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Assessment:	Portfolio
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Feedback	

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Case Study

In today's world, even with modern technology designed for comfort and privacy, many low-income residents still struggle with problems such as burglary and having their belongings accessed illegally and stolen. Privacy is important for everyone, and today's tools can be adapted to help protect it. According to findings of Tilley, Tseloni and Farrell, (2011) between 1995 and 2008, domestic burglary in England and Wales fell overall, largely due to increased use of security measures. Wealthier households, with greater access to high-tech and enhanced security, experienced lower burglary rates, while poorer households, with low-income, continued to face higher burglary risks. Their conclusion was that expanding enhanced security for low-income households could further reduce national burglary rates.

Another common issue happens when people who live alone spend most of their day at work. When they return home, especially to small apartments, they often face uncomfortable indoor conditions such as too much heat and poor air flow. They have to wait in this uncomfortable environment until ventilation improves, and they must turn on fans or windows themselves. According to the World Health Organization, (2024) indoor poor air quality was responsible for around 3.2 million deaths in 2020 alone, including over 237 000 deaths of children under the age of 5. The total impact of household environment air pollution corresponds to an estimated 6.7 million premature deaths per year. Even though there are solutions that fix these problems, they are usually expensive. Therefore, the solution in question needs to be low-cost, easy to install in homes with low-maintenance, and able to expand for wider use. This case and its solution support Sustainable Development Goal (SDG) 11, which aims to make cities safe, inclusive, resilient, and sustainable. The further relevance of the proposed solution to SDG 11 goals will be discussed further in the following paragraphs.

Proposed Solution

Before delving into solutions let's first understand what technology is. Modern technologies serve as the building blocks of the Internet of Things (IoT). They power today's digital infrastructure, such as smart home devices, wearable gadgets, connected vehicles, and industrial sensors. In other words, when we talk about these technologies, we are effectively referring to the fundamental "*Lego blocks*" of IoT that make up today's advanced technologies.

The findings of Mobaraki et al., (2022) demonstrate that even with reduced monitoring budgets, residents can still utilize low-cost sensors, which are DHT11/DHT22 to monitor the environment temperature, while still being accurate and even comparable to high cost measurement devices. The accuracy of their developed monitoring systems showed that the measurement errors tend to decrease with the increase in the number of sensors. Based on the DHT11 values, the automatic control of fan logic can further be applied to improve the occupant comfort without a high budget. A key aspect of this solution's relevance to SDG 11 is not just monitoring indoor temperature but also actively controlling apartment ventilation. According to Less et al., (2019), the sensor-driven fan achieved significant energy savings while providing better thermal regulation compared to always-on fan solutions.

Vardakis et al. (2024) highlight that IoT-enabled homes enhance security through automated monitoring with cameras and sensors, improving situational awareness via alerts and logs. Even if an intruder enters, indoor cameras can help identify them and recover stolen items. While the authors' review emphasizes general benefits, using real-time door-approach alerts along with keypad unlocking, beyond traditional keys, can notably reduce the time of intruders getting inside of the house. Additionally, generating an audible alert for incorrect password attempts can draw neighbor's attention and they may potentially intervene, ultimately lowering the likelihood of burglary and enhancing perceived safety.

Overall, the impact of the proposed solution directly contributes to SDG by sustaining the safety of the house, health and comfort of residents while also being relatively cheap and saving natural resources. However, this solution is not without its flaws, as of Vardakis et al. (2024) concern with the increased cybersecurity risks, IoT devices increase digital attack and privacy intrusions.

Things used

Here is the list of all devices used in this project along with their configurations:

Sensors:

- Ultrasonic distance sensor (*HC-SR04*)
- Temperature & Humidity sensor (*DHT11*)
- IR sensor
- 4×4 Membrane Keypad

Actuators:

- Servo motor (*SG90*)
- LED
- Buzzer (*activate*)
- Small Fan

Sensor pins:

- Ultrasonic (*HC-SR04*) → TRIG, ECHO
- DHT11 → digital pin
- IR sensor → digital pin
- Keypad → 8 pins (*rows & columns*)

Actuator pins:

- Servo → PWM pin
- LED → digital pin
- Buzzer → digital pin
- Fan → digital pin

Libraries:

- DHT.h for DHT11
- Keypad.h for 4×4 keypad
- Servo.h for servo motor
- NewPing for Ultrasonic
- ArduinoJson.h for sending data

