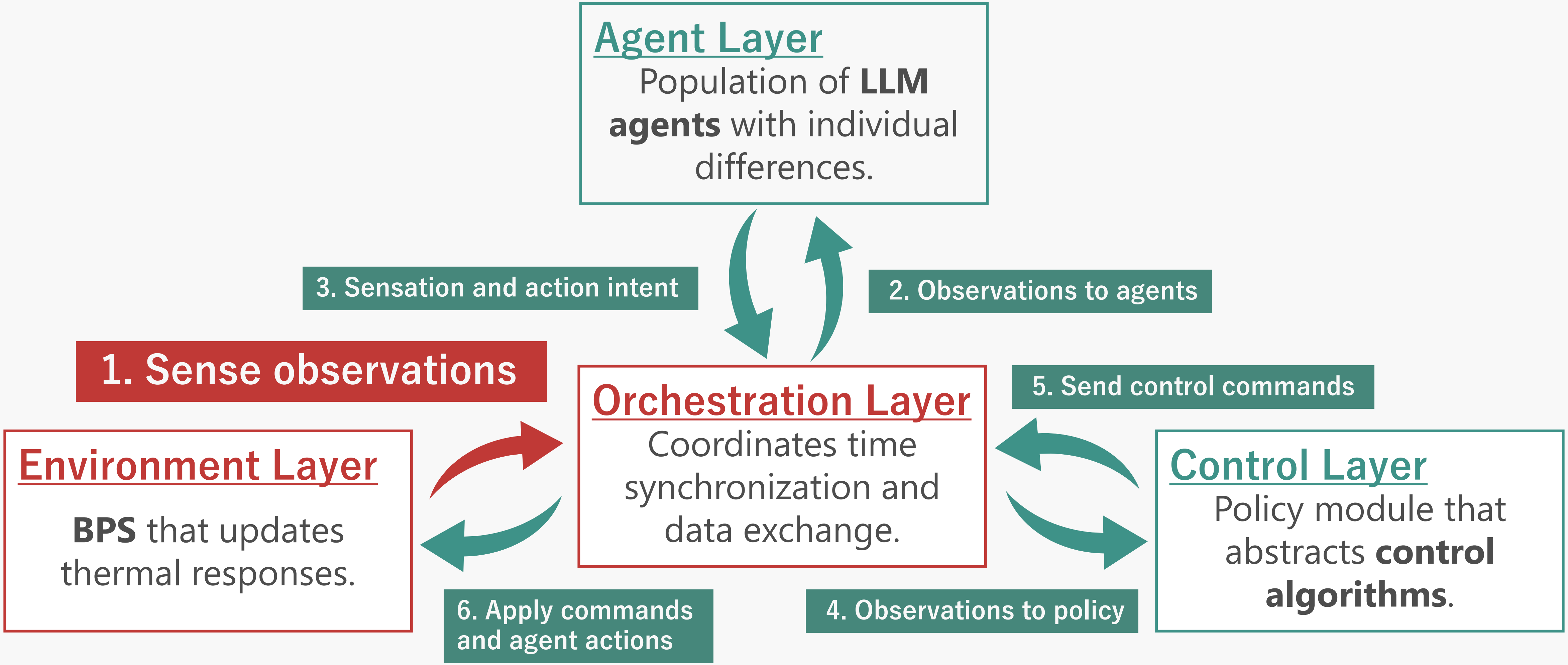
- Delegate agent's decision-making to an LLM.
- LLMs enable agents to express individuality and context-dependent judgements.

We propose a framework that models occupants' subjective thermal sensations and movement behaviors as LLM agents, and couples them with a Building Performance Simulation (BPS).



