ASSIGNMENT FINAL REPORT

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INTRODUCTION

This course offers a comprehensive understanding of IoT, covering principles, architectures, sensor networks, communication protocols, data analytics, security, and privacy. Through hands-on projects and case studies, students will gain practical experience in designing IoT solutions and developing innovative applications. Join us to explore how IoT is driving the next wave of technological innovation.

Scenario: I'm a product developer at a startup, designing IoT products for various clients. Recently, I was tasked with developing a new IoT product. My role involves identifying a target user, testing with them, and refining the product based on their feedback.

❖ **This report consists of the following chapters**:

Chapter 1: Analyse what aspects of iot are necessary and appropriate when designing software applications. (LO1)

- **P1:** Explore various forms of IoT functionality
- **P2:** Review standard architecture, frameworks, tools, hardware and APIs available for use in IoT development.ss

Chapter 1: Outline a plan for an appropriate iot application, using common architecture, frameworks, tools, hardware and apis. (LO2)

- **P3:** Investigate architecture, frameworks, tools, hardware and API techniques available to develop IoT applications.
- **P4:** Discuss a specific problem to solve using IoT.

Chapter 3: Develop an iot application using any combination of hardware, software, data, platforms and services. (LO3)

- **P5:** Analyse what aspects of IoT are necessary and appropriate when designing IoT system on network platform.
- **P6:** Run end user experiments and examines feedback.

Chapter 4: Evaluate your iot application and the problems it faces may be encountered when integrating into the broader iot ecosystem. (LO4)

- **P7:** Evaluate end user feedback from your IoT application.
- **P8:** Investigate the potential problems the IoT application might encounter when integrating into the wider system.

LO1 : ANALYSE WHAT ASPECTS OF IOT ARE NECESSARY AND APPROPRIATE WHEN DESIGNING SOFTWARE APPLICATIONS.

1. Explore various forms of IoT functionality. (P1)

1.1. What is IoT?

The Internet of Things (IoT) is defined as "a dynamic global network infrastructure with self-configuring capabilities based on standard and interoperable communication protocols where physical and virtual 'things' have identities, physical attributes, and virtual personalities and use intelligent interfaces, and are seamlessly integrated into the information network, often communicate data associated with users and their environments."

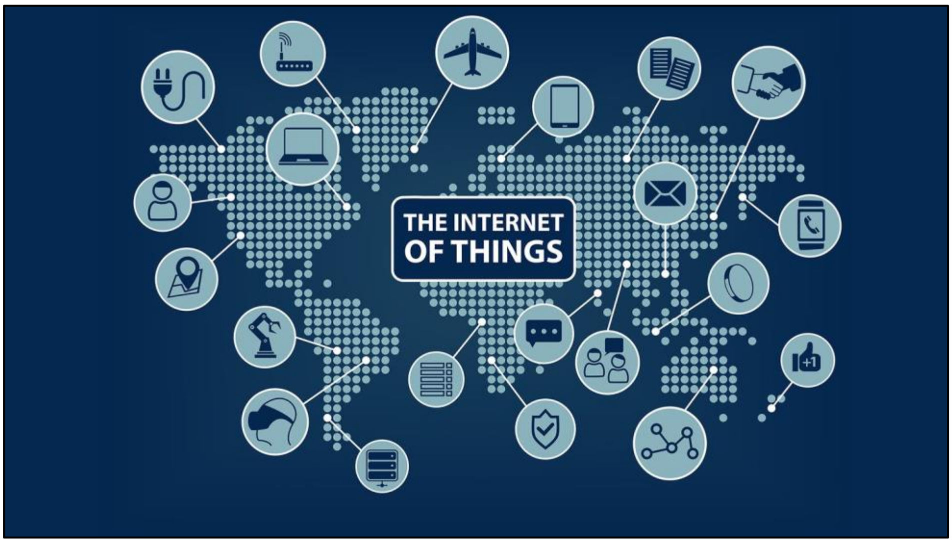


Figure 1-1 The Internet of Things (IoT)

1.2. History of IoT.

The history of the Internet of Things (IoT) showcases its evolution from a novel concept with an internet-connected toaster in 1989 to a transformative technology with over 10 billion active devices by 2021, revolutionizing connectivity and efficiency in various aspects of life and industry.

❖ **Early Beginnings (1980s-1990s)**

- 1989: The first IoT device was created by John Romkey, who connected a toaster to the internet, allowing it to be controlled remotely. This was a groundbreaking step towards the integration of physical devices with the internet.
- 1993: The first online webcam was used at the University of Cambridge. This device was designed to monitor a coffee pot, enabling staff to check its status online, marking an early example of remote monitoring.
- 1994: Steve Mann, a researcher at the University of Toronto, created WearCam, one of the

first wearable devices with internet connectivity, laying the groundwork for future development of smart wearables.

❖ **Development of Terminology and Technology (1999-2000s)**

- 1999: Kevin Ashton, a researcher at MIT, coined the term "Internet of Things" (IoT) during a presentation at Procter & Gamble. He envisioned a system where the internet was connected to the physical world via sensors.

- 2000: LG announced the first smart refrigerator, a household appliance with internet connectivity, marking a significant milestone in the application of IoT in everyday life.

❖ **Standardization and Early Applications (2000s)**

- 2005: The United Nations published its first report on the Internet of Things, highlighting the potential of connected devices to improve human life and resource management.

- 2007: Apple launched the first iPhone, a mobile device with robust internet connectivity, which spurred the development of mobile IoT applications.

- 2008: The number of connected devices surpassed the number of people in the world, marking the official "birth" of IoT.

❖ **Expansion and Growth (2009-2016)**

- 200: The original Fitbit activity tracker was released, enabling users to monitor their health and daily activities online, demonstrating the practical applications of IoT in personal health.

- 2011: The Industrial Internet of Things (IIoT) emerged, applying IoT technology to industries such as manufacturing, energy, and transportation to optimize processes and improve efficiency.

- 2014: Seoul became the world's first smart city, using IoT technology to manage traffic, energy, and public services more effectively.

- 2015: IoT became mobile with the development of smartphone applications, allowing users to control and monitor IoT devices remotely.

- 2016: Amazon Web Services (AWS) launched AWS IoT Core, a cloud platform that facilitated the connection and interaction of IoT devices, accelerating the growth of IoT in various sectors.

❖ **Global Recognition and Impact (2020-2022)**

2020: The number of IoT device connections increased to more than 50% of active connected devices, indicating a rapid expansion in the adoption of IoT technology.

- 2021: More than 10 billion active IoT devices were in use, reflecting the widespread and growing influence of IoT globally.
- 2022: The World Economic Forum recognized IoT as one of the three most impactful technological advancements, underscoring its critical role in shaping the future of technology and human life.

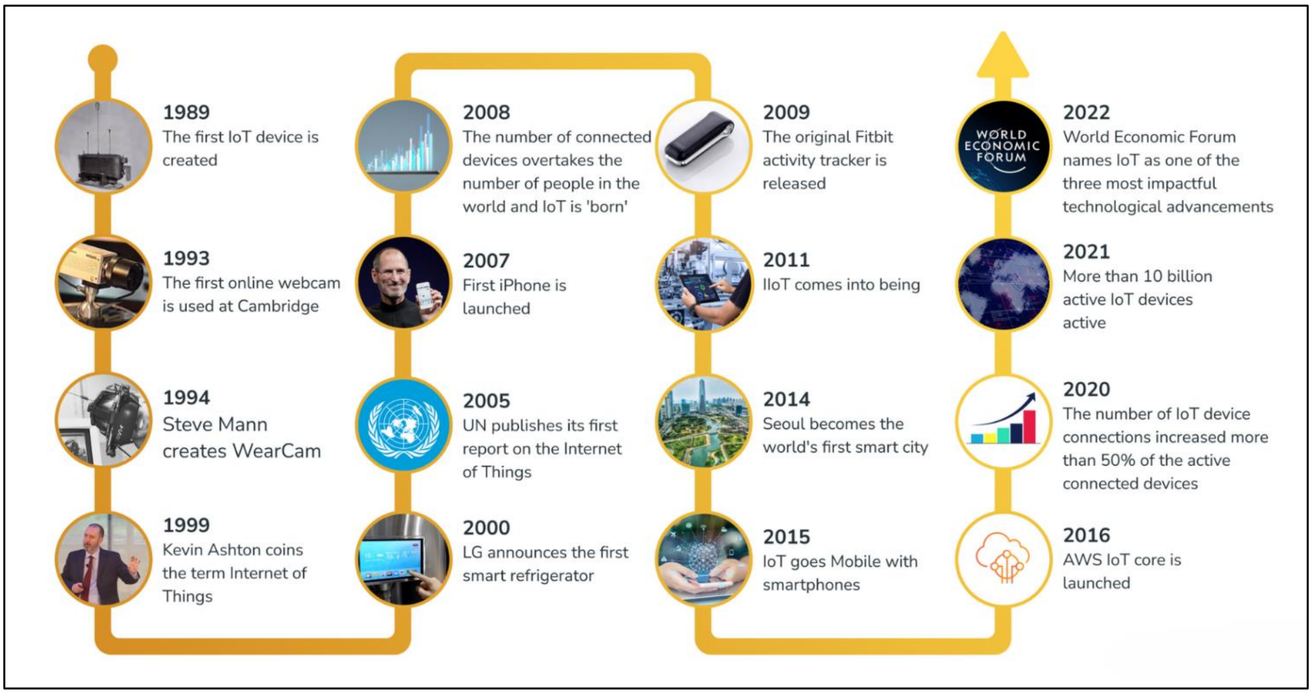


Figure 1-2 The history of the Internet of Things (IoT)

➢ From its humble beginnings with an internet-connected toaster, the Internet of Things has evolved into a vast ecosystem encompassing billions of devices. IoT now influences every aspect of our lives and industries, demonstrating its potential to revolutionize the way we interact with the world around us. The journey of IoT is not just a technological evolution but a transformative process that continues to redefine connectivity and efficiency across the globe.

1.3. Characteristics of IoT.

Dynamic & Self-Adapting: IoT devices and systems have the capability to dynamically adapt based on changing contexts and take actions based on their operating conditions, user's context, or sensed environment. For example, consider a surveillance system comprising of a number of surveillance cameras. The surveillance cameras can adapt their modes (to normal or infrared-night modes) based on whether it is day or night. Cameras could switch from lower resolution to higher resolution modes when any motion is detected and alert nearby cameras to do the same. In this example, the surveillance system is adapting itself based on the context and changing (e.g., dynamic) conditions.

Figure 1-3 Dynamic & Self-Adapting

Self-Configuring: IoT devices may have self-configuring capability, allowing a large number of devices to work together to provide certain functionality (such as weather monitoring). These devices have the ability to configure themselves (in association with the IoT infrastructure), setup the networking, and fetch latest software upgrades with minimal manual or user intervention.

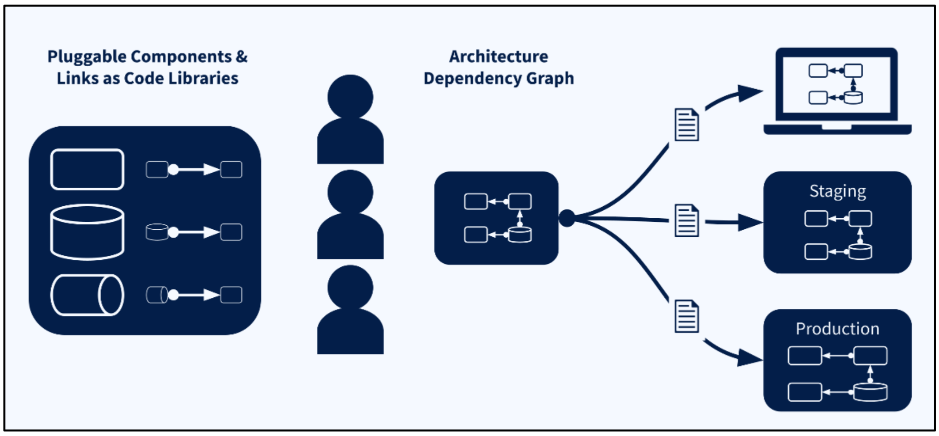


Figure 1-4 Self-Configuring

Interoperable Communication Protocols: IoT devices must support a number of interoperable communication protocols and can communicate with other devices and also with the infrastructure. We describe some of the commonly used communication protocols and models in later sections.

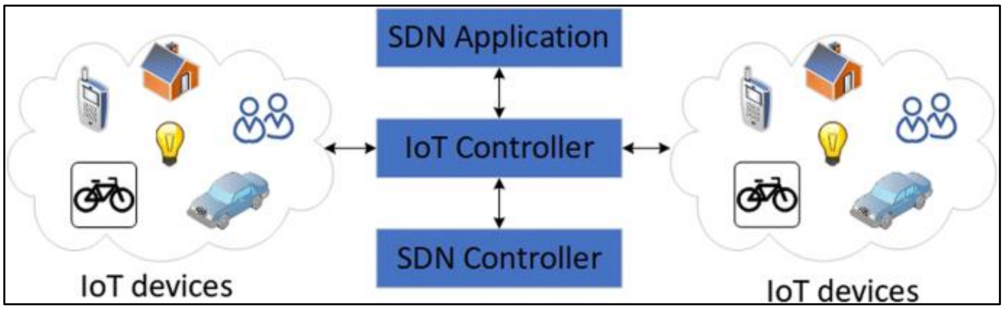


Figure 1-5 Interoperable Communication Protocols

Unique Identity: Each IoT device has a unique identity and a unique identifier (such as an IP address or a URI). IoT systems may have intelligent interfaces which adapt based on the context, allow communicating with users and the environmental contexts. IoT device interfaces allow users to query the devices, monitor their statuses, and control them remotely, in association with the control, configuration, and management infrastructure.