Pin modes:

- Sensors: INPUT
- Actuators: OUTPUT

Default states:

- Servo → 0° (*door closed*)
- LED → Off
- RGB → Off
- Buzzer → Off
- Fan → Off

Communications:

- USB serial cable

Link for the web application (Works on Chrome, Edge, Opera): *https://iot-security.netlify.app*

Link for the github repository: *https://github.com/00015775/iot-security*

Cisco Packet Tracker Badge (*Public Link*):
https://www.credly.com/badges/7a9e639f-89d9-4908-aaf3-5832fa9c722f/public_url

Because high-quality cameras are expensive, this security project uses an HC-SR04 ultrasonic sensor and IR sensors instead. The ultrasonic sensor detects if someone is approaching the door and sends a notification to the user through the web app. However, since the HC-SR04 does not work well at very close range, an IR sensor was added. The IR sensor detects when a person is standing directly at the door. When that happens, a message or voice alert is shown on a display, telling the visitor to enter a code on the keypad.

If the code entered is incorrect, a buzzer sounds for 1–2 seconds and the RGB LED turns red. The owner is also notified through the web dashboard and can see how many failed attempts have happened. This process continues until the correct code is entered. When the correct code is entered, the door opens automatically for 4 seconds and then closes again so it is not left open.

The system also includes a sensor-controlled fan for air ventilation. It runs whether someone is inside the house or not. When the temperature detected by the DHT11 sensor goes above a set limit, the fan turns on to keep the room temperature below the chosen value. DHT11 was specifically used as per the requirements of the solution being low-cost but yet accurate as it was discussed by Mobaraki et al., (2022).

All communication between the system and the web interface uses USB serial communication, which provides fast access to sensor data and control of devices. Through the web interface, the user can monitor, control, and change different values in the system

Control of actuators:

- Servo (*Door Lock*): Open / Close
- Fan: Turn ON/OFF override
- RGB LED: Choose (*Red, Blue*)
- Buzzer: Turn ON/OFF (*for alarm test*)

Password Management:

- Change the door unlock password (*Arduino keypad code*).
- Require confirmation before saving.
- Minimum 4 digits.
- Push new password to Arduino.

Data Visualization:

- Temperature trend (*line chart, last 30 seconds*).
- Number of door unlock attempts (*bar chart*).

Data Analysis:

- Average Temperature: 23.5°C
- Total Visitors Today: 12
- Failed Attempts Today: 3
- Maximum Temperature Today: 29°C
- Number of times Fan Activated: 5

Device Settings:

- Set temperature threshold for fan.
- Set ultrasonic thresholds (*someone approaching the door*).
- Set a new door unlock password.
- Reset settings to the default state.

The chosen components were selected mainly for affordability and reliability. The HC-SR04 ultrasonic sensor was used because it can detect objects from a longer distance at a low cost, making it suitable for early detection when someone approaches the door. However, as discussed due to HC-SR04 limitations, an IR sensor was added as a secondary short-distance detector, which also comes at the low cost. Even though the camera could have done a better job for this task, it is certainly more expensive than the combined price of HC-SR04 and IR sensors. USB serial communication was preferred over alternatives like Wi-Fi or Bluetooth because it gives faster, more stable access to sensor data without additional setup costs or high latency issues. Together, these choices provide a reliable, low-cost, and practical home security system that still achieves real-time monitoring and control through a web interface.

Although the listed components were chosen for this project, the system's performance could be improved by using a camera instead of ultrasonic and IR sensors. A camera is generally more expensive, but there are still reasonably priced models that offer HD quality, and even 720p provides comparable results. For remote access, a Wi-Fi module could have been used to enable true online control of the system, but this would increase the risk of cybersecurity threats to the home network.

The web interface was developed using basic HTML with inline CSS and JavaScript for interactivity. Since the author of this project is not much of a web developer, the huge reliance was towards external sources such as GitHub repositories to implement the communication between the Arduino and the computer, allowing sensor data to be displayed on the UI. Additionally, YouTube tutorials were used and modified to fit the requirements of the project. All references for the Arduino and HTML code, as well as unit testing for each component, are included in the project files and can also be found on the GitHub repository.