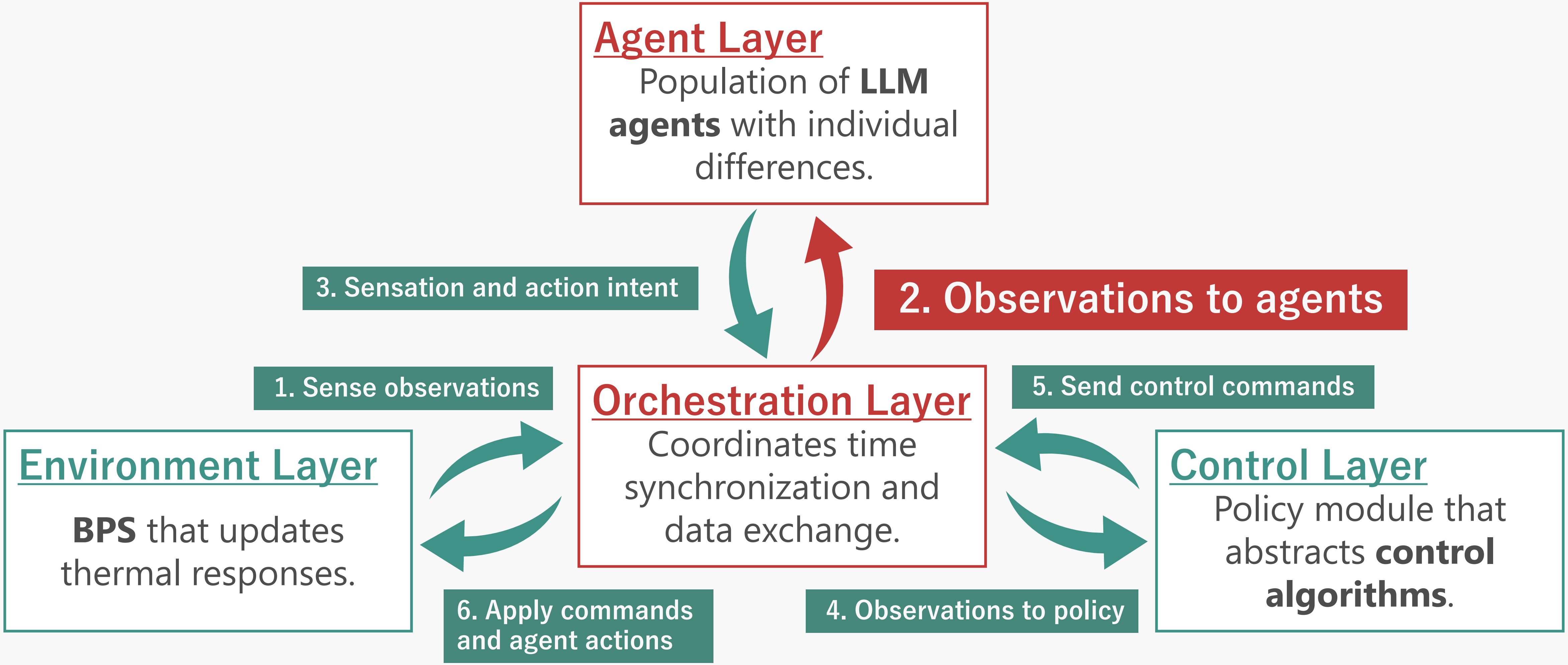
Proposed Framework: System Overview

We propose a framework that models occupants' subjective thermal sensations and movement behaviors as LLM agents, and couples them with a Building Performance Simulation (BPS).



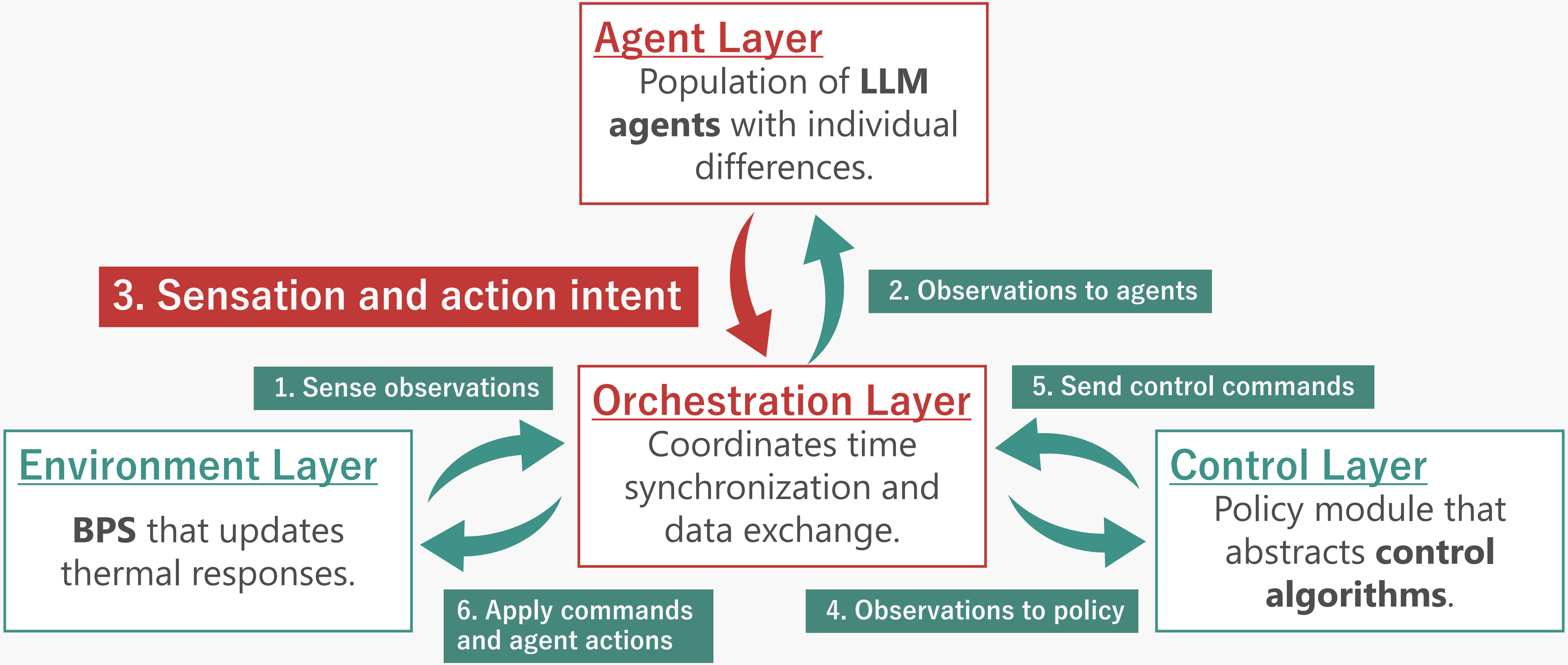
Proposed Framework: System Overview

We propose a framework that models occupants' subjective thermal sensations and movement behaviors as LLM agents, and couples them with a Building Performance Simulation (BPS).

