Temporal Fingerprint Degradation in Sub-Zone Wi-Fi RSSI Occupancy Classification: Quantifying the Accuracy to Energy Transfer for Recalibration Optimized HVAC Control

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HVAC systems account for approximately 40% of building energy consumption, with significant waste arising from conditioning unoccupied spaces. While occupant-centric HVAC systems improve efficiency, most operate at the room level and fail to account for intra-room occupancy distribution, resulting in continued inefficiencies. Wi-Fi RSSI fingerprinting provides an infrastructure-free solution for indoor localization; however, existing research assumes temporal stability of signal patterns. In reality, indoor environments are dynamic, causing signal drift and degradation in localization performance. The impact of this degradation on HVAC efficiency and recalibration frequency remains insufficiently quantified. This study developed a prototype sub-zone HVAC control system evaluated over a four-week longitudinal experiment in a room divided into three sub-zones. RSSI fingerprints were collected using existing access points and classified using a K-NN model (k = 5). Data were collected weekly without retraining to simulate deployment conditions. Sub-zone detection accuracy declined from 95.0% at Week 0 to 65.0% at Week 4 without retraining. Overall system accuracy first fell below the 85% operational threshold at Week 3 (75.0%), with Zone B breaching the threshold one week earlier at Week 2 (80.0%). The accuracy-to-energy transfer function (r = -1.00) showed that each 10 percentage-point reduction in classification accuracy corresponded to approximately 882 J of additional estimated HVAC energy waste per session. Bi-weekly recalibration restored classification accuracy to 92.1%, confirming that bi-weekly maintenance interval is sufficient to maintain reliable sub-zone HVAC control above the operational threshold.

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