- Calculations on the approximate power/current/voltage usage:

Power formula: Power = Voltage × Current:
- HC-SR04: V=5, C=0.015 → P=5×0.015=0.075 W
- DHT11: V=5, C=0.0002 → P=5×0.0002=0.001 W
- IR Sensor: V=5, C=0.043 → P=5×0.043=0.215 W
- 4×4 Keypad: V=5, C=0.005 → P=5×0.005=0.025 W
- SG90 Servo: V=5, C=0.220 → P=5×0.220=1.10 W
- Buzzer: V=5, C=0.02 → P=5×0.02=0.10 W
- Fan: V=5, C=0.13 → P=5×0.13=0.65 W

Total Current: 0.4632 A
Total Power: 5×0.4632=2.32 W
Fan transistor base: (5−0.7)/1000=0.0043 A

The approximate values for each components were derived from this websites:

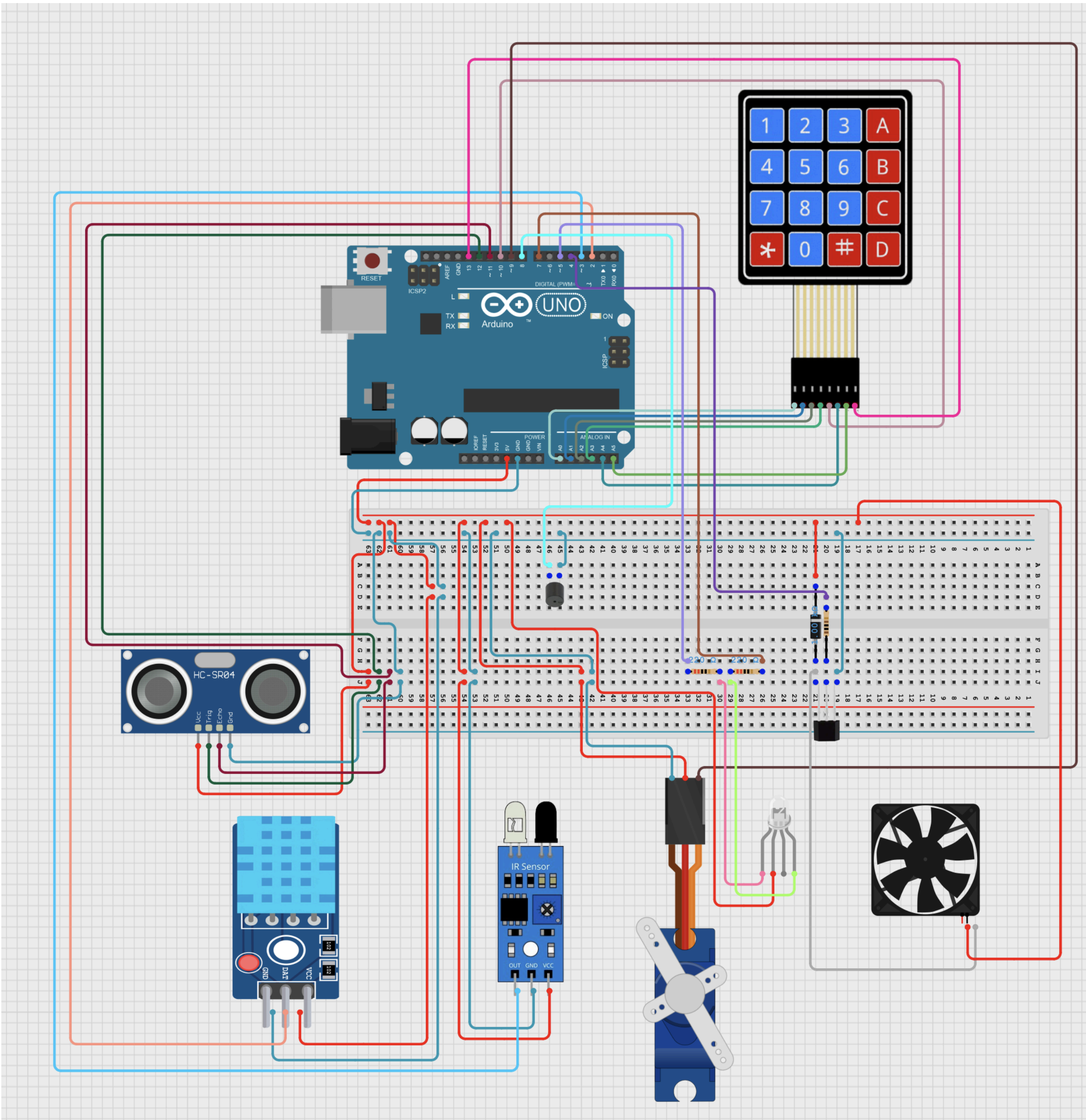
Wikipedia (2019). Available at https://en.wikipedia.org/wiki/Arduino_Uno.