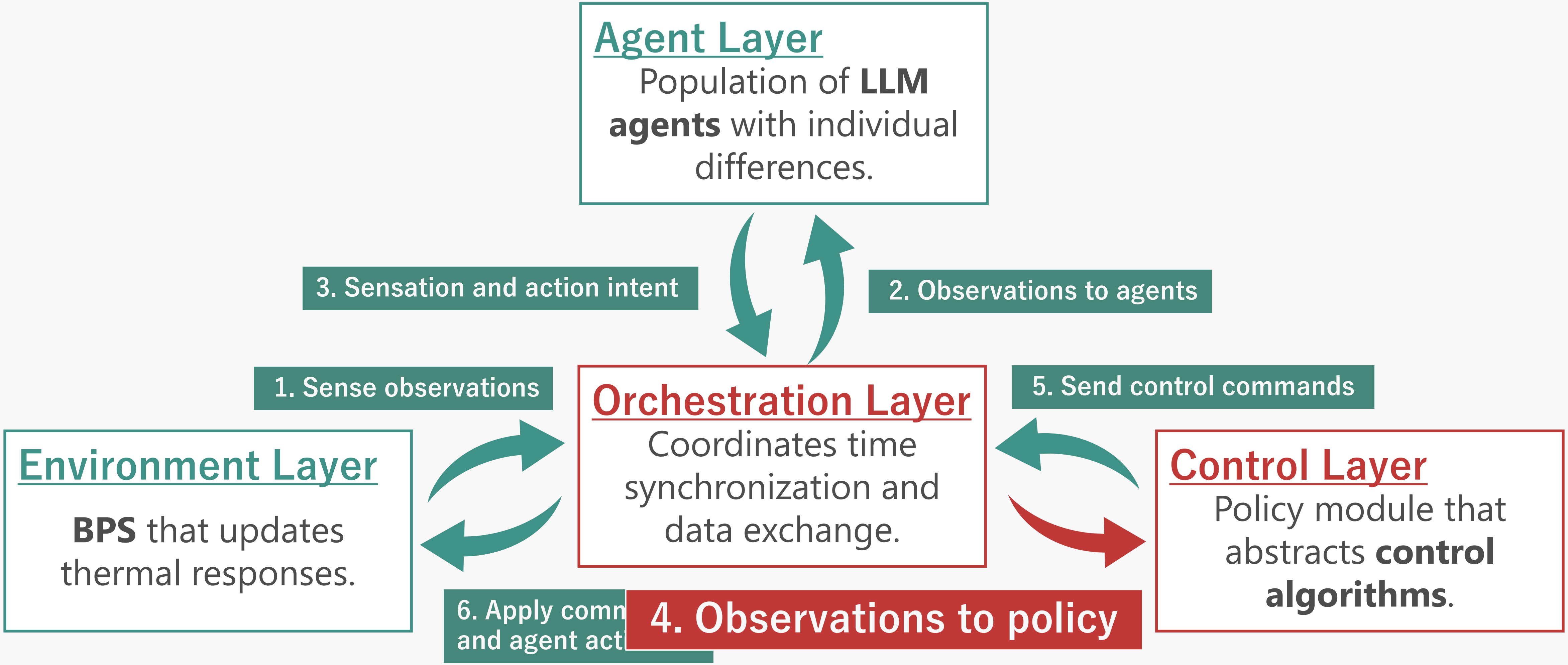


Proposed Framework: System Overview

We propose a framework that models occupants' subjective thermal sensations and movement behaviors as LLM agents, and couples them with a Building Performance Simulation (BPS).

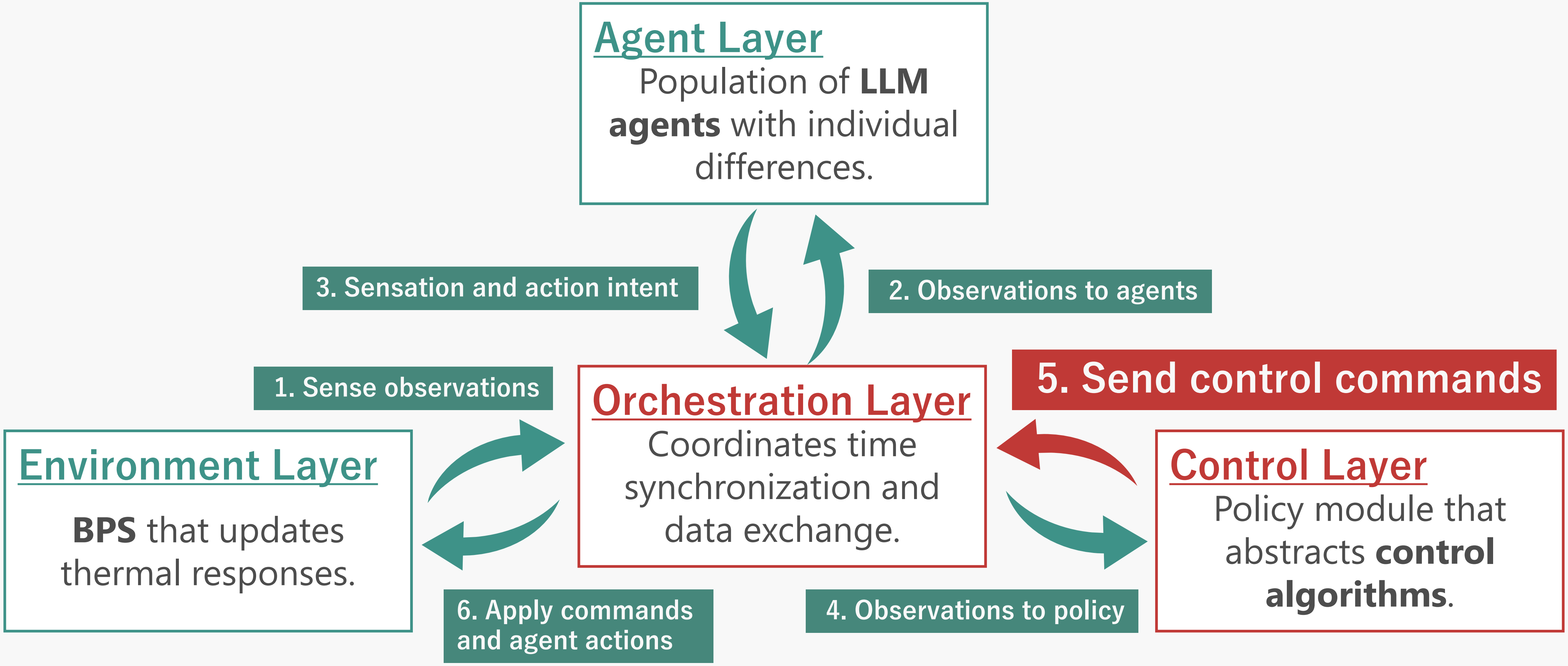


We propose a framework that models occupants' subjective thermal sensations and movement behaviors as LLM agents, and couples them with a Building Performance Simulation (BPS).