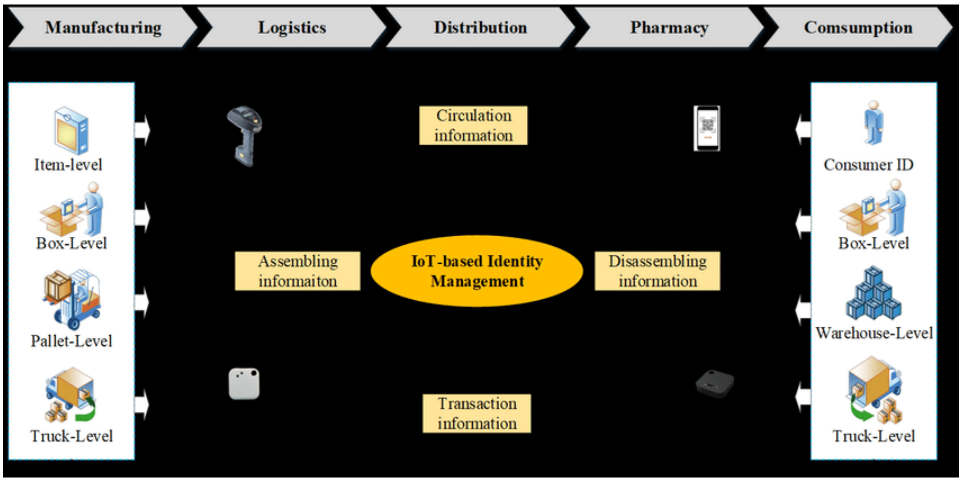


Figure 1-6 Unique Identity

Integrated into Information Network: IoT devices are usually integrated into the information network that allows them to communicate and exchange data with other devices and applications. IoT devices can be dynamically discovered in the network, by automatically connecting to the network, and have the capability to describe themselves (and their data) to other devices or user applications. For example, a weather sensor device could provide extensive monitoring capabilities to another connected node or application, enabling data exchange and sharing. Integration into the information network makes IoT systems "smarter" due to the collective intelligence derived from multiple devices. Information gathered from monitoring IoT nodes can be aggregated and analyzed to provide useful insights.

Figure 1-7 Integrated into Information Network

1.4. Why use IoT?

The use of IoT (Internet of Things) offers numerous benefits across various domains, making it a transformative technology in today's digital age. Here are some key reasons to use IoT:

❖ **Improved Efficiency:**

- Automation: IoT devices can automate routine tasks, reducing the need for manual intervention. For example, smart thermostats can adjust home temperatures based on occupancy, and industrial IoT devices can automate manufacturing processes.

- Resource Management: IoT can optimize the use of resources such as energy, water, and raw materials, leading to cost savings and environmental benefits. Smart grids, for example, optimize electricity distribution.

❖ **Enhanced Data Collection and Insights:**

- Real-Time Monitoring: IoT devices provide real-time data on various parameters, enabling continuous monitoring of systems and processes. For instance, wearable health devices can monitor vital signs and alert users to potential health issues.

- Data-Driven Decision Making: The data collected by IoT devices can be analyzed to uncover trends and insights, helping businesses and individuals make informed decisions. Predictive maintenance in factories is one example where IoT data can prevent equipment failures.

❖ **Increased Safety and Security:**

- Surveillance and Monitoring: IoT-enabled security cameras and sensors can enhance surveillance and security in homes, offices, and public spaces. They can detect and alert users to suspicious activities or environmental hazards.

- Health and Safety: IoT devices can monitor environmental conditions and personal health metrics to ensure safety and well-being. Smart smoke detectors, carbon monoxide alarms, and health monitoring devices are examples.

❖ **Convenience and Comfort:**

- Smart Homes: IoT devices can automate and control home systems such as lighting, heating, and appliances, enhancing comfort and convenience for residents. Voice-activated assistants like Amazon Alexa or Google Assistant can control these devices seamlessly.

- Personalization: IoT devices can learn user preferences and behaviors to provide personalized experiences. For example, smart refrigerators can suggest recipes based on available ingredients and user dietary preferences.

❖ **Cost Savings:**

- Operational Efficiency: By optimizing operations and reducing waste, IoT can lead to significant cost savings. For instance, smart logistics solutions can optimize delivery routes, reducing fuel consumption and labor costs.

- Predictive Maintenance: IoT can predict equipment failures before they happen, allowing for maintenance to be performed only when necessary, reducing downtime and maintenance costs.

❖ **Enhanced Customer Experience:**

- Improved Services: Businesses can use IoT to offer better services to their customers. For example, retail stores can use IoT to track inventory levels in real time and provide timely updates to customers.

- Engagement and Interaction: IoT enables new forms of interaction and engagement with customers. For instance, IoT-enabled wearable devices can provide personalized fitness coaching and feedback.

❖ **Sustainability:**

- Environmental Monitoring: IoT devices can monitor environmental conditions, helping to manage and reduce the impact on the environment. Smart agriculture solutions can optimize water and fertilizer usage, promoting sustainable farming practices.

- Energy Efficiency: IoT solutions can enhance energy efficiency in buildings and cities by optimizing heating, cooling, and lighting systems based on real-time data.

➢ Overall, IoT offers a multitude of benefits that enhance efficiency, safety, convenience, and sustainability, making it a valuable technology for a wide range of applications.

1.5. Domain-specific applications of IoT.

The Internet of Things (IoT) has wide-ranging applications across various domains, each harnessing the power of connected devices to enhance efficiency, improve decision-making, and provide better user experiences. Here are some domain-specific applications of IoT:

❖ **Healthcare**

- Remote Patient Monitoring: IoT devices such as wearables and connected medical devices monitor patients' vital signs in real-time, allowing healthcare providers to track health metrics and respond quickly to any issues.

- Smart Medication Dispensers: These devices remind patients to take their medications on time and track adherence.

- Telemedicine: IoT enables remote consultations and diagnostics, making healthcare accessible to people in remote areas.

❖ **Agriculture**

- Precision Farming: IoT devices collect data on soil moisture, weather conditions, and crop health to optimize farming practices, improving yield and reducing resource use.

- Smart Irrigation: Sensors monitor soil moisture levels and automatically adjust irrigation systems to ensure optimal watering, conserving water.

- Livestock Monitoring: IoT devices track the health and location of livestock, improving herd management and disease prevention.

❖ **Manufacturing**

- Predictive Maintenance: IoT sensors monitor the condition of machinery and predict when maintenance is needed, reducing downtime and maintenance costs.

- Asset Tracking: IoT devices track the location and status of assets within the manufacturing process, improving inventory management and logistics.

- Quality Control: Sensors monitor production processes in real-time to ensure product quality and consistency.

❖ **Smart Cities**

- Traffic Management: IoT sensors and connected traffic lights optimize traffic flow and reduce congestion.

- Waste Management: Smart bins equipped with sensors monitor waste levels and optimize collection routes, reducing costs and environmental impact.

- Public Safety: IoT devices, such as surveillance cameras and environmental sensors, enhance public safety by monitoring and responding to incidents in real-time.

❖ **Energy Management**

- Smart Grids: IoT devices monitor and manage electricity distribution, optimizing energy use and integrating renewable energy sources.

- Home Energy Management: Smart meters and connected appliances allow homeowners to monitor and control their energy consumption, leading to cost savings.
- Predictive Maintenance: Sensors in energy infrastructure detect faults and predict failures, improving reliability and reducing maintenance costs.

❖ **Retail**

- Inventory Management: IoT devices track inventory levels in real-time, reducing stockouts and overstock situations.
- Customer Experience: IoT devices such as smart shelves and beacons enhance the shopping experience by providing personalized recommendations and offers.
- Supply Chain Optimization: IoT sensors monitor the condition of goods during transit, ensuring quality and reducing losses.

❖ **Transportation and Logistics**

- Fleet Management: IoT devices track the location, condition, and performance of vehicles in real-time, optimizing routes and reducing operational costs.
- Asset Tracking: IoT sensors monitor the location and status of cargo, improving supply chain visibility and efficiency.
- Predictive Maintenance: Monitoring vehicle health in real-time helps predict and address maintenance needs before they lead to breakdowns.

❖ **Home Automation**

- Smart Home Devices: IoT-enabled devices such as thermostats, lighting systems, and security cameras provide automation, remote control, and energy efficiency.
- Home Security: Connected security systems monitor homes for intrusions and other emergencies, providing real-time alerts to homeowners.
- Health Monitoring: Wearables and other IoT health devices track personal health metrics, providing insights and alerts to maintain well-being.

❖ **Environmental Monitoring**

- Air and Water Quality Monitoring: IoT sensors monitor environmental conditions, providing data to improve public health and manage pollution.
- Disaster Management: IoT devices monitor environmental conditions to provide early

warnings for natural disasters such as floods and earthquakes.

- Wildlife Monitoring: Sensors and tracking devices help monitor and protect wildlife, providing data on animal movements and habitats.

❖ **Building Management**

- Smart Buildings: IoT systems manage building operations, such as HVAC, lighting, and security, to improve energy efficiency and occupant comfort.
- Predictive Maintenance: Sensors in building infrastructure detect issues early, enabling timely maintenance and reducing costs.
- Space Utilization: IoT devices track the use of spaces within buildings, optimizing layouts and improving resource allocation.

➢ These applications demonstrate how IoT can transform various industries by improving operational efficiency, enhancing safety and security, and providing valuable insights through real-time data collection and analysis.

2. Review standard architecture, frameworks, tools, hardware and APIs available for use in IoT development. (P2)

2.1. Physical and logical design of IoT.

The design of IoT systems can be broken down into two main components: physical design and logical design. Both are essential for the development and implementation of effective IoT solutions. Here's a detailed look at each:

Physical design of IoT	Logical design of IoT
It provides an elaborative and detailed overview.	It provides a high-level overview which is brief.
It emphasizes the configuration and assembling of any specific entity	It emphasizes the design factors which include assumptions, requirements, onstraints, and risks.
It contains more graphic content than textual content.	It comprises both textual and graphic content.

Figure 2-1 Physical and logical design of IoT

❖ Physical Design of IoT

The physical design refers to the tangible components and hardware involved in IoT systems. These components include:

- **Devices/Sensors:**

- Sensors: These devices collect data from the environment. Examples include temperature sensors, humidity sensors, motion detectors, and cameras.
- Actuators: These devices perform actions based on data received. Examples include motors, relays, and valves.

- **Connectivity:**

- Network Protocols: IoT devices use various communication protocols to connect and exchange data. Common protocols include Wi-Fi, Bluetooth, Zigbee, LoRaWAN, and cellular networks (3G, 4G, 5G).
- Gateways: These devices aggregate data from multiple sensors and transmit it to the cloud or central server. Gateways often provide protocol translation and edge processing capabilities.

- **Edge Devices:**

- Edge Computing: Devices that process data locally, close to where it is generated, reducing latency and bandwidth use. Examples include Raspberry Pi and other edge computing platforms.

- **Cloud/Servers:**

- Cloud Services: Centralized servers or cloud platforms that store, process, and analyze data collected from IoT devices. Examples include AWS IoT, Microsoft Azure IoT, and Google Cloud IoT.

- **User Interfaces:**

- Mobile Apps: Applications that allow users to interact with IoT devices through their smartphones or tablets.
- Web Interfaces: Browser-based dashboards and control panels that provide data visualization and device management capabilities.

❖ Logical Design of IoT

The logical design refers to the abstract, software-based aspects of IoT systems. It includes the architecture, protocols, data flow, and functional blocks that define how an IoT system operates. Key components of logical design include:

- **Architecture:**

- Three-Layer Architecture: Typically includes the perception layer (sensors and actuators), the network layer (communication and data transmission), and the application layer (data processing and application-specific functionality).
- Five-Layer Architecture: Expands on the three-layer architecture by adding the processing layer (data analysis and processing) and the business layer (application management and business logic).

- **Communication Models:**

- Device-to-Device (D2D): Direct communication between IoT devices without an intermediary.
- Device-to-Gateway (D2G): Devices communicate with a gateway that aggregates and processes data before sending it to the cloud.
- Device-to-Cloud (D2C): Devices send data directly to the cloud for processing and storage.
- Back-End Data-Sharing: IoT data is shared between cloud platforms or applications.

- **Data Management:**

- Data Acquisition: The process of collecting data from IoT sensors and devices.
- Data Processing: Filtering, aggregating, and analyzing data to derive meaningful insights. This can occur at the edge or in the cloud.
- Data Storage: Storing collected data in databases or data lakes for future analysis and retrieval.

- **Security and Privacy:**

- Authentication and Authorization: Ensuring that only authorized devices and users can access the IoT system.
- Data Encryption: Protecting data in transit and at rest to prevent unauthorized access and tampering.
- Network Security: Implementing firewalls, intrusion detection systems, and secure communication protocols to protect the IoT network.

- **Application Layer:**

- Application Development: Creating applications that utilize IoT data for specific use cases, such as smart homes, industrial automation, or healthcare monitoring.

- User Interfaces: Designing intuitive interfaces for users to interact with IoT systems, including dashboards, mobile apps, and web interfaces.

2.2. IoT protocols.

IoT protocols are essential for enabling communication and data exchange between IoT devices and systems. These protocols ensure reliable, efficient, and secure data transmission across diverse IoT environments. Here's an overview of some common IoT protocols categorized by their primary use cases:

Figure 2-2 IoT protocols

❖ **Communication Protocols**

▪ **Wi-Fi**

- Usage: High-bandwidth applications requiring reliable connectivity, such as smart home devices, video streaming, and high-data rate sensors.
- Advantages: High data transfer rates, widespread availability.
- Disadvantages: High power consumption, limited range compared to some other protocols.