“5V DC Fan.”, (2025). *AmoTech Electronics*, Available at: www.amotechelectronics.com/product-page/5v-dc-fan.

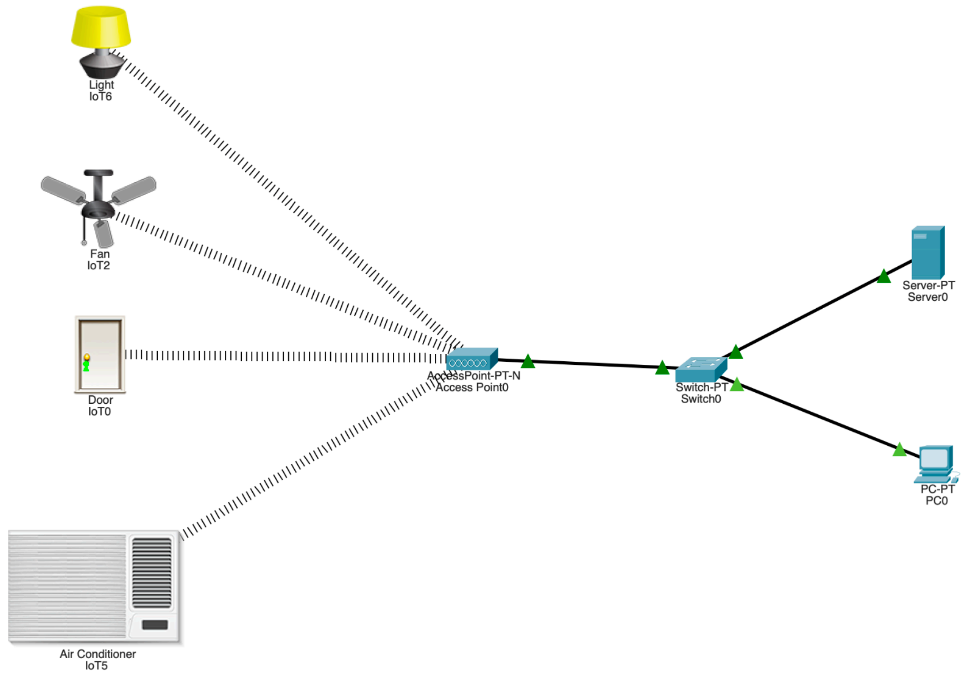
“SG90 Servo.”, (2025). *RoboRider Labs*. Available at: roboriderlabs.com/pages/sg90-servo.

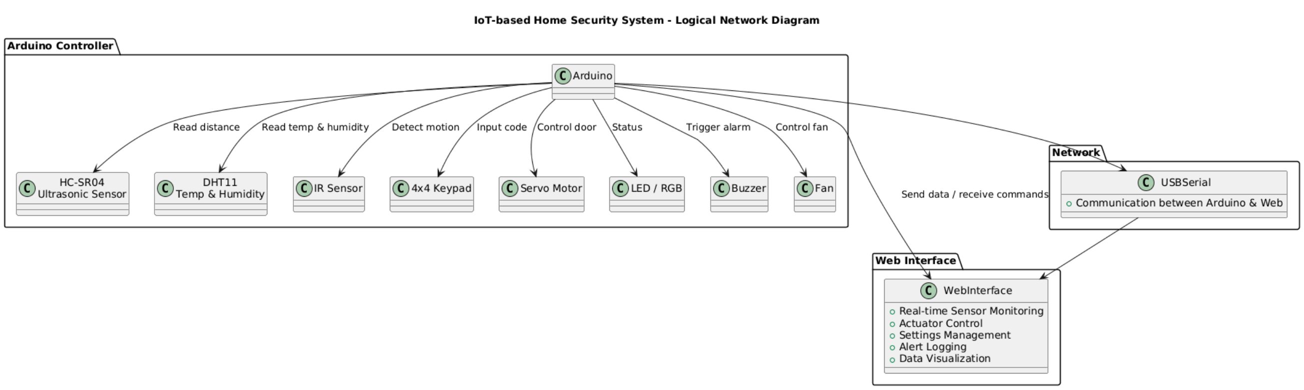
Complete Guide for Ultrasonic Sensor HC-SR04 with Arduino (n.d.). Available at: https://universal-solder.ca/downloads/HC-SR04_Ultrasonic_arduino_guide.pdf