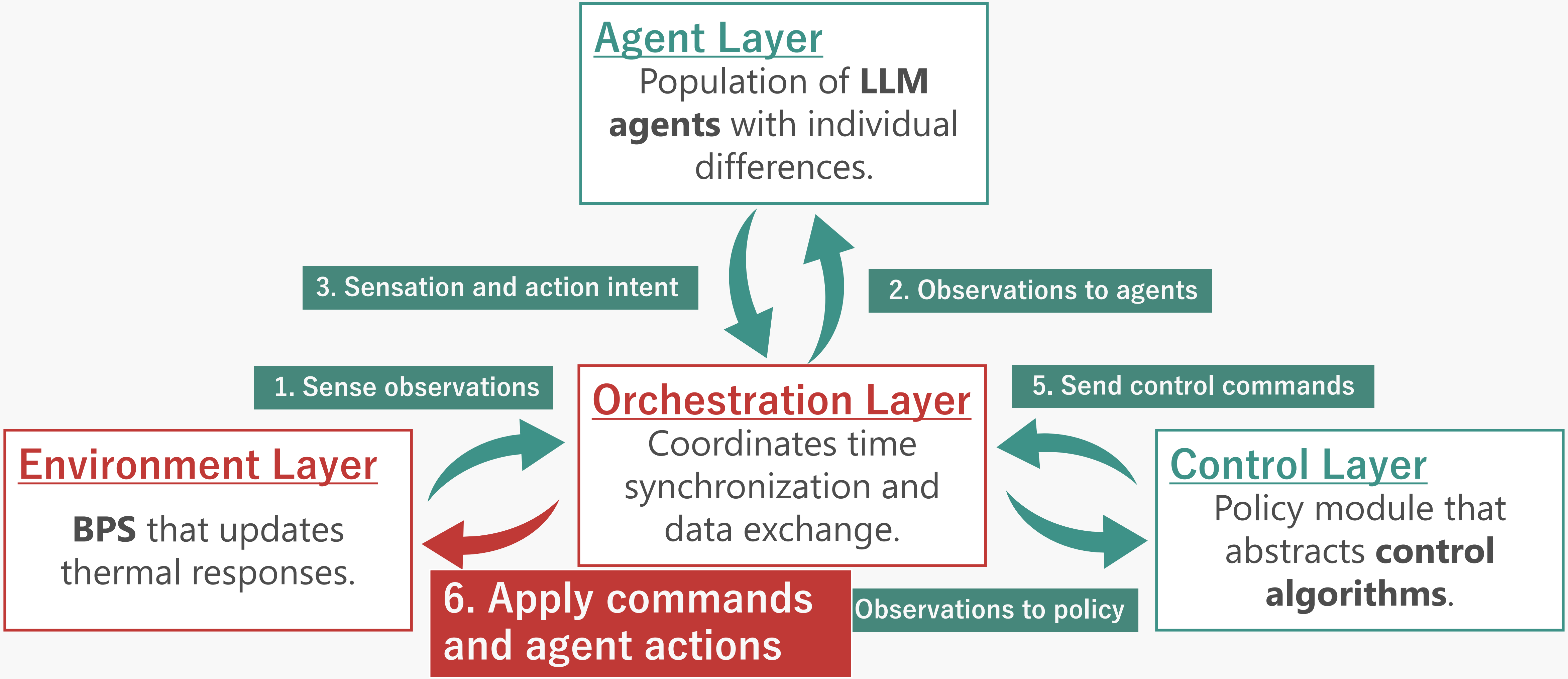


Proposed Framework: System Overview

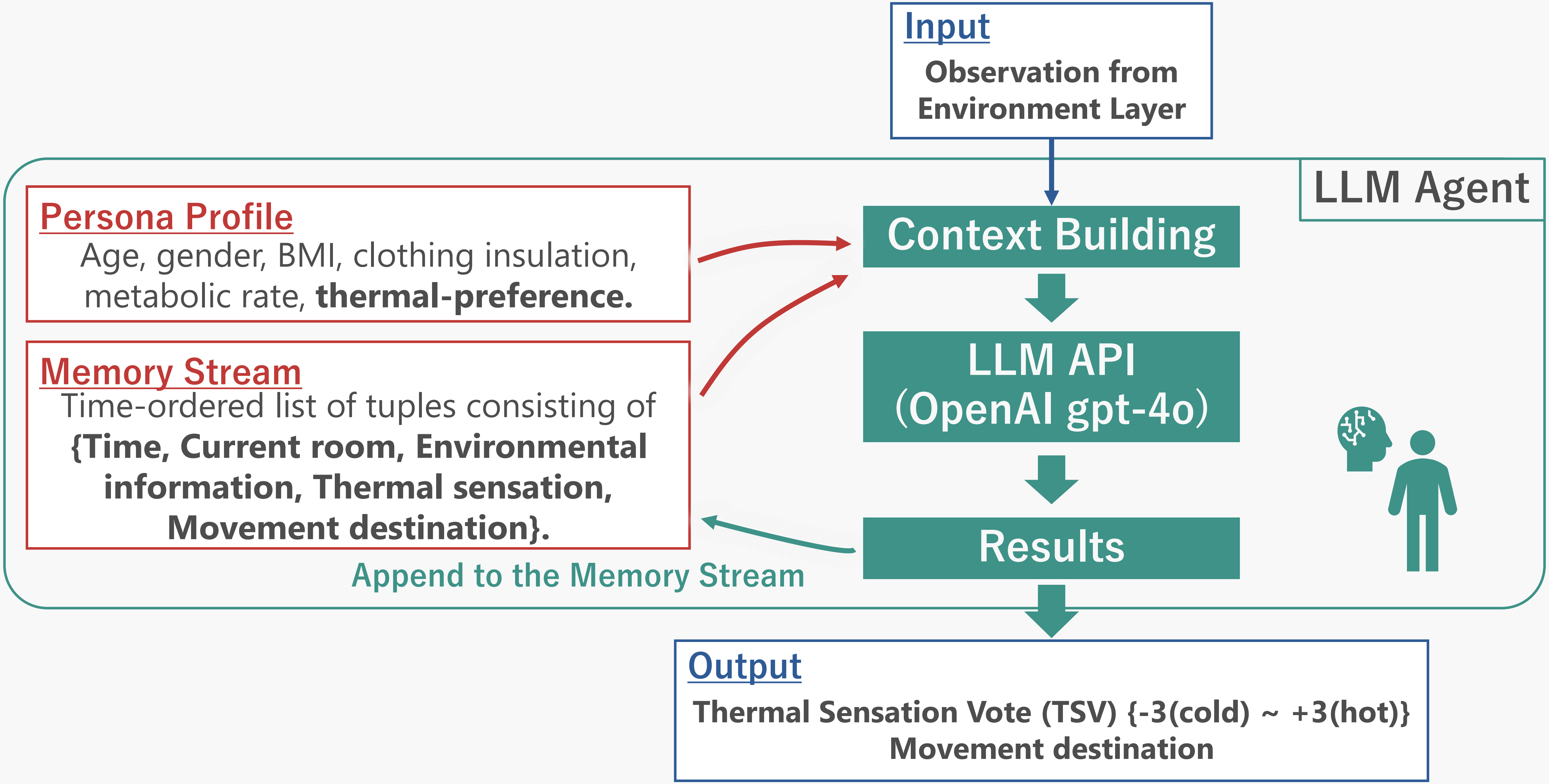
We propose a framework that models occupants' subjective thermal sensations and movement behaviors as LLM agents, and couples them with a