▪ **Bluetooth and Bluetooth Low Energy (BLE)**

- Usage: Short-range communication for wearables, health devices, and smart home gadgets.
- Advantages: Low power consumption (especially BLE), ease of pairing.
- Disadvantages: Limited range, lower data transfer rates compared to Wi-Fi.

▪ **Zigbee**

- Usage: Home automation, industrial control, and low-power, low-data rate applications.
- Advantages: Low power consumption, mesh networking capability.

- Disadvantages: Limited data transfer rates, interoperability issues with different manufacturers' devices.

  - **LoRaWAN**

- Usage: Long-range, low-power applications like smart cities, agriculture, and environmental monitoring.
- Advantages: Long-range communication, low power consumption.
- Disadvantages: Low data transfer rates, higher latency.

  - **NB-IoT (Narrowband IoT)**

- Usage: Cellular-based IoT applications such as smart metering, asset tracking, and industrial IoT.
- Advantages: Wide area coverage, deep penetration, low power consumption.
- Disadvantages: Dependent on cellular network availability, potential cost of cellular data plans.

  - **6LoWPAN (IPv6 over Low-Power Wireless Personal Area Networks)**

- Usage: Home and building automation, environmental monitoring.
- Advantages: Integration with IP-based networks, low power consumption.
- Disadvantages: Requires adaptation layers, lower data transfer rates.

❖ **Messaging Protocols**

  - **MQTT (Message Queuing Telemetry Transport)**

- Usage: Resource-constrained devices and unreliable networks, used in applications like remote monitoring, IoT telemetry, and real-time messaging.
- Advantages: Lightweight, low bandwidth, supports publish/subscribe model.
- Disadvantages: No built-in security, requires additional layers for encryption.

  - **CoAP (Constrained Application Protocol)**

- Usage: Simple electronics like smart energy and building automation devices.
- Advantages: Lightweight, runs over UDP, suitable for low-power and lossy networks.
- Disadvantages: Limited built-in security, requires DTLS for secure communication.

  - **AMQP (Advanced Message Queuing Protocol)**

- Usage: High-performance, enterprise messaging systems for financial services, telecommunications.

- Advantages: Reliable, interoperable, supports complex messaging scenarios.
- Disadvantages: Higher overhead compared to MQTT and CoAP, more complex implementation.

▪ **HTTP/HTTPS**

- Usage: Web-based IoT applications and RESTful services.
- Advantages: Ubiquitous, well-understood, secure (with HTTPS).
- Disadvantages: Higher overhead, not optimized for low-power devices.

❖ **Data Protocols**

▪ **DDS (Data Distribution Service)**

- Usage: Real-time, mission-critical applications like defense systems, autonomous vehicles, and healthcare.
- Advantages: High-performance, scalable, supports publish/subscribe communication.
- Disadvantages: More complex implementation, higher resource requirements.

▪ **OPC UA (OPC Unified Architecture)**

- Usage: Industrial automation and interoperability between various industrial systems.
- Advantages: Secure, reliable, platform-independent.
- Disadvantages: Complexity, higher overhead compared to lighter protocols.

❖ **Network and Transport Protocols**

▪ **UDP (User Datagram Protocol)**

- Usage: Applications requiring fast, connectionless communication, such as real-time data streaming.
- Advantages: Low latency, low overhead.
- Disadvantages: Unreliable, no guarantee of delivery.

▪ **TCP (Transmission Control Protocol)**

- Usage: Applications requiring reliable, ordered delivery of data, such as web services.
- Advantages: Reliable, ensures data integrity and delivery.
- Disadvantages: Higher overhead, potential latency due to connection setup and error-checking.

❖ **Security Protocols**

▪ **DTLS (Datagram Transport Layer Security)**

- Usage: Secure communication over UDP, suitable for CoAP.
- Advantages: Provides encryption, authentication, and integrity for UDP communication.
- Disadvantages: Additional overhead, can be complex to implement.

▪ **TLS/SSL (Transport Layer Security/Secure Sockets Layer)**

- Usage: Secure communication over TCP, widely used for HTTPS.
- Advantages: Provides strong encryption, authentication, and data integrity.
- Disadvantages: Higher overhead, requires proper certificate management.

2.3. IoT communication models.

IoT communication models are frameworks that describe how devices in an Internet of Things ecosystem interact and communicate with each other and with centralized systems like servers or cloud platforms. Understanding these models is crucial for designing effective and efficient IoT solutions. Here are the primary IoT communication models:

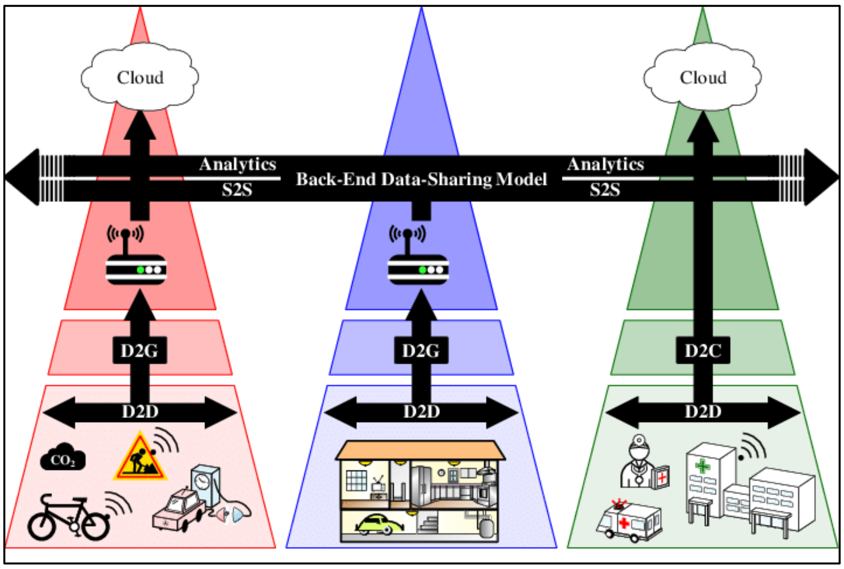


Figure 2-3 IoT communication models

❖ **Device-to-Device (D2D)**

In the Device-to-Device communication model, IoT devices communicate directly with each other without requiring an intermediary. This model is often used in environments where devices need to share data or control actions in real-time.

- Usage: Smart homes, industrial automation.
- Advantages:
  - Low latency since data does not need to traverse through an intermediary.
  - Can operate without internet connectivity if devices are within range.
- Disadvantages:
  - Limited range of communication.
  - May require complex setup to manage device discovery and connectivity.

❖ **Device-to-Gateway (D2G)**

In the Device-to-Gateway communication model, IoT devices communicate with a local gateway, which then processes the data and forwards it to a cloud service or centralized server. The gateway often provides additional functionalities like protocol translation, data aggregation, and preliminary processing.

- Usage: Smart homes, industrial IoT, healthcare monitoring.
- Advantages:
  - Reduces the burden on individual devices by offloading data processing to the gateway.
  - Can handle multiple communication protocols through the gateway.
  - Enhances security by limiting direct exposure of devices to the internet.
- Disadvantages:
  - Potential single point of failure if the gateway malfunctions.
  - Additional cost and complexity due to the need for a gateway device.

❖ **Device-to-Cloud (D2C)**

In the Device-to-Cloud communication model, IoT devices connect directly to cloud-based services to send data and receive commands. This model leverages internet connectivity to allow devices to interact with cloud platforms for storage, processing, and analysis.

- Usage: Consumer IoT devices, remote monitoring systems.
- Advantages:
  - Simplifies device management by centralizing data storage and processing in the cloud.

- Enables remote access and control from anywhere with internet connectivity.
- Facilitates integration with other cloud services and data analytics tools.

▪ Disadvantages:

- Dependent on reliable internet connectivity.
- Potential latency issues due to the distance between devices and cloud servers.
- Security concerns due to exposure of devices to the internet.

❖ **Device-to-Server (D2S)**

In the Device-to-Server communication model, IoT devices communicate with a centralized server, often within a local network or private cloud. This server processes data, manages devices, and may interface with external cloud services if necessary.

▪ Usage: Industrial IoT, enterprise applications.

▪ Advantages:

- Provides centralized control and data management within a secure environment.
- Can operate independently of external internet connectivity if within a local network.
- Allows for custom server configurations tailored to specific application needs.

▪ Disadvantages:

- Requires maintenance and management of local server infrastructure.
- Scalability may be limited compared to cloud-based solutions.

❖ **Back-End Data-Sharing Model**

In the Back-End Data-Sharing model, data collected from IoT devices is shared between different backend systems or cloud services. This model facilitates integration and interoperability between multiple IoT applications and services.

▪ Usage: Smart cities, connected transportation systems.

▪ Advantages:

- Promotes data interoperability and integration across various platforms and services.
- Enables complex IoT ecosystems where data from different sources can be combined for richer insights.

- Can enhance the functionality of IoT applications by leveraging shared data.

▪ Disadvantages:

- Requires robust security and privacy mechanisms to protect shared data.
- Can involve complex data integration and management challenges.
- Potentially increased latency due to multiple data exchanges between backend systems.

2.4. Sensor.

In the context of the Internet of Things (IoT), sensors are fundamental components that enable devices to collect and transmit data from their environments. They play a crucial role in gathering real-time information that can be processed, analyzed, and used to make decisions or trigger actions. Here's an in-depth look at sensors in IoT:

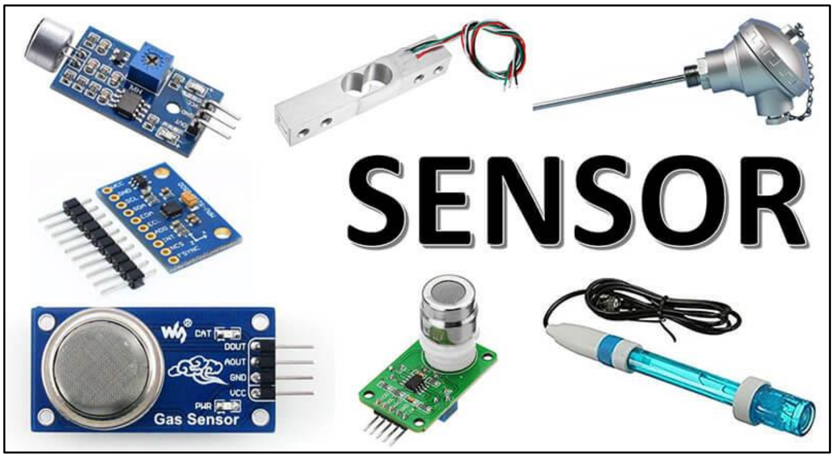


Figure 2-4 Sensor

❖ **Types of Sensors in IoT**

▪ Temperature Sensors:

- Function: Measure the temperature of their environment.
- Applications: HVAC systems, smart thermostats, industrial processes, food storage monitoring.

▪ Humidity Sensors:

- Function: Measure the moisture level in the air.
- Applications: Climate control systems, agriculture, weather stations, indoor air quality monitoring.

▪ Pressure Sensors:

- Function: Measure the pressure of gases or liquids.
- Applications: Weather monitoring, industrial automation, automotive systems, water supply systems.

▪ Proximity Sensors:
  - Function: Detect the presence of nearby objects without physical contact.
  - Applications: Security systems, industrial automation, mobile devices, automotive parking assistance.

▪ Light Sensors (Photo Sensors):
  - Function: Measure the intensity of light.
  - Applications: Smart lighting, security systems, environmental monitoring, consumer electronics.

▪ Motion Sensors:
  - Function: Detect movement or vibrations.
  - Applications: Security systems, smart home automation, fitness trackers, gaming devices.

▪ Gas Sensors:
  - Function: Detect the presence of various gases.
  - Applications: Environmental monitoring, industrial safety, air quality monitoring, automotive emission control.

▪ Accelerometers:
  - Function: Measure acceleration and tilt.
  - Applications: Wearable devices, mobile phones, automotive systems, industrial machinery monitoring.

▪ Gyroscopes:
  - Function: Measure rotational motion and orientation.
  - Applications: Navigation systems, drones, virtual reality systems, robotics.

▪ Magnetic Sensors:
  - Function: Detect magnetic fields.

- Applications: Compass applications, industrial automation, security systems, automotive sensing.

- Sound Sensors (Microphones):
  - Function: Capture audio signals.
  - Applications: Voice-controlled devices, environmental noise monitoring, security systems, smart home assistants.
- Ultrasonic Sensors:
  - Function: Measure distance using ultrasonic waves.
  - Applications: Object detection, robotics, automotive parking sensors, water level measurement.

❖ **Working Principles of Sensors**

- **Physical Principles:** Many sensors operate based on physical principles such as changes in resistance, capacitance, inductance, or the piezoelectric effect. For example:
- **Thermistors** (temperature sensors) change their resistance with temperature.
- **Capacitive sensors** detect changes in capacitance due to the proximity of an object.
- **Chemical Reactions:** Some sensors, like gas sensors, detect the presence of specific chemicals through reactions that produce measurable changes in electrical properties.
- **Optical Methods:** Light sensors and certain proximity sensors use light (visible, infrared, or ultraviolet) to detect changes in the environment.
- **Acoustic Methods:** Ultrasonic sensors emit sound waves and measure the reflection to determine distance or detect objects.

❖ **Applications of Sensors in IoT**

- **Smart Homes:**

Examples: Temperature and humidity sensors for climate control, motion sensors for security systems, light sensors for automated lighting.

- **Healthcare:**

Examples: Wearable devices with heart rate monitors, accelerometers for activity tracking, glucose sensors for diabetes management.

- **Industrial Automation:**

Examples: Pressure sensors for monitoring machinery, proximity sensors for safety systems, accelerometers for vibration monitoring.