Circuit Diagram

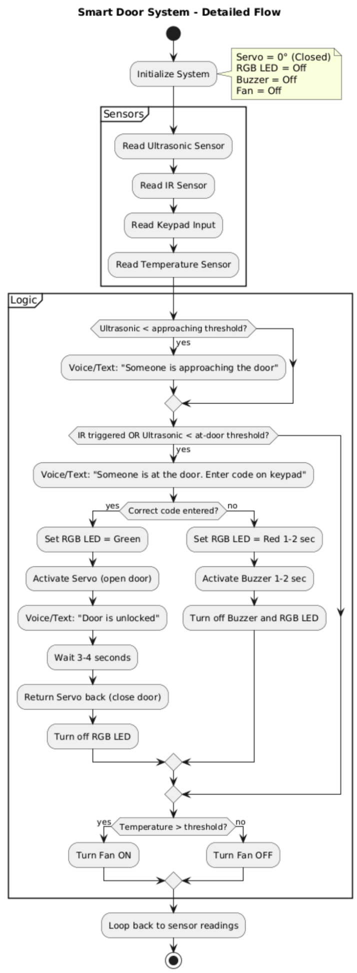


Network Diagram





Flow Diagram



Reflection on results and future work

While the proposed low-cost IoT security and ventilation system demonstrates its potentials, it is not without limitations. The usage of distance sensors cannot provide the detailed visual details that a camera has to offer, potentially limiting the identification of intruders. The system relies on USB serial communication, which restricts true remote access, meaning that users cannot monitor or control their home systems truly online without being physically connected to the Arduino. Additionally, the current setup does not address cybersecurity risks, as there is no user or admin privileges or passwords enforced in order to access the web application. A single DHT11 sensor may not accurately measure temperature changes across larger rooms, which limits the precise climate control. The keypad logic does not have a set of specific number of trials, which can help to prevent the intruder from trying to guess the password. Despite these limitations, the prototype more or less achieves the stated proposed solution and goal of improving safety and improving the occupant comfort at the low-cost budget. Future improvements could include adding a camera module such as ESP32CAM for enhanced visual security and also implementing WIFI module for a true remote monitoring and control of actuators. As with WIFI module integration, cybersecurity measures should also be considered. Overall, while the prototype more or less reaches its stated goal, the discussed enhancements would make the system more reliable and scalable for wider use.

References

Less, B.D., Dutton, S.M., Walker, I.S., Sherman, M.H. and Clark, J.D. (2019). *Energy savings with outdoor temperature-based smart ventilation control strategies in advanced California homes*. Energy and Buildings, 194, pp.317–327. doi:https://doi.org/10.1016/j.enbuild.2019.04.028. (Accessed: 8th December).

Mobaraki, B., Komarizadehasl, S., Castilla Pascual, F.J. and Lozano-Galant, J.A. (2022). *Application of Low-Cost Sensors for Accurate Ambient Temperature Monitoring*. Buildings, [online] 12(9), p.1411. doi:https://doi.org/10.3390/buildings12091411. (Accessed: 8th December).

Tilley, N., Tseloni, A. and Farrell, G. (2011). *Income Disparities of Burglary Risk: Security Availability during the Crime Drop*. British Journal of Criminology, 51(2), pp.296–313. doi:https://doi.org/10.1093/bjc/azr010. (Accessed: 8th December).

Vardakis, G., Hatzivasilis, G., Koutsaki, E. and Papadakis, N. (2024). *Review of Smart-Home Security Using the Internet of Things*. Electronics, [online] 13(16), pp.3343–3343. Available at: https://www.mdpi.com/2079-9292/13/16/3343. (Accessed: 8th December).

World Health Organization (2024). *Household Air Pollution and Health*. [online] who.int. Available at: https://www.who.int/news-room/fact-sheets/detail/household-air-pollution-and-health. (Accessed: 8th December).

Appendix:

Cisco Packet Tracker Badge (*Public Link*): https://www.credly.com/badges/7a9e639f-89d9-4908-aaf3-5832fa9c722f/public_url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