Building Performance Simulation (BPS).



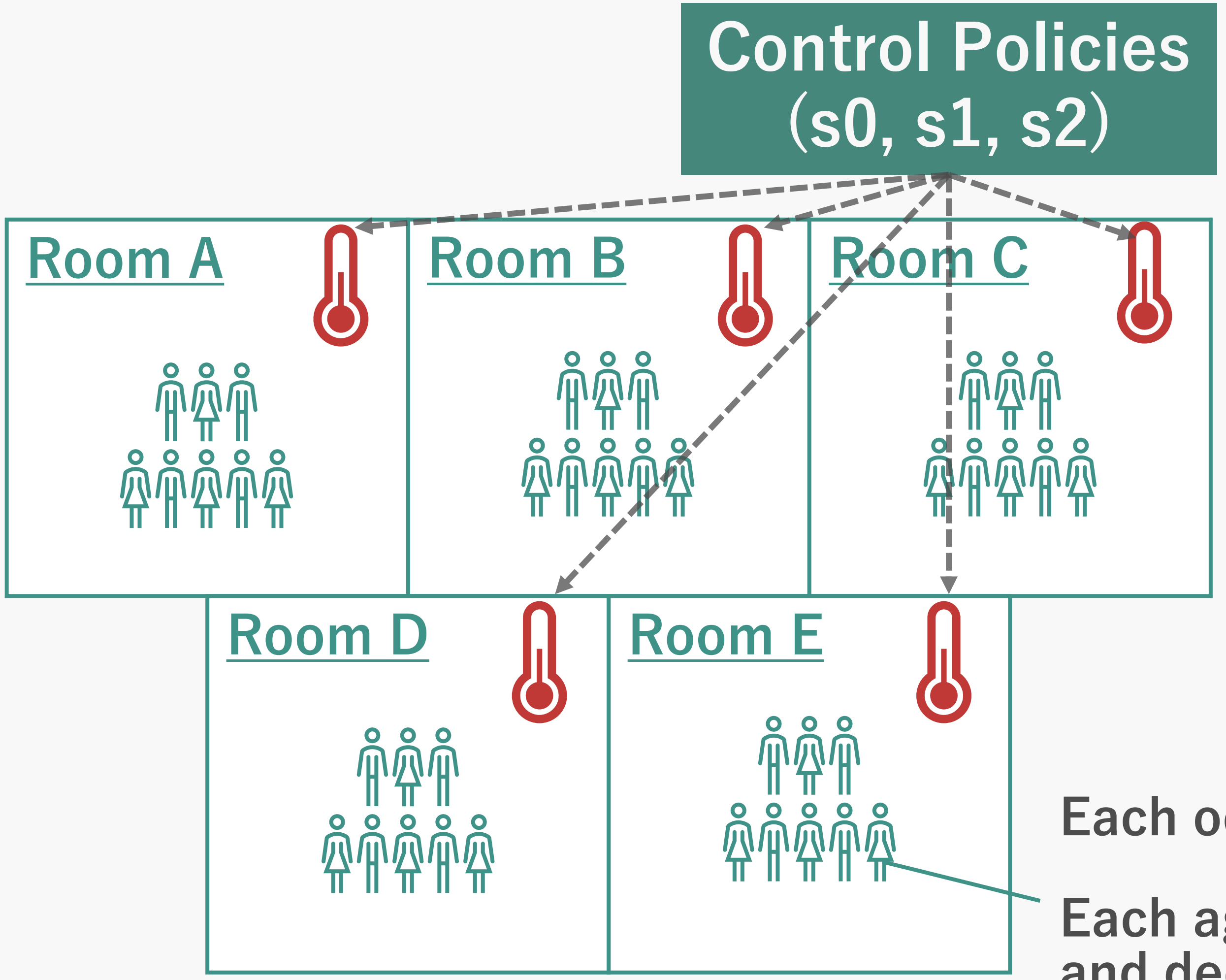
We propose a framework that models occupants' subjective thermal sensations and movement behaviors as LLM agents, and couples them with a Building Performance Simulation (BPS).