- **Environmental Monitoring:**

Examples: Gas sensors for air quality monitoring, weather stations with temperature and humidity sensors, water quality sensors.

- **Automotive:**

Examples: Pressure sensors for tire pressure monitoring, gyroscopes for stability control, proximity sensors for parking assistance.

- **Agriculture:**

Examples: Soil moisture sensors for irrigation management, temperature sensors for greenhouse monitoring, environmental sensors for weather tracking.

❖ **Challenges and Considerations**

- **Accuracy and Precision:** Ensuring sensors provide reliable and precise measurements is critical, especially in applications like healthcare and industrial automation.

- **Power Consumption:** Many IoT applications require sensors to operate on low power, particularly in remote or battery-powered devices.

- **Environmental Conditions:** Sensors must be robust and capable of operating under various environmental conditions, such as extreme temperatures or humidity.

- **Integration and Interoperability:** Ensuring sensors can communicate and integrate effectively with other IoT components and systems.

- **Security and Privacy:** Protecting the data collected by sensors from unauthorized access and ensuring user privacy.

➢ Sensors are the foundational elements of IoT, enabling devices to perceive and interact with the physical world. By choosing the appropriate types of sensors and addressing the associated challenges, IoT systems can be designed to provide valuable insights, automate processes, and enhance the overall quality of life across various domains.

2.5. Arduino/ Raspberry board and end device.

❖ **Arduino**

- **Overview:**

Arduino is a family of microcontroller boards that are easy to use for a wide range of applications. They are popular for prototyping and educational purposes due to their simplicity and versatility.

Figure 2-5 Arduino

- **Key Features:**
  - Microcontroller-Based: Uses microcontrollers like ATmega328 on the Arduino Uno.
  - Simple and Beginner-Friendly: Easy to program using the Arduino IDE and a simple C/C++-based language.
  - GPIO Pins: General-purpose input/output pins for interfacing with sensors, actuators, and other devices.
  - Power Consumption: Generally low power, suitable for battery-operated projects.
  - Real-Time Control: Great for applications requiring real-time control and direct hardware manipulation.
- **Applications:**
  - Embedded Systems: Projects like simple robots, home automation, and DIY electronics.
  - Education: Widely used in educational settings to teach electronics and programming basics.
  - Prototyping: Ideal for quickly prototyping electronic devices and systems.
  - IoT Devices: With added network modules (Wi-Fi, Bluetooth), Arduinos can be used for basic IoT applications.
- **Popular Models:**

- Arduino Uno: The most popular model, great for beginners.
- Arduino Nano: A smaller, more compact version.
- Arduino Mega: More GPIO pins and memory, suitable for more complex projects.

❖ **Raspberry Pi**

- **Overview:**

Raspberry Pi is a series of single-board computers (SBCs) that run a full operating system, typically a version of Linux. They are more powerful and versatile than microcontroller-based boards like Arduino.

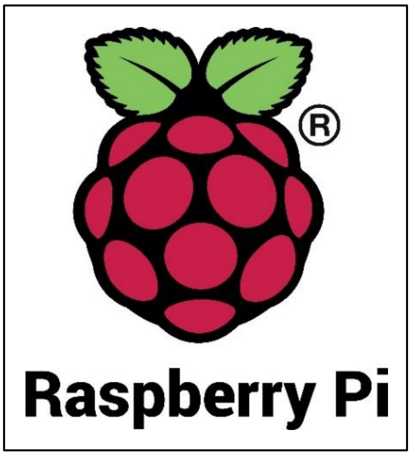


Figure 2-6 Raspberry Pi

- **Key Features:**
  - Full-Fledged Computer: Includes a processor, memory, storage, and ports for peripherals.
  - Operating System: Runs a full OS like Raspberry Pi OS, Ubuntu, or even Windows 10 IoT Core.
  - GPIO Pins: Like Arduino, it has GPIO pins for hardware interfacing.
  - Connectivity: Built-in Ethernet, Wi-Fi, Bluetooth (on newer models).
  - Multimedia: Capable of handling multimedia tasks, including video playback and streaming.
- **Applications:**
  - Computing: Acts as a low-cost, low-power computer for various tasks.
  - IoT Hub: Acts as a central hub for IoT projects, collecting and processing data from various sensors and devices.

- Home Automation: Controls smart home devices, media centers, and home servers.
- Education: Teaches computer science, electronics, and programming in a more advanced context.
- Prototyping: Suitable for developing complex projects that require significant processing power.

▪ **Popular Models:**

- Raspberry Pi 4: The latest and most powerful model, with options for 2GB, 4GB, and 8GB of RAM.
- Raspberry Pi 3: Previous generation, still powerful and widely used.
- Raspberry Pi Zero: A smaller, cost-effective version for simple projects.

❖ **End Devices in IoT**

▪ **Overview:**

End devices in IoT are the physical objects that collect data, execute tasks, or perform specific functions in an IoT ecosystem. They can be sensors, actuators, or any device with embedded capabilities.

▪ **Examples:**

- Sensors: Collect environmental data such as temperature, humidity, light, motion, and gases.
- Actuators: Perform actions based on commands from the central system, like turning on a light, opening a valve, or moving a robotic arm.
- Wearables: Devices like smartwatches and fitness trackers that collect health and activity data.
- Smart Appliances: Home devices like smart refrigerators, washing machines, and thermostats that can be controlled remotely.

▪ **Characteristics:**

- Connectivity: Use various communication protocols (Wi-Fi, Bluetooth, Zigbee, LoRa, etc.) to connect to the network.
- Interactivity: Often have interfaces (buttons, screens) for user interaction.

- Low Power: Many end devices are designed to be energy-efficient, especially those running on batteries.
- Embedded Intelligence: Some end devices have embedded processing capabilities to perform local data processing.

▪ **Challenges:**

- Security: Protecting devices from unauthorized access and ensuring data privacy.
- Interoperability: Ensuring devices from different manufacturers can work together seamlessly.
- Power Management: Optimizing power usage to extend battery life or reduce energy consumption.

2.6. IoT levels & deployment templates.

An IoT system comprises of the following components:

- **Device**: An IoT device allows identification, remote sensing, actuatingandremote monitoring capabilities. You learned about various examplesofIoTdevices in section
- **Resource**: Resources are software components on the IoT deviceforaccessing, processing, and storing sensor information, or controllingactuators connected to the device. Resources also include thesoftwarecomponents that enable network access for the device
- **Controller Service**: Controller service is a native service that runsonthedevice and interacts with the web services. Controller servicesendsdatafrom the device to the web service and receives commands fromtheapplication (via web services) for controlling the device
- **Database**: Database can be either local or in the cloud andstoresthedatagenerated by the IoT device
- **Web Service**: Web services serve as a link between the IoT device, application, database and analysis components. Web servicecanbeeitherimplemented using HTTP and REST principles (REST service) or usingWebSocket protocol (WebSocket service)
- **Analysis Component**: The Analysis Component is responsiblefor analyzingthe IoT data and generate results in a form which are easy for theusertounderstand
- **Application**: IoT applications provide an interface that the users canusetocontrol and monitor various aspects of the IoT system. Applicationsalsoallow users to view the system status and view the processeddata

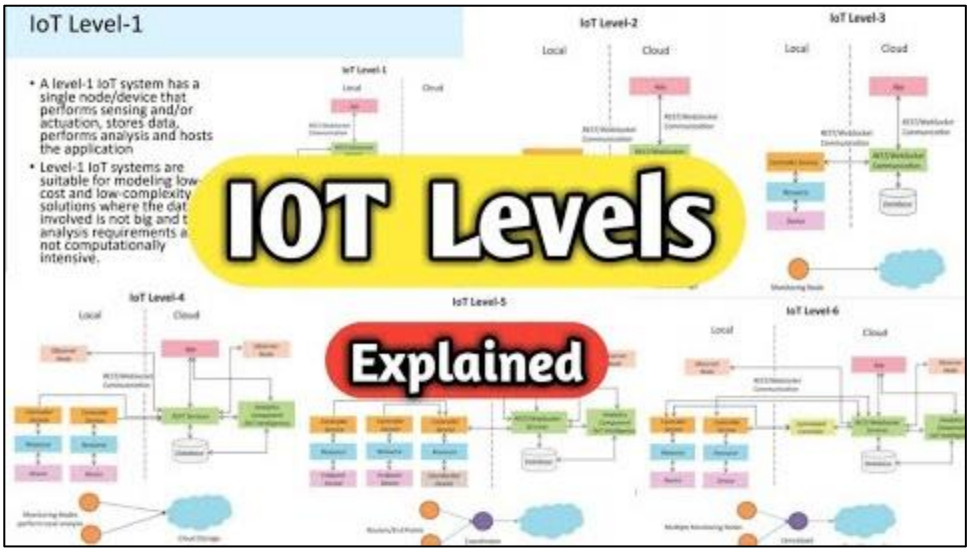


Figure 2-7 IoT levels & deployment templates

❖ IoT Level-1

- A level-1 IoT system has a single node/device that performs sensing and/or actuation, stores data, performs analysis and hosts the application
- Level-1 IoT systems are suitable for modeling low- cost and low-complexity solutions where the data involved is not big and the analysis requirements are not computationally intensive

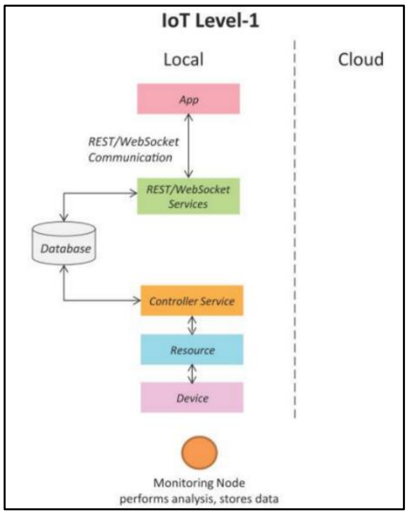


Figure 2-8 IoT Level-1

❖ IoT Level-2

- A level-2 IoT system has a single node that performs sensing and/or actuation and local analysis
- Data is stored in the cloud and application is usually cloud- based
- Level-2 IoT systems are suitable for solutions where the data involved is big, however, the primary analysis requirement is not computationally intensive and can be done locally itself

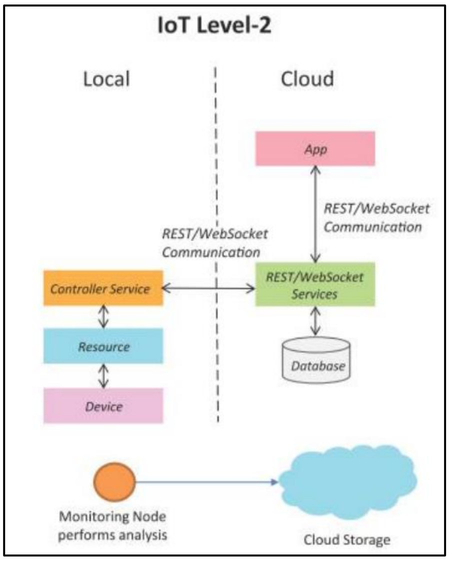


Figure 2-9 IoT Level-2

❖ IoT Level-3

- A level-3 IoT system has a single node. Data is stored and analyzed in the cloud and application is cloud- based

- Level-3 IoT systems are suitable for solutions where the data involved is big and the analysis requirements are computationally intensive

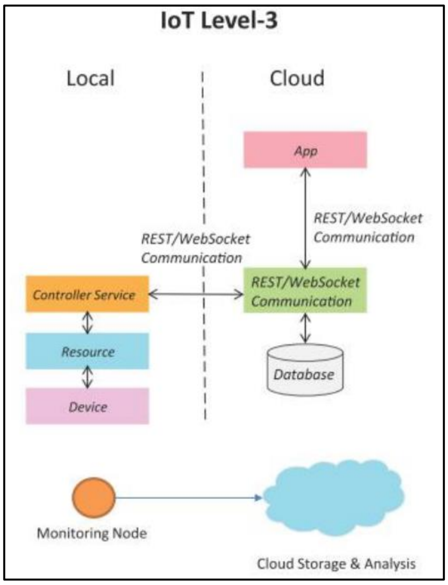


Figure 2-10 IoT Level-3

❖ IoT Level-4

- A level-4 IoT system has multiple nodes that perform local analysis. Data is stored in the cloud and application is cloud-based.

- Level-4 contains local and cloud- based observer nodes which can subscribe to and receive information collected in the cloud from IoT devices

- Level-4 IoT systems are suitable for solutions where multiple nodes are required, the data involved is big and the analysis requirements are computationally intensive

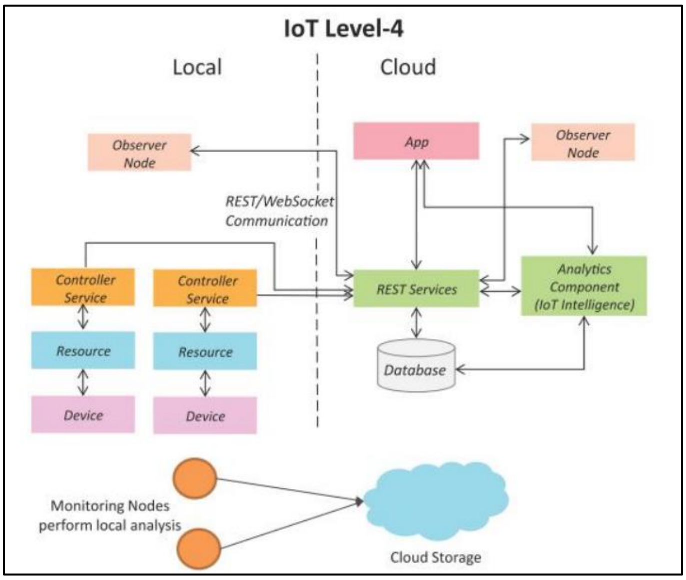


Figure 2-11 IoT Level-4

❖ IoT Level-5

- A level-5 IoT system has multiple end nodes and one coordinator node

- The end nodes that perform sensing and/or actuation
- Coordinator node collects data from the end nodes and sends to the cloud
- Data is stored and analyzed in the cloud and application is cloud-based
- Level-5 IoT systems are suitable for solutions based on wireless sensor networks, in which the data involved is big and the analysis requirements are computationally intensive

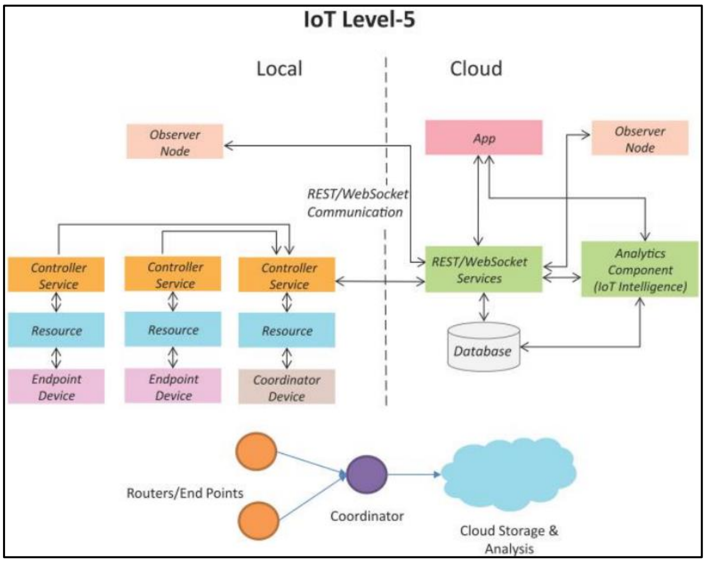


Figure 2-12 IoT Level-5

❖ IoT Level-6

- A level-6 IoT system has multiple independent end nodes that perform sensing and/or actuation and send data to the cloud.
- Data is stored in the cloud and application is cloud-based
- The analytics component analyzes the data and stores the results in the cloud database
- The results are visualized with the cloud-based application
- The centralized controller is aware of the status of all the end nodes and sends control commands to the nodes

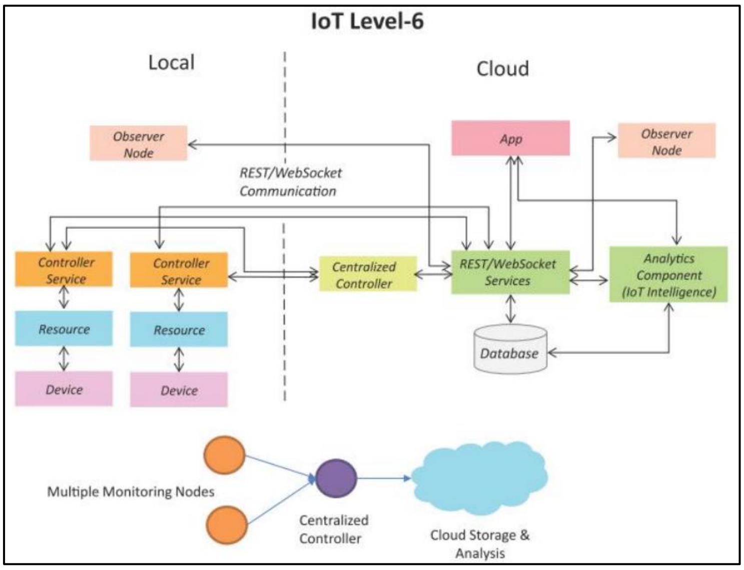


Figure 2-13 IoT Level-6

2.7. IoT communication APIs.

In the IoT ecosystem, communication APIs (Application Programming Interfaces) play a crucial role in enabling devices, applications, and services to interact and exchange data seamlessly. These APIs provide standardized methods for connecting, managing, and controlling IoT devices over various communication protocols. Here's an overview of some widely used IoT communication APIs:

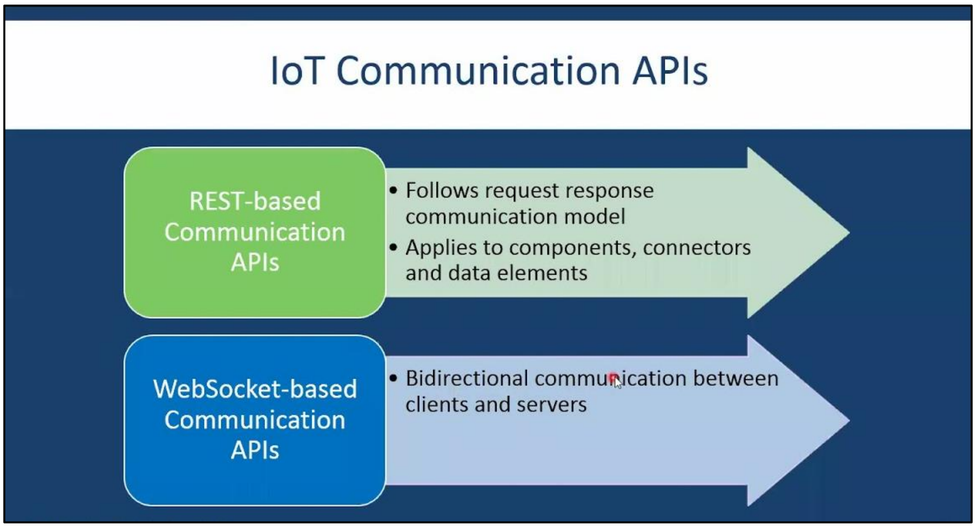


Figure 2-14 IoT communication APIs

❖ **HTTP/HTTPS APIs**

▪ **Overview:**

HTTP (Hypertext Transfer Protocol) and HTTPS (HTTP Secure) are the foundational protocols for web communication. They are commonly used in IoT for device communication with cloud services and web applications.

- **Features:**
  - Widely Supported: Nearly all devices and services support HTTP/HTTPS.
  - RESTful APIs: Use Representational State Transfer (REST) principles to create scalable and stateless services.
  - Security: HTTPS provides encryption for secure communication.
- **Use Cases:**
  - Data Retrieval and Upload: Devices can send sensor data to a cloud server and receive control commands.
  - Web Dashboards: Use HTTP APIs to fetch data from IoT devices and display it on web dashboards.

❖ **MQTT (Message Queuing Telemetry Transport)**

- **Overview:**

MQTT is a lightweight, publish-subscribe messaging protocol designed for low-bandwidth, high-latency networks. It is highly efficient for IoT applications.

- **Features:**
  - Low Overhead: Minimal packet size makes it suitable for constrained devices and networks.
  - QoS Levels: Quality of Service levels to ensure message delivery reliability.
  - Publish-Subscribe Model: Devices can publish messages to topics and subscribe to topics of interest.
- **Use Cases:**
  - Remote Monitoring: Devices publish sensor data to MQTT brokers, and clients subscribe to receive updates.
  - Home Automation: Control smart home devices by sending commands via MQTT.

❖ **CoAP (Constrained Application Protocol)**

- **Overview:**

CoAP is a protocol designed for use in constrained devices and networks. It operates over UDP and is optimized for low-power, low-bandwidth applications.

- **Features:**
  - Lightweight: Small header size and low overhead.
  - RESTful Interaction: Similar to HTTP, supports methods like GET, POST, PUT, and DELETE.
  - Observations: Clients can observe resources and receive notifications on changes.
- **Use Cases:**
  - Sensor Networks: Efficiently collect data from a large number of sensors.
  - Smart Lighting: Control and monitor lighting systems with minimal communication overhead.

❖ **WebSockets**

- **Overview:**

WebSockets provide a full-duplex communication channel over a single, long-lived TCP connection. This is ideal for real-time applications.

- **Features:**
  - Bi-Directional Communication: Enables two-way communication between client and server.
  - Low Latency: Reduces latency by maintaining a persistent connection.
  - Real-Time Updates: Suitable for applications requiring immediate data updates.
- **Use Cases:**
  - Real-Time Monitoring: Track real-time metrics and status updates from IoT devices.
  - Interactive Applications: Enable real-time interactions in applications like gaming or collaborative tools.

❖ **AMQP (Advanced Message Queuing Protocol)**

- **Overview:**

AMQP is a robust, message-oriented protocol designed for high reliability and performance. It is used in enterprise-grade applications.

- **Features:**
  - Message Queues: Supports complex messaging patterns with queues and topics.

- Reliability: Ensures message delivery with confirmation receipts.
- Flexible Routing: Supports various routing mechanisms for message distribution.

▪ **Use Cases:**

- Industrial IoT: Reliable data transmission for monitoring and controlling industrial processes.
- Enterprise Applications: Integrate IoT data with enterprise systems and workflows.

❖ **DDS (Data Distribution Service)**

▪ **Overview:**

DDS is a middleware protocol and API standard for real-time, scalable, and high-performance data exchanges.

▪ **Features:**

- Quality of Service: Fine-grained control over data delivery and reliability.
- Real-Time: Designed for time-sensitive applications with low latency.
- Scalability: Supports dynamic discovery and configuration of data publishers and subscribers.

▪ **Use Cases:**

- Autonomous Systems: Real-time data sharing in autonomous vehicles and robotics.
- Healthcare: Real-time monitoring and control in medical devices and systems.

❖ **gRPC (Google Remote Procedure Call)**

▪ **Overview:**

gRPC is a high-performance, open-source RPC framework that uses HTTP/2 for transport and Protocol Buffers as the interface description language.

▪ **Features:**

- Efficient: High-performance communication with low latency and high throughput.
- HTTP/2: Benefits from HTTP/2 features like multiplexing and header compression.
- Language Support: Supports multiple programming languages.

▪ **Use Cases:**

- Microservices: Communication between microservices in an IoT system.
- Edge Computing: Efficient data exchange between edge devices and central servers.

➢ These communication APIs and protocols enable a wide range of IoT applications, each with its strengths tailored to specific requirements such as low power consumption, real-time communication, scalability, and reliability. Selecting the appropriate API depends on the specific use case, device capabilities, network conditions, and performance requirements of the IoT solution.

LO2 : OUTLINE A PLAN FOR AN APPROPRIATE IOT APPLICATION, USING COMMON ARCHITECTURE, FRAMEWORKS, TOOLS, HARDWARE AND APIS.

3. Investigate architecture, frameworks, tools, hardware and API techniques available to develop IoT applications. (P3)

3.1. Architecture and frameworks

We chose **Centralized Architecture** for our smart home project. The benefits are ease of management, higher security, and easy integration with cloud services. We use a central device, **Raspberry Pi**, to collect data from sensors and control devices.

- **Raspberry Pi** is a compact, cheap and powerful computer designed to provide computer science education and ease of implementation of IoT projects. Here are some of the characteristics and advantages of the Raspberry Pi:

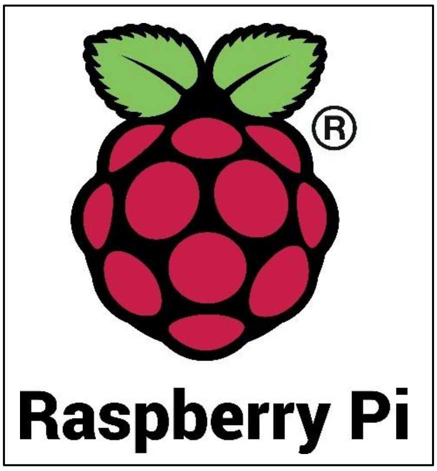


Figure 3-1 Raspberry Pi

- ✓ **Characteristic**

Compact size: Raspberry Pi has a small size, making it easy to attach to other devices or place in places with limited space.

Powerful performance: With an ARM processor, Raspberry Pi is powerful enough to run lightweight operating systems and perform complex tasks.

Diverse connection ports: There are USB, HDMI, Ethernet, GPIO ports, making it easy to connect to many peripheral devices and sensors.

Operating system: Usually uses Raspbian (currently Raspberry Pi OS), a version of Linux optimized for Raspberry Pi.

Low price: Reasonable cost, suitable for personal and educational projects.

✓ **Advantage**

Easy installer: Supports many language installation programs such as Python, C++, Java, helping users easily develop applications.

Large Community: There is an extensive user community that provides documentation, support, and shared experiences.

Easy integration with the cloud: Can easily connect to cloud services for data storage and analysis.

Scalability: Can be expanded by adding modules, emotion variables, and other peripherals.

❖ **Cloud Platform:** We have opted to utilize **Blynk Cloud** for controlling Internet of Things devices.

Figure 3-2 Blynk Cloud

Blynk Cloud is a cloud service that enables you to connect to and manage Internet-of-things devices, including Arduino, ESP8266, Raspberry Pi, and many more. It's a platform that offers widgets and an easy-to-use interface to let developers create Internet of Things apps fast and effortlessly. Project management, remote device access, integration of sensor data, and remote device control via mobile applications are just a few of the services offered by Blynk Cloud. or internet.

3.2. Tools, hardware, and API

❖ **Arduino IDE & Tinker Cad**

The Arduino Integrated Development Environment (IDE) is an integrated development environment for programming and uploading code to Arduino boards. With a simple and user-friendly interface, Arduino IDE makes it easy for users to code, compile, and upload programs directly to the Arduino board. Supporting multiple programming languages, especially C/C++, and coming with an extensive library, the Arduino IDE is ideal for both beginners and experienced programmers in developing IoT and electronics projects. In addition, the Arduino IDE supports a variety of boards and provides scalability through additional libraries and tools, making development more flexible and efficient. The Arduino ecosystem also includes a strong community where users can share knowledge, documentation, and experiences, which enhances support and collaboration during project learning and development.

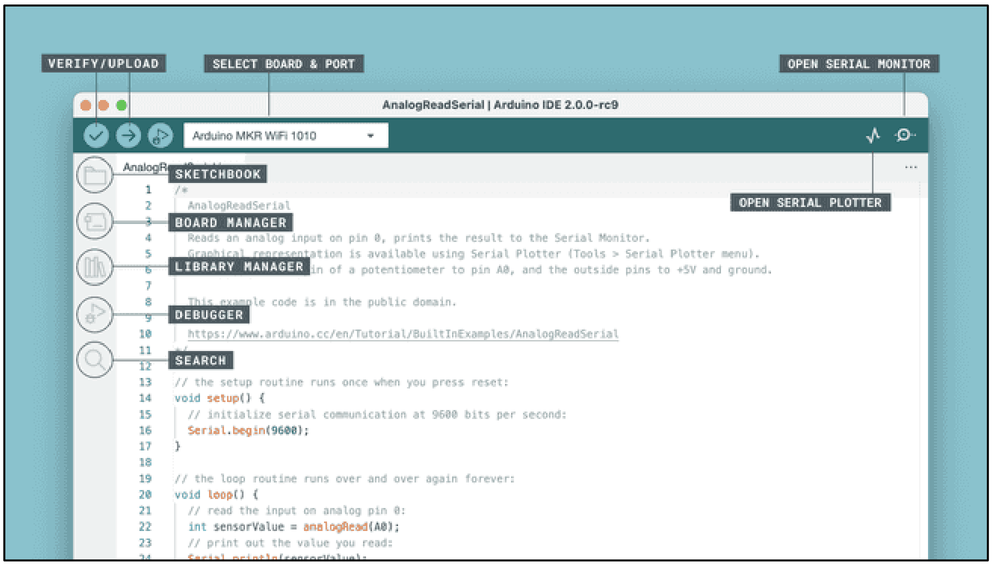


Figure 3-3 Arduino IDE

Tinkercad is a free online tool from Autodesk that allows users to design and simulate electronic circuits and 3D models. Designed with an intuitive and easy-to-use interface, Tinkercad is a great choice for learning and testing Arduino projects without the need for physical hardware. Users can write and simulate Arduino code directly in Tinkercad, facilitating the learning and development of STEM skills.

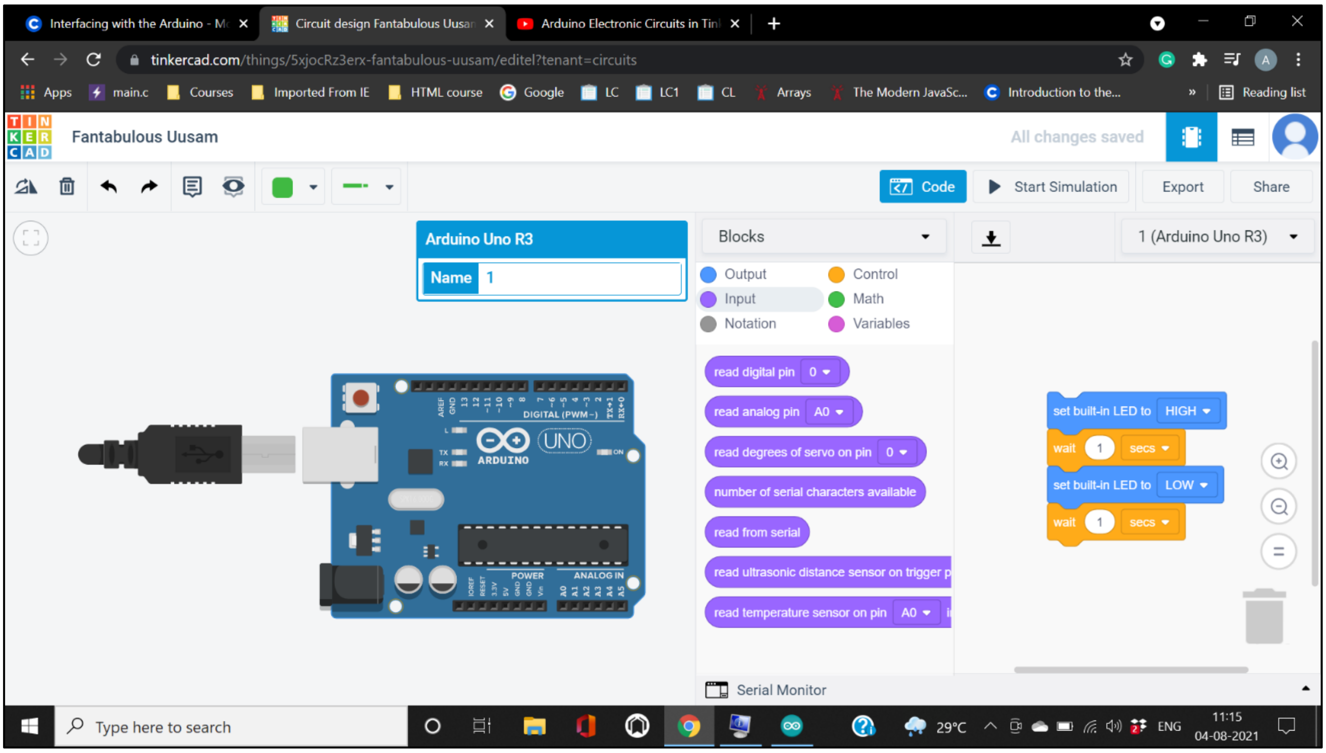


Figure 3-4 Tinkercad

❖ **Hardware**

Ultrasonic sensor turns lights on and off for hallway and Gas Gas Leak Sensor

- **Ultrasonic Sensor:**

HC-SR04: One of the popular ultrasonic sensors, used for ultrasonic distance detection.

Figure 3-5 Ultrasonic Sensor

- **Microcontroller:**

The Arduino Uno R3 is a versatile and widely-used microcontroller board based on the ATmega328P, ideal for beginners and experienced developers to create a variety of interactive projects.

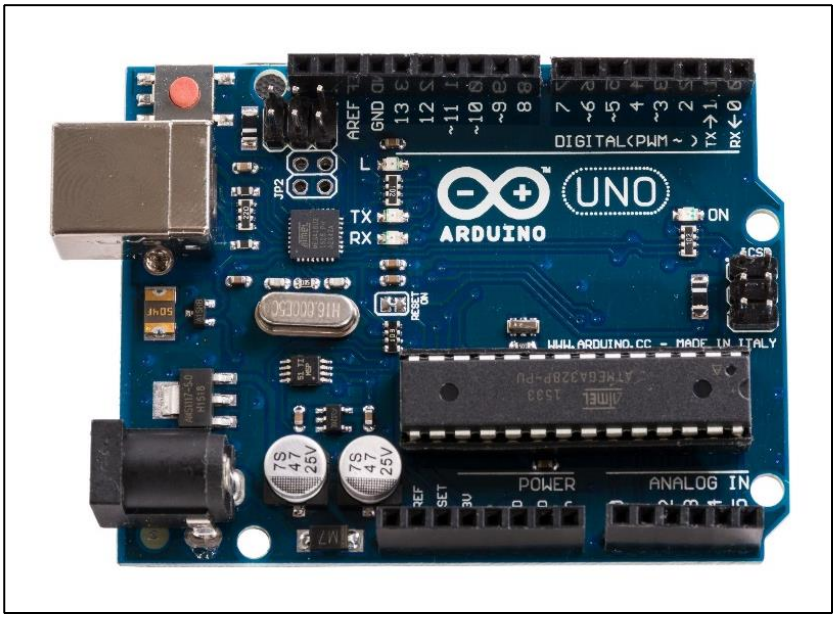


Figure 3-6 Arduino Uno R3

- **Relay Module:**

To turn on/off the light based on the signal from the microcontroller.

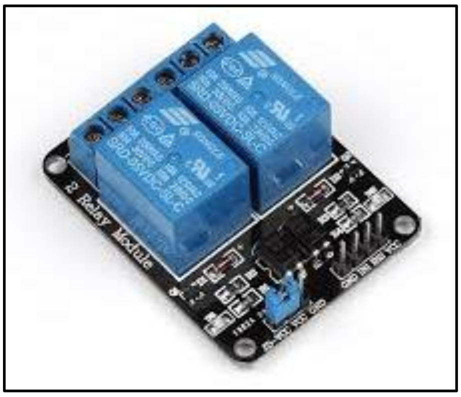


Figure 3-7 Relay Module

- **Lighting:**

LED or Conventional Light: Control on/off by relay.

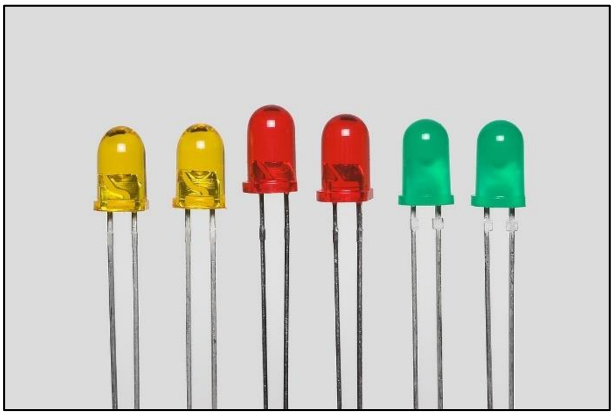


Figure 3-8 LED

- **Connection module:**

Wi-Fi Module (such as ESP8266/ESP32): If a wireless connection is needed for remote control or integration into a smart home system.

Figure 3-9 Wi-Fi Module

- **Gas Sensor:**

  MQ-2 : Gas sensors are common for detecting gas leaks such as LPG, CO, and flammable gases.

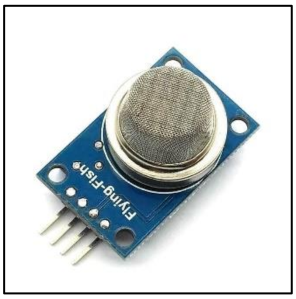


Figure 3-10 MQ-2 Sensor

- **Alarm Buzzer:**

  To sound an alarm when a gas leak is detected.

ss

Figure 3-11 Buzzer 5V

- **Power Supply:** Provides power to devices, be it batteries or direct power.

Figure 3-12 Power Supply

- **LCD LED Display:**

  16x2 LCD or OLED Display: To display sensor status, gas concentration detected, and alarmed.

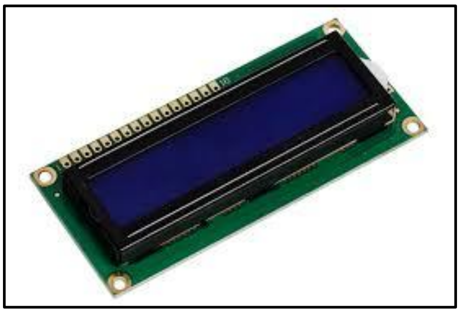


Figure 3-13 LCD LED Display

3.3. Network devices

We choose to utilize the following in order to transfer data from the terminal to the application.

- **Gateways:** MS48-LR LoRaWAN Gateway is the one we'll go with. It makes data collecting from a wide range of terminals possible.

Figure 3-14 Gateways

- **Router:** Our choice of industrial routers, such the Cisco IR800 series, offers exceptional stability and dependability, guaranteeing a steady and uninterrupted network connection.

Figure 3-15 Router

4. Discuss a specific problem to solve using IoT. (P4)

4.1. About Project

In today's technological age, a beautiful home requires the integration of modern, convenient, safe and easy-to-use technology. Understanding that need, we have designed a smart home project. The two IoT applications we use in the project are ultrasonic sensors that turn lights on and off in the hallway and gas leak sensors.

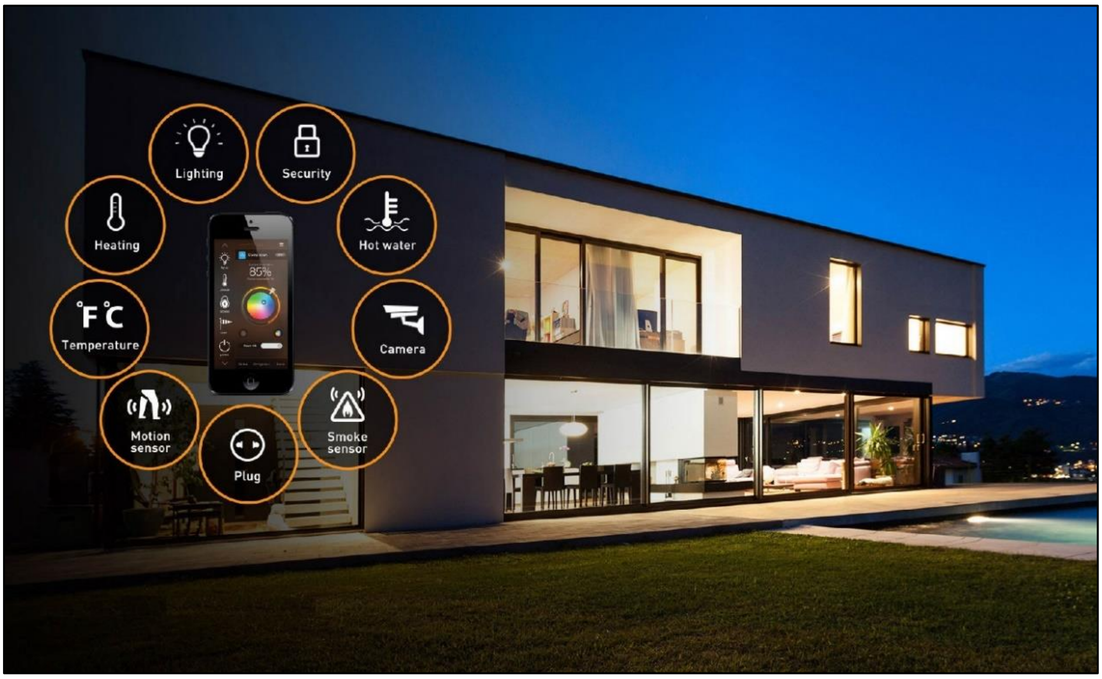


Figure 4-1 Smart Home

❖ **Identify the problem to be solved and the purpose of the project**

- **Ultrasonic sensor turns lights on and off for hallways:**

- Problem: Hallways are not illuminated when needed and power consumption is inefficient when the lights are always on.

- Purpose: Automatically turn on the lights when someone moves into the hallway and turn off the lights when no one is around, helping to save energy.

- **Gas Leak Sensor:**

- Problem: Gas leaks pose a fire and explosion hazard and affect health.

- Purpose: Early detection of gas leaks and warning users to promptly handle and ensure safety.

⇨ *Create a smart home system with sensors to automate light management and gas safety.*

❖ **Functions of the project:**

- **Ultrasonic sensor turns lights on and off:**

- Motion detection in the hallway.

- Turn on the lights when someone moves into the hallway.

- Turn off the lights when there is no movement after a certain period of time.

- **Gas Leak Sensor:**

- Detecting gas concentrations exceeding the safe threshold.

- Alert users via alarm or phone notifications.

4.2. Design of the system

❖ **Component list**

Name	Quantity	Component
HC-SRO4	1	Ultrasonic Sensor
U3	1	Arduino Uno R3
MQ-2	1	MQ-2 Sensor
D2	3	LED
5V	1	5V Buzzer
1602	1	1602 LCD Display
SONGLE	1	5V Relay Module SONGLE

Table 4-1 Component list

❖ **Flowchart**

A flowchart is a diagram that represents the sequential steps of a process, system, or algorithm using shapes and arrows to depict actions, decisions, and data flow.

- **Key Characteristics of a Flowchart**

- **Visual Representation:** Flowcharts provide a clear and visual overview of a process, making it easy for viewers to understand the steps and their order.
- **Standard Shapes:** Steps in a flowchart are represented using standard shapes such as rectangles (for actions), diamonds (for decisions), and ovals (for start and end points).
- **Arrows Indicate Direction:** Arrows are used to indicate the direction of the flow of information or the process, connecting the steps in a logical sequence.
- **Sequential and Conditional:** Flowcharts can represent both sequential steps and conditional decisions, allowing for branching and repetition based on specific conditions.
- **Simplicity and Clarity:** Flowcharts help simplify and clarify complex processes, making analysis and communication easier.

- **Analysis and Design Tool:** Flowcharts are essential tools in analyzing, designing, and documenting systems and processes, particularly in engineering and management fields.

  - **Examples of Standard Shapes in Flowcharts:**

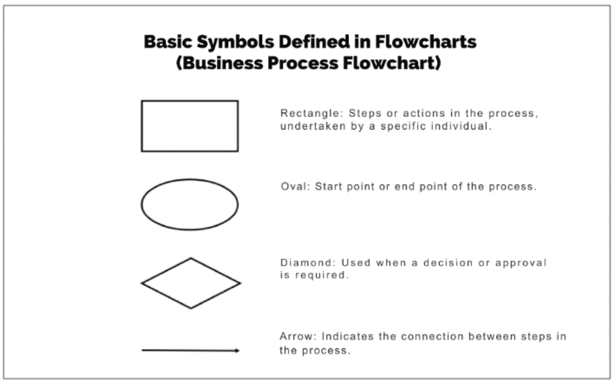


Figure 4-2 Shapes in Flowchart

⇨ *Flowcharts are useful tools for describing, analyzing, and designing processes and systems in a clear and organized manner.*

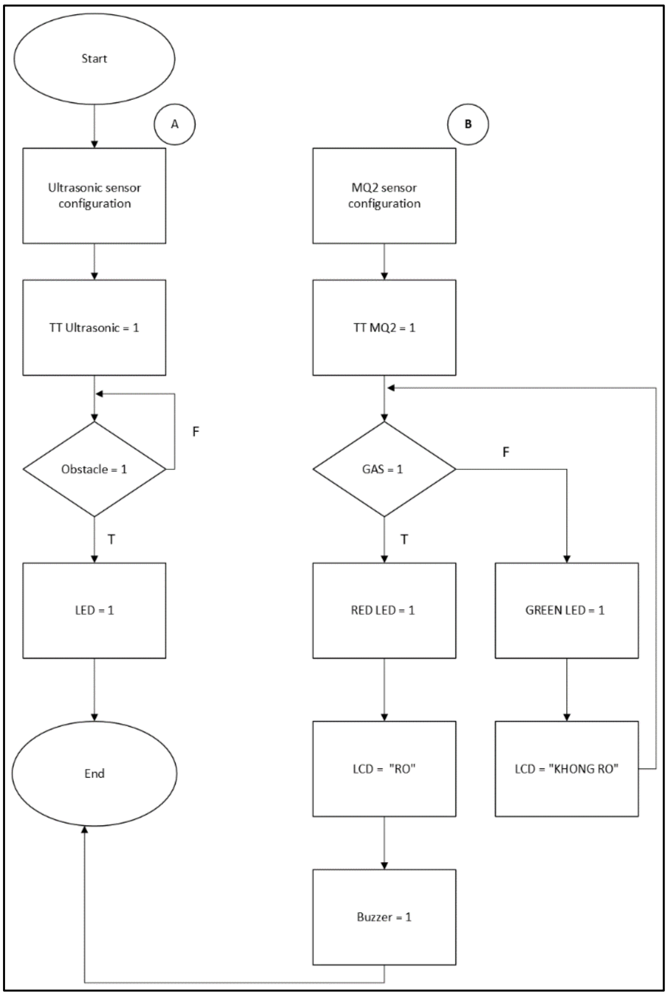


Figure 4-3 Algorithm diagram

* **Explain Flowchart**

Branch A: Ultrasonic Sensor for Light Control

* **Start**: Begin the process.
* **Ultrasonic sensor configuration**: Configure the ultrasonic sensor.
* **TT Ultrasonic = 1**: Confirm that the ultrasonic sensor is ready (TT = status).
* **Obstacle = 1**: Check for the presence of an obstacle.
    * If an obstacle is detected (T - True), move to the next step.
    * If no obstacle is detected (F - False), loop back to the obstacle check.
* **LED = 1**: Turn on the LED light when an obstacle is detected.
* **End**: End the process.

Branch B: Gas Leak Detection Sensor

* **Start**: Begin the process.
* **MQ2 sensor configuration**: Configure the MQ2 gas sensor.
* **TT MQ2 = 1**: Confirm that the MQ2 sensor is ready (TT = status).
* **GAS = 1**: Check for the presence of gas.
    * If gas is detected (T - True), proceed to the next step.
    * If no gas is detected (F - False), follow the other branch.
* **RED LED = 1**: Turn on the red LED when gas is detected.
* **LCD = "RO"**: Display the message "LEAK" on the LCD screen.
* **Buzzer = 1**: Activate the buzzer to alert the user.

Branch B When No Gas is Detected

* **GREEN LED = 1**: Turn on the green LED when no gas is detected.
* **LCD = "KHONG RO"**: Display the message "NO LEAK" on the LCD screen.

This flowchart describes the two sensor systems in the smart home project:

* An ultrasonic sensor system to turn on/off the light based on motion detection in the hallway.
* A gas leak detection system to identify and alert users when there is a gas leak in the house.

This process ensures that the sensors operate correctly and the corresponding actions are performed when the specified conditions (motion or gas leak) are detected.

LO3: DEVELOP AN IOT APPLICATION USING ANY COMBINATION OF HARDWARE, SOFTWARE, DATA, PLATFORMS AND SERVICES.

5. Employ an appropriate set of tools to develop a plan into an IoT application. (P5)

After putting the project through testing, we discovered that using an ultrasonic sensor would not be optimal when applied in practice, nor would it achieve the best results for our system. Therefore, we replaced it with a PIR motion sensor to optimize the automatic hallway lighting system. With these improvements, we addressed the errors made during the project implementation as follows:

❖ **Step-by-Step Implementation:**

➢ **Step 1: Set Up the Hardware Components**

- **Arduino Uno**

- Purpose: The Arduino Uno serves as the central microcontroller of the system, responsible for receiving signals from the sensors (PIR and MQ2) and controlling the output devices (LEDs and buzzer) based on the pre-programmed logic.

- **PIR Sensor (Passive Infrared Sensor)**

- Purpose: The PIR sensor is used to detect human motion by sensing changes in infrared radiation within its monitoring area. When motion is detected, the sensor sends a signal to the Arduino to turn on the LED, illuminating the hallway. When no motion is detected, the LED will be turned off to save energy.

- **LED (controlled by PIR sensor)**

- Purpose: This LED is used to provide a visual indication of human presence in the hallway. When a person passes by, the LED will light up, and when no one is present, the LED will turn off.

- **MQ2 Gas Sensor**

- Purpose: The MQ2 gas sensor is used to detect the presence of flammable gases such as methane, propane, butane, and smoke. When the gas concentration exceeds a safe threshold, the sensor sends a signal to the Arduino to activate the alert system.

- **LED (controlled by MQ2 gas sensor)**

- Purpose: This LED is used as a visual indicator when a gas leak is detected. When the gas concentration reaches a dangerous level, the LED will light up to alert the user.

- **Buzzer**

- Purpose: The buzzer is used to emit a sound alert when a gas leak is detected. If the gas concentration continues to rise, the buzzer will be activated to warn the user of the potential danger.

- **Breadboard and Jumper Wires**

- Purpose: The breadboard is used to assemble the electronic circuits without the need for soldering, allowing for easy modification or adjustment of the circuit during development. The jumper wires are used to connect the sensors, LEDs, and buzzer to the Arduino Uno, forming a complete system.

➢ **Step 2: We simuleted the system on Tinker Cad**

The finished system is simulated by us using Tinker Cad:

