Department of

Computer Engineering

Abdullah Gül University

Internet of Things Project Report

COMP413

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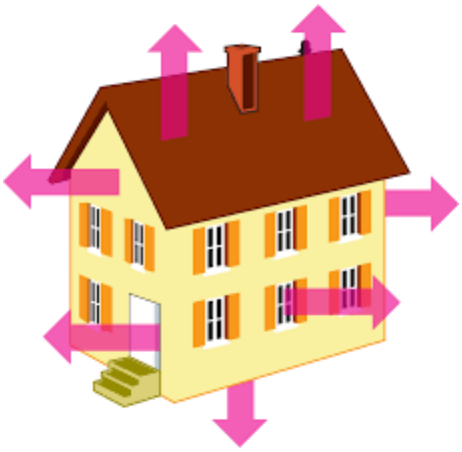
1. INTRODUCTION

This project aims to analyze and reduce heat loss in buildings to optimize energy consumption and maintain environmental sustainability. In daily life, minimizing heat loss is especially important in colder climates where high energy costs are a problem and helps individuals save energy and increase their comfort levels. By leveraging IoT technology, the project offers real-time data collection and analysis, helping users monitor and improve the efficiency of their structures. In the future, this system can be applied on a larger scale. For example, it can be integrated into smart city infrastructures to create energy efficiency maps of buildings and guide city governments in saving energy. Additionally, the incorporation of advanced technologies such as thermal cameras and satellite imaging can improve energy efficiency in larger communities and contribute to sustainable development goals.

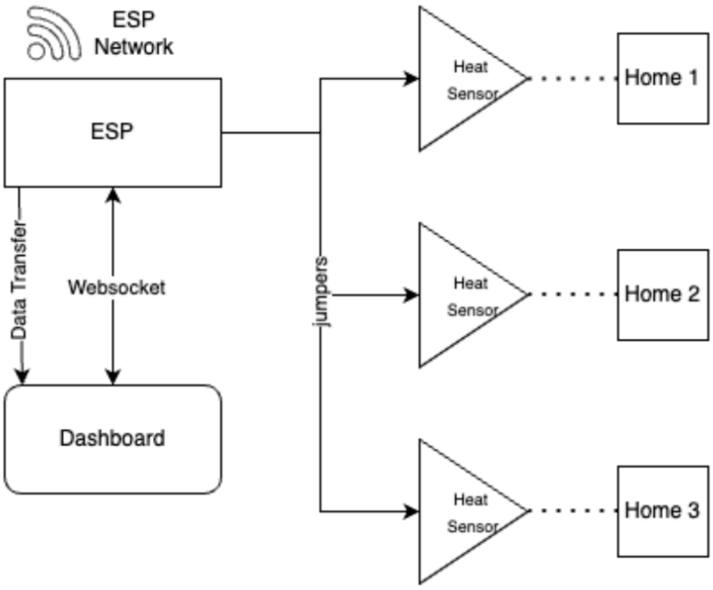
2. PROJECT DESCRIPTION

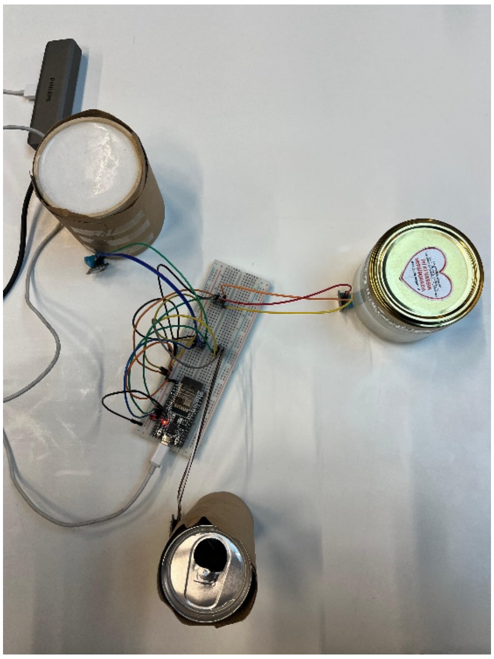
This project focuses on analyzing and reducing heat loss in buildings to adjust energy consumption in a balanced way while ensuring environmental sustainability. The project addresses the challenges posed by high energy costs and unnecessary heat retention, especially in colder weather, by providing innovative solutions that help people save energy and improve comfort in their homes.