Agent Layer: Internalizing Occupants' Sensation and Movement



Adjusting per-room setpoints using control policies to maximize occupant comfort.

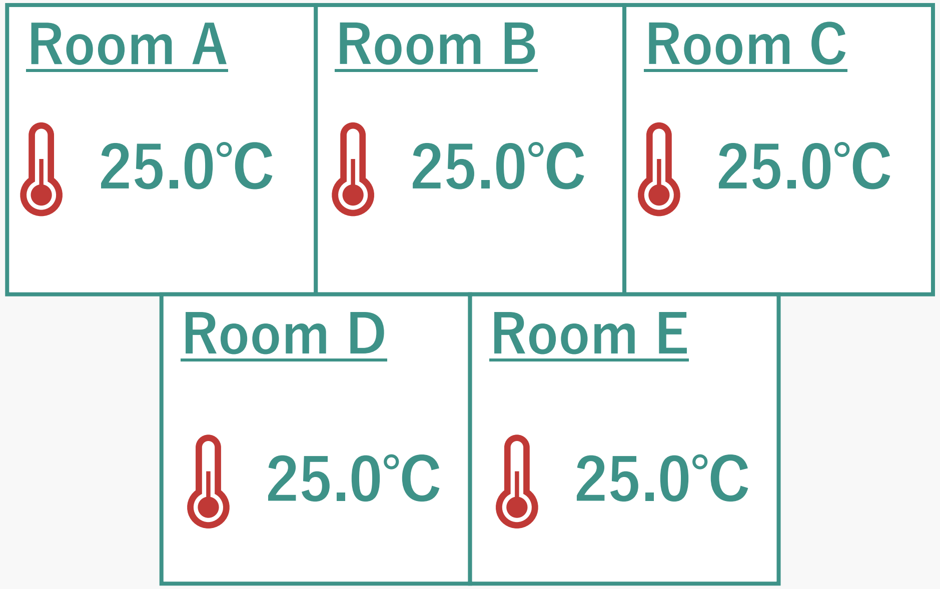


- Environment: A five-room building.
- Season: Summer
- Population: 50 occupants overall.
- Horizon: 10 hours (8 am to 6 pm).
- BPS : EnergyPlus 24.1.0

Each occupant is represented by an LLM agent.

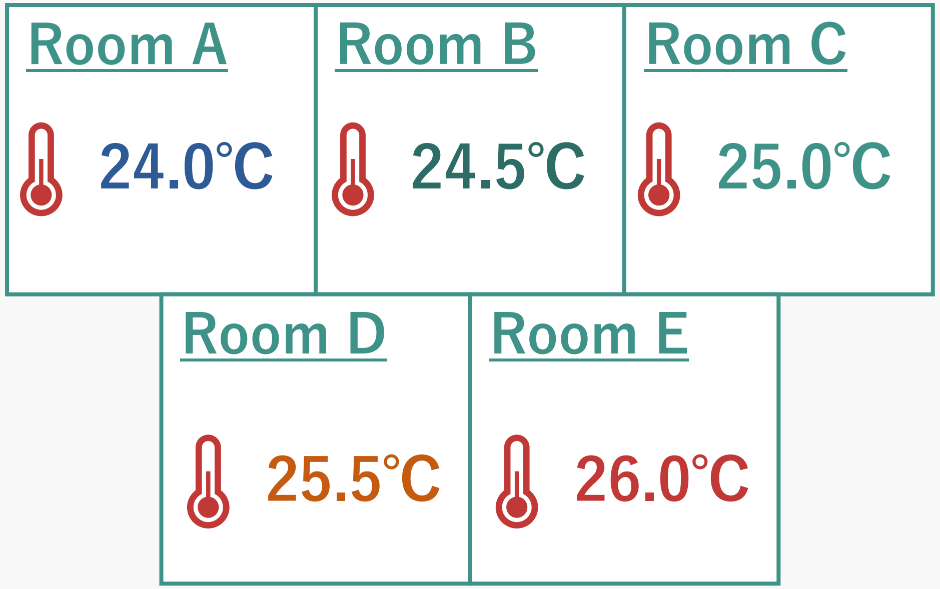
Each agent outputs a Thermal Sensation Vote (TSV) and decide whether to move.

Case Study: Control Policies (s0, s1)



s0: Global Fixed

- Conventional uniform-control.
- No agent-derived information is used, and actions do not change over time.



s1: Per-room Fixed

- Deliberately creates spatial thermal diversity.
- Passively leverages autonomous agent relocation for comfort improvement.

s2 adapts each room's setpoint temperature "t" using the UCB() algorithm.

UCB algorithm

$$UCB_t = \overline{R_t} + c\sqrt{\frac{2\ln n}{n_t}}$$

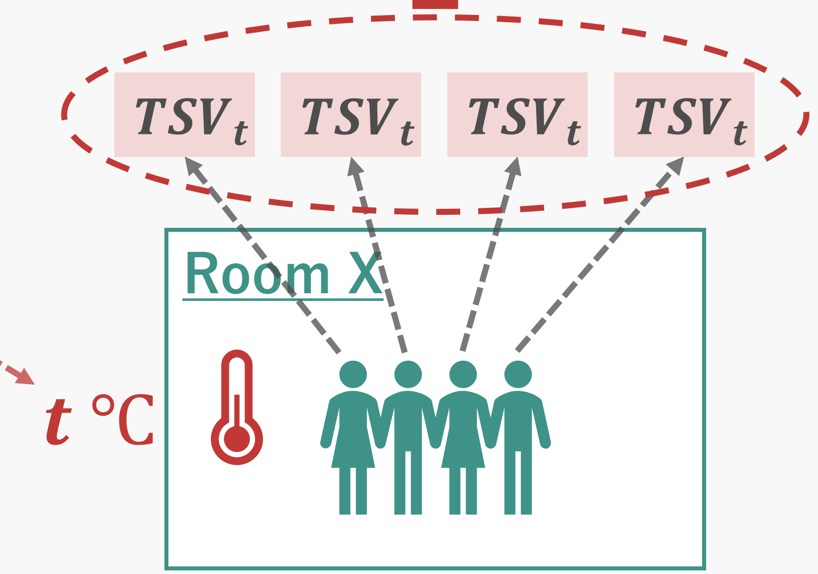
- Play the arm "t" that maximizes UCB_t

Loop

- Update UCB_t score

Reward $R_t \in [0, 1]$

$$(R_t = \overline{S_t},\ S_t = max\left\{0, 1 - \frac{|TSV_t|}{2}\right\})$$



Thermal Sensation Vote (TSV) $\in \{-3, -2, -1, 0, +1, +2, +3\}$

$\overline{R_t}$: The empirical mean reward of arm "t"
n : The total number of trials
n_t : The number of pulls of arm "t"
c : A tunable parameter ($c \in \{1.0, 0.5, 0.3, 0.1\}$)
A larger c prioritizes exploration.

Results: Thermal Sensation Vote (TSV) Distribution Over Time

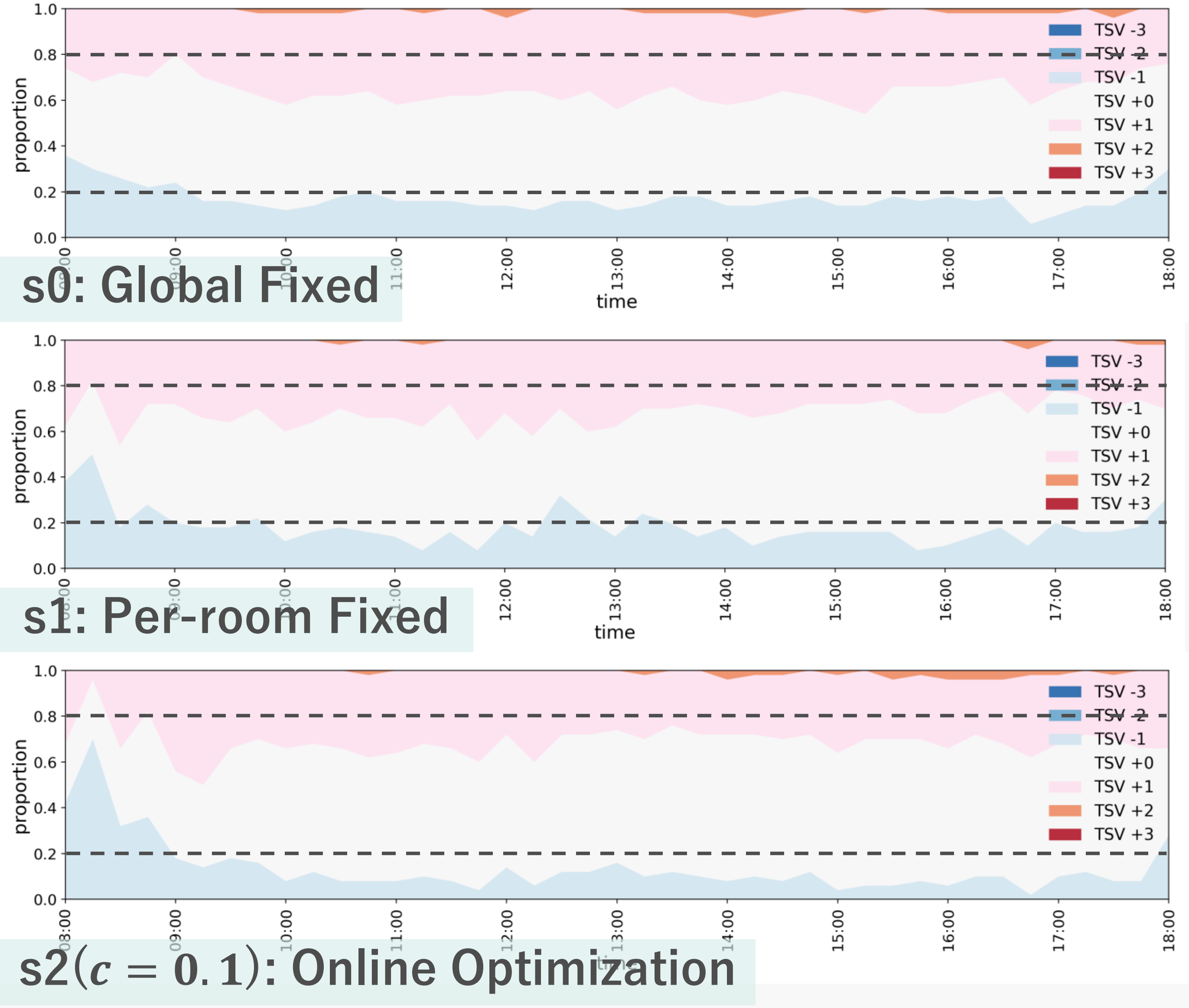


Fig: TSV distribution over time

- **s0: Lowest neutral share; extreme votes frequent (e.g., $\mathbf{TSV} \geq 2$).**
  - Occupants have different thermal preferences.
- **s1: Yields larger neutral ($\mathbf{TSV} = 0$) share and <u>fewer extreme votes</u> than s0.**
  - Occupants autonomously move between rooms in search of comfort.
- **s2($c = 0.1$): Achieve <u>highest neutral share.</u>**
  - Online optimization improves occupant comfort.

*** c : exploration coefficient**

Results: Cumulative Average |TSV| By Policy.

- s0: discomfort persists due to occupant heterogeneity.
- s1: improves comfort via spatial diversity and passive self-selection.
- s2: decline in discomfort, but slow initial gains.

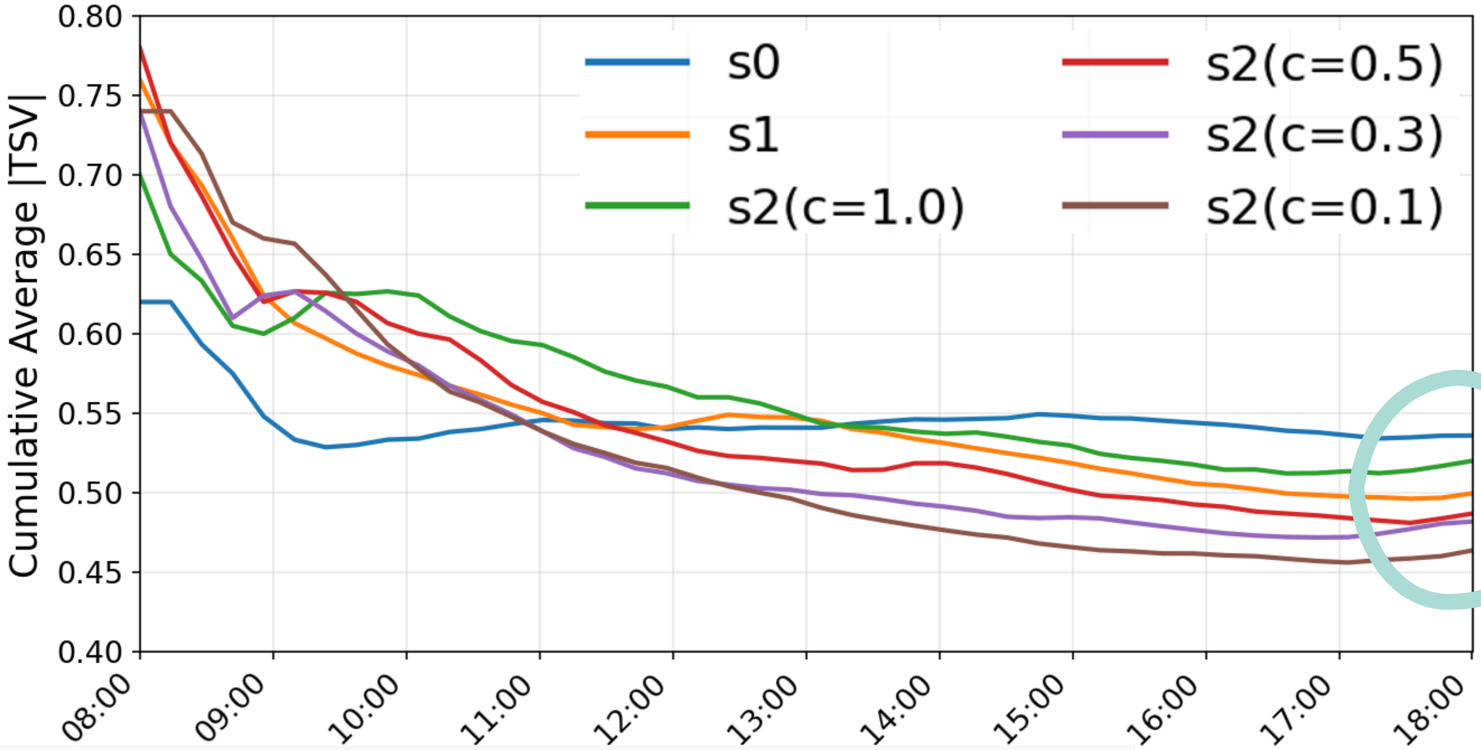


Fig: Cumulative average |TSV| by policy.

s2, with a tuned "c" and sufficient horizon, improves cumulative comfort.

s0: Global Fixed
s1: Per-room Fixed
s2($c \in \{1.0, 0.5, 0.3, 0.1\}$): Online Optimization

Conclusion

- Proposed framework successfully couples LLM agents with BPS.
- It establish a policy-agnostic evaluation testbed that allows for fair comparison of HVAC control strategies.
- It has the potential to be applied to real-world HVAC operation.

Future Work

- Extend scenarios (multiple buildings, climates, longer horizons).
- Conduct multi-objective studies (optimizing comfort, energy, fairness).
- Validate external validity using real occupant data.