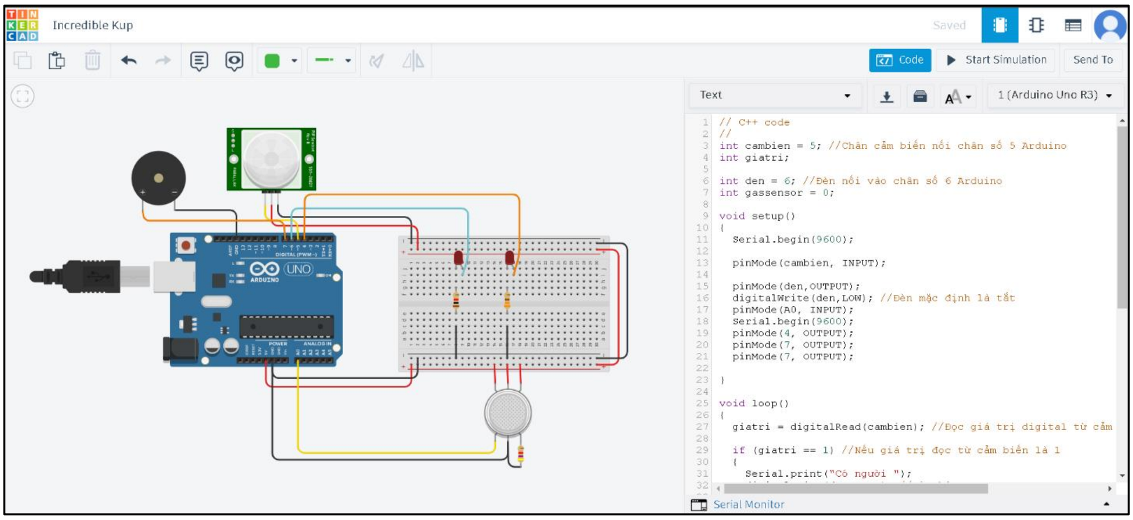


Figure 5-1 System Simulation on Tinker Cad 1

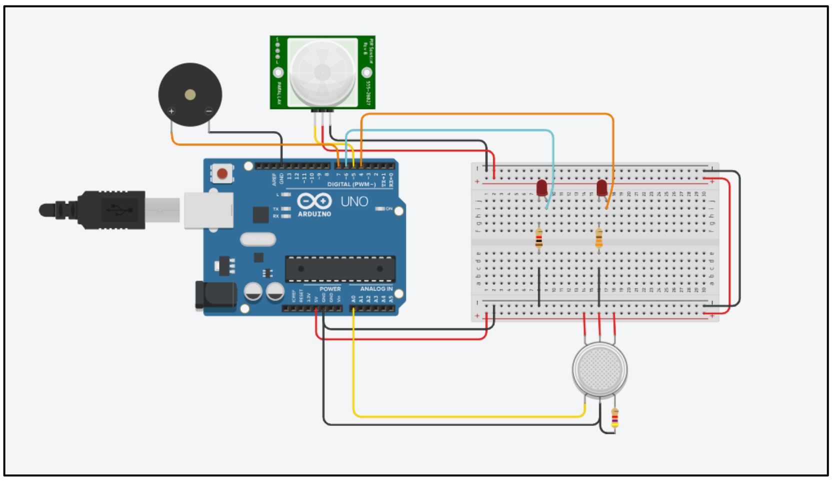


Figure 5-2 System Simulation on Tinker Cad 2

➤ Step 3: Write Arduino IDE source code

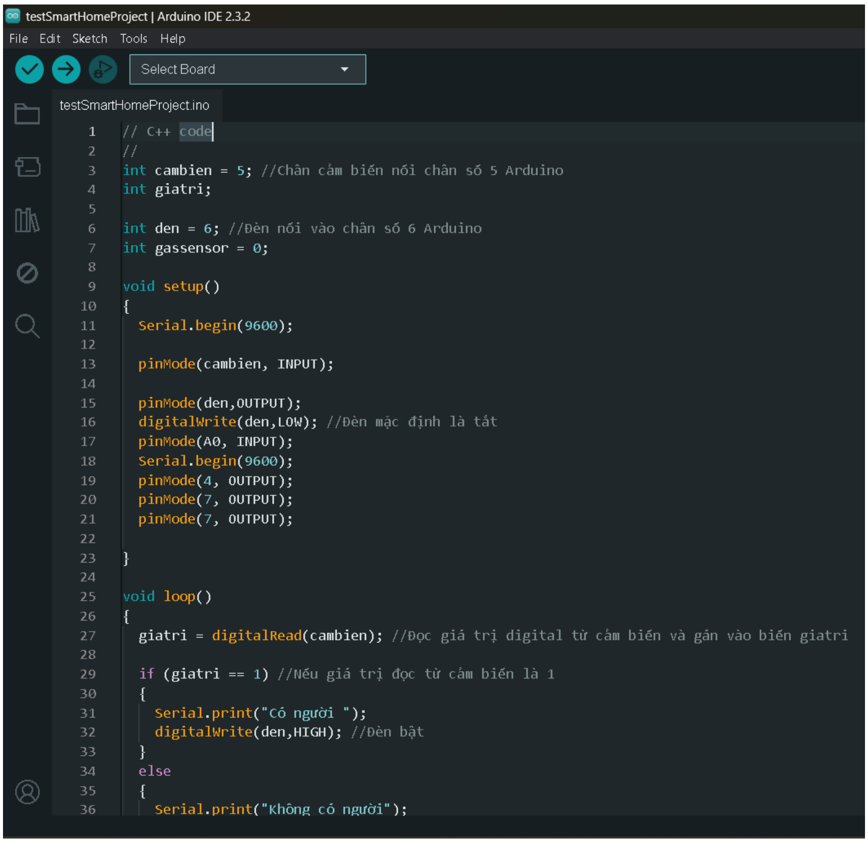


Figure 5-3 Source code Arduino IDE 1

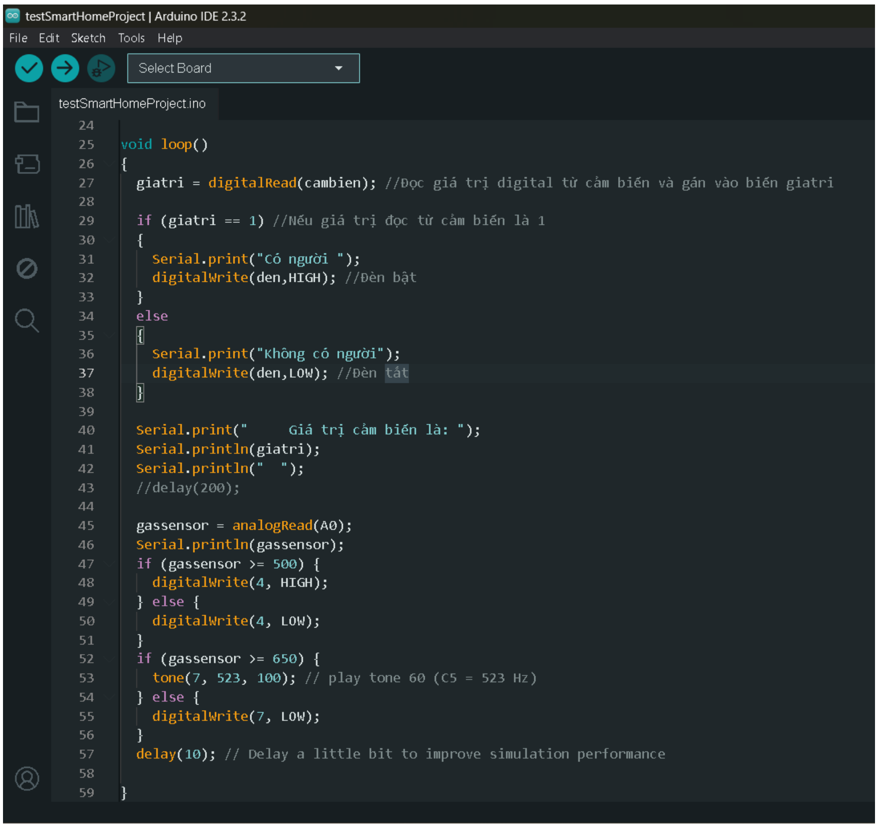


Figure 5-4 Source code Arduino IDE 2

- **Step 4: Connect hardware devices and circuits to the Arduino IDE**

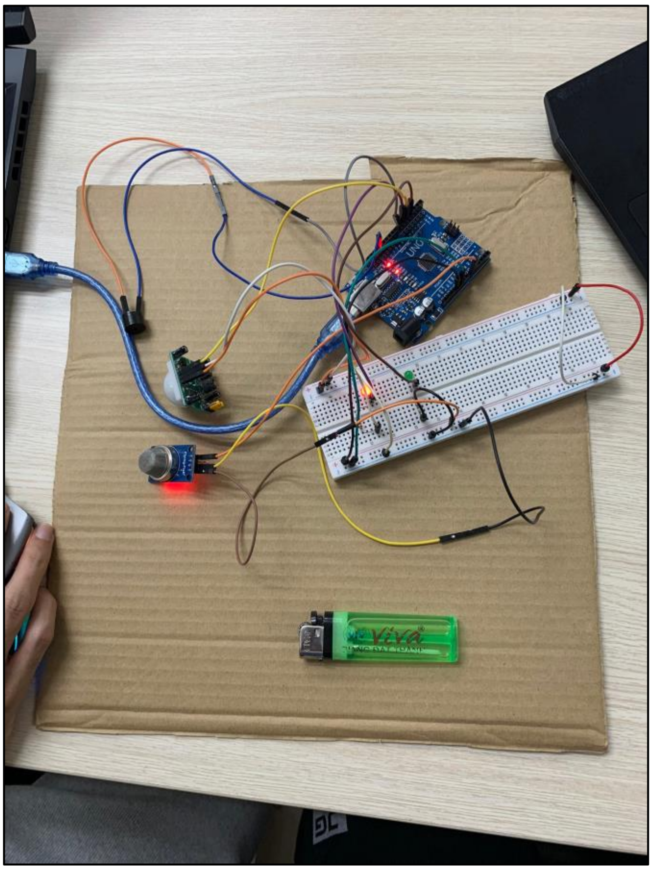


Figure 5-5 Connect hardware devices and circuits to the Arduino IDE

- **Step 5: Testing**

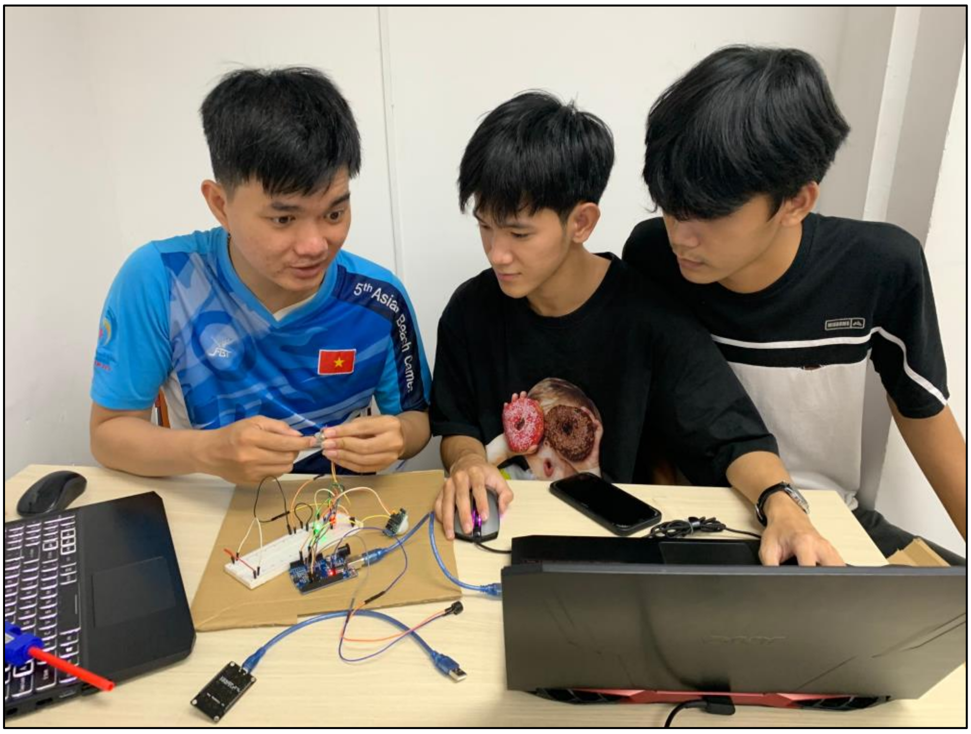


Figure 5-6 Testing

Video Demo: https://youtu.be/j0Jd51VnVHY

6. Create a detailed test plan and examine feedback. (P6)

6.1. Check how the system works

❖ **Perform testing on the actual system**

The devices we use in the system are: Alarm Buzzer, Arduino Uno, MQ-2 sensor, WiFi Module ESP8266, LED, Arduino Uno and PIR motion sensor.

Our information delivery system is completed after developing the source code on both Arduino and ESP8266 boards. Our system can work well in practice after many tests. Tasks including the gas leak sensor and the body temperature motion sensor that turns on and off the electrical corridor all work normally and stably.

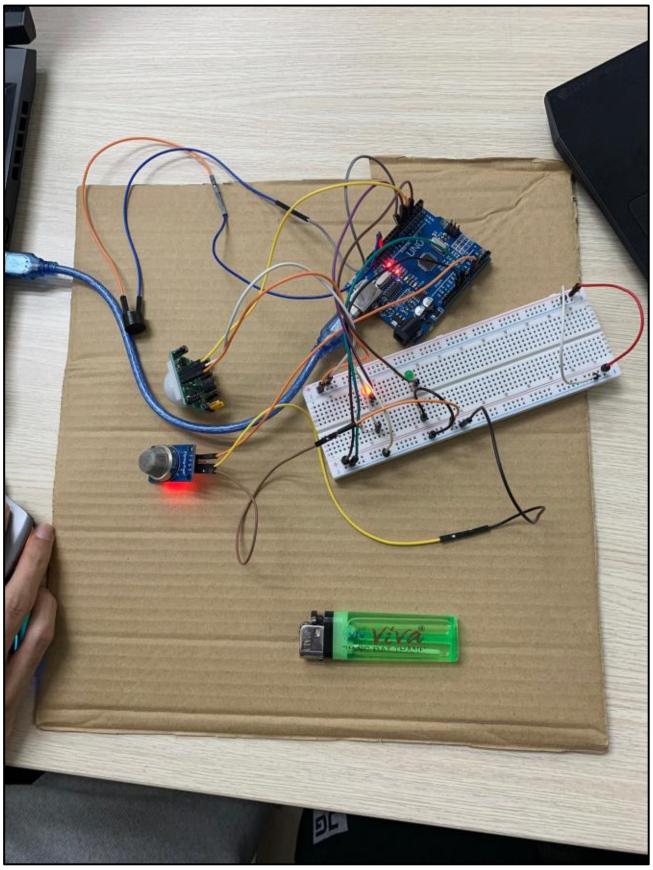


Figure 6-1 Set up client and user requirements

❖ **Make a test plan, check the functions of the IoT project of students that have met the set requirements**

In the context of constantly developing technology, smart home systems (Smart Home) are becoming an inevitable trend to improve the quality of life. Our Smart Home project focuses on creating a comfortable, safe and energy-efficient living environment through the application of advanced IoT technologies. In particular, our IoT system consists of 2 important components: an PIR body temperature sensor turns off hallway lights and a gas leak sensor.

Below we will make a test plan, check whether the functions of the IoT project meet the requirements, and then make a final conclusion for the Smart Home project.

❖ **Below is a test table of the functions of IoT PIR body temperature sensor turns off hallway lights:**

STT	Test content	Describe	Implementation process	Expected Results	Actual results	Condition
1	Motion Detection	Check the motion detection sensor and turn on the lights	- Walk through the corridor - Observe the lights on	Lights on when someone passes by	Lights on when someone passes by	Pass
2	Automatically turn off the lights	Check for lights that automatically turn off after no motion is detected	- Stand still after the light is on - Measure the time from no movement to when the light goes off	Lights turn off after default timeout	The light turns off after waiting for 200 seconds when the person has passed	Pass
3	Sensor sensitivity	Testing the sensitivity of the sensor with different objects	- Walk through the corridors at different speeds - Use objects of different sizes	The light turns on when a person or object moves by.	The light comes on as soon as the sensor system is moved by a person or object	Pass
4	Detection Distance	Sensor Motion Detection Distance Test	- Move remotely to close to the sensor - Record the maximum distance	Motion detection sensor at maximum	Motion detection sensor at a maximum	Pass

			at which the sensor detects motion	distance	distance of 200 cm	
5	Respons e time	Check the time between motion detection and light on	- Walk through the corridor - Measures the time from the start of movement to when the light turns on	Lights on during quick response times	Lights on during quick response times	Pass
6	Energy Consum ption	Check the power consumption of sensors and lights	- Use a power meter to measure the consumption of the system during operation - Record results	Energy consumption within permissible limits	Saves more energy than usual	Pass

Table 6-1 Test 1

⇨ **Test conclusion for the above functions:** The testing process of the IoT system PIR body temperature sensor turns off hallway lights has shown that most of the functions work as expected. The system is capable of detecting movement and turning on/off lights accurately and in a timely manner, meeting the criteria of sensitivity, detection distance, response time, energy consumption