The system, which also uses IoT technology, allows real-time data collection and analysis, which allows users to track and improve the energy efficiency of their buildings.



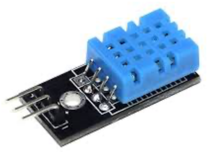
In the long term, the system can be enlarged and integrated into smart city infrastructures to create detailed energy efficiency maps of urban areas. These maps can help city governments identify energy-saving opportunities and develop policies that will promote sustainability. In addition, advanced technologies such as thermal cameras and satellite imaging can be incorporated to improve the accuracy and scalability of the system, facilitate energy efficiency improvements in larger communities, and significantly contribute to the global sustainable development goals.





The system architecture is designed to monitor and analyze heat loss in multiple homes using IoT technology. Heat sensors installed in each home collect temperature and heat loss data, which is transmitted to an ESP module via jumpers. The ESP module acts as the central hub, processing the incoming data and sending it to a real-time dashboard using websocket communication. The dashboard visualizes the data, providing insights into heat loss trends and enabling comparisons across homes to optimize energy efficiency. This scalable design allows for easy integration of additional homes and sensors, supporting broader applications in smart city infrastructures.

ESP Module: The ESP module is the core of the system, responsible for managing data transmission between heat sensors and the dashboard. It processes the collected data and ensures real-time communication through websocket protocols, enabling low-latency updates.



Heat Sensors: Heat sensors are deployed in each home to monitor temperature and detect heat loss. These sensors provide critical data for analyzing the energy efficiency of buildings and identifying areas for improvement.

2.1 DASHBOARD

The dashboard is a central component of the "Analyzing and Reducing Heat-Loss in Smart Cities" project, offering users an intuitive interface to monitor and manage heat loss data in real-time. Built with the Dash framework and Dash Bootstrap Components, the dashboard ensures a responsive and visually appealing design compatible with desktops, tablets, and smartphones.

a) Key Features

1. Real-Time Data Streaming

• Websocket Integration: Utilizes Websocket protocols to maintain a continuous connection with the ESP module, enabling the dashboard to receive and display temperature and humidity data from heat sensors every five seconds without manual refreshes.

• Dynamic Visualization: Real-time updates allow users to instantly observe changes in their environment, facilitating prompt actions to address excessive heat loss.

2. Heat Loss Alerts

• Threshold-Based Notifications: Users can set specific temperature thresholds. When sensor readings exceed these limits, the system triggers alerts, notifying users of potential heat loss issues.

• Modal Pop-Ups: Alerts are displayed as modal pop-ups, clearly indicating which sensor has breached the threshold and prompting necessary actions.

3. Time-Dependent Analysis

• Historical Data Visualization: Interactive graphs display temperature and humidity trends over time, enabling users to identify patterns and assess the effectiveness of insulation measures.

• Customizable Time Frames: Users can adjust the time range for data visualization, supporting both short-term monitoring and long-term analysis.

4. Data Download and Export

• CSV Export Functionality: Users can download sensor data in CSV format for further analysis or record-keeping, accessible via a dedicated download button.

• User-Friendly Interface: The export feature is seamlessly integrated, allowing effortless data retrieval without leaving the main dashboard.

5. User Interface and Experience

• Responsive Design: Ensures consistent performance across various devices, enhancing accessibility and usability.

• Intuitive Navigation: Organized layout with navigation bars, sensor information cards, interactive graphs, and actionable buttons for easy feature access.

b) Integration and Scalability

The dashboard integrates seamlessly with the system architecture, acting as the hub for data visualization and user interaction. Its modular design supports the addition of new sensors and features, ensuring scalability for larger smart city deployments.

c) Benefits

• Enhanced Monitoring: Real-time data and alerts help maintain optimal energy efficiency.

• Informed Decision-Making: Comprehensive visualizations enable data-driven energy management.

• Scalability: Accommodates future expansions, suitable for growing urban environments.

• User Empowerment: Provides actionable insights for effective energy consumption management.

The dashboard is essential for achieving the project's goal of reducing heat loss and enhancing energy efficiency, contributing to sustainable urban development.

1.1. TINYML INTEGRATION

The integration of TinyML into the **“Analyzing and Reducing Heat-Loss in Smart Cities”** project significantly enhances the system’s capability to process data efficiently at the edge, thereby optimizing energy consumption and improving overall performance. TinyML refers to the deployment of machine learning algorithms on low-power, resource-constrained devices, enabling intelligent data processing directly on the sensor nodes.

a) Implementation

In this project, TinyML is deployed on the ESP modules that act as central hubs for data collection from heat sensors. Lightweight machine learning models are trained to analyze temperature and humidity data in real-time, enabling immediate detection of anomalies and predictive maintenance. The models are optimized for low memory and computational power, ensuring seamless operation without draining the device’s battery or requiring extensive processing resources.

b) Key Features

1. Anomaly Detection

• Real-Time Monitoring: TinyML models continuously monitor incoming sensor data to identify unusual patterns indicative of excessive heat loss or sensor malfunctions.

• Immediate Alerts: Upon detecting an anomaly, the system generates instant alerts, allowing users to take prompt corrective actions to mitigate heat loss and maintain energy efficiency.

2. Predictive Analytics

• Heat Loss Prediction: By analyzing historical and real-time data, TinyML models predict potential heat loss trends, enabling proactive measures such as adjusting heating systems or enhancing insulation before significant energy loss occurs.

• Energy Consumption Forecasting: The models forecast future energy usage based on current trends, assisting users in optimizing their energy consumption strategies.

3. Edge Processing

• Data Reduction: TinyML processes data locally on the ESP modules, reducing the volume of data transmitted to the dashboard. This not only minimizes bandwidth usage but also enhances data privacy by limiting the amount of raw data sent to central servers.

• Latency Minimization: Processing data at the edge ensures low-latency responses to critical events, such as sudden temperature drops, thereby improving the system's responsiveness and reliability.

c) Benefits

• Enhanced Efficiency: By offloading data processing to the edge, the system reduces the need for continuous data transmission, leading to lower energy consumption and extended device lifespan.

• Scalability: TinyML enables the system to scale effortlessly by adding more sensor nodes without overwhelming the central processing unit, supporting the expansion into larger smart city infrastructures.

•Cost-Effectiveness: Local data processing reduces the reliance on cloud-based services, lowering operational costs and improving the overall cost-effectiveness of the solution.

3. REAL-WORLD INSPIRATION

The inspiration for this project stems from the need to address energy inefficiencies in buildings, which contribute significantly to global energy consumption and carbon emissions. At the same time, in many parts of the world, especially in regions with colder climates, poor heat retention in buildings leads to higher energy costs and environmental strain.

The project is aligned with global initiatives such as the United Nations Sustainable Development Goals (SDG 7 and SDG Jul 11), which emphasize sustainable cities and communities, as well as affordable and clean energy. Inspired by the real-world challenges of balancing energy efficiency with environmental responsibility, it ensures that it is both timely and effective for modern urban development.

4. RESULTS AND DISCUSSION

The project monitored and analyzed heat loss in multiple homes using real-time data collected from IoT-based heat sensors. The instrument panel showed temperature variations, comparing decking materials and information about heat retention efficiency. The data showed significant heat loss from windows and walls, highlighting the importance of better insulation strategies to improve energy efficiency and reduce costs.

During the project, various difficulties were encountered, including sensor calibration, which required precise adjustments to ensure accurate data collection. Network connection outages interrupted real-time data transmission, affecting the dashboard's performance.

The project has sufficient potential for future applications and scalability. By combining advanced technologies such as thermal cameras and satellite imaging, the system can be used to create large-scale energy efficiency maps. Integration into smart city infrastructures will enable city governments to develop comprehensive energy-saving strategies.

5. REFERENCES

-M. R. Johnson and T. R. Lee, "Energy efficiency and the role of IoT in a smart city connected community," in IEEE Conference Publication

-J. A. Smith, "Energy Efficiency in Smart Buildings: IoT Approaches," in IEEE Journals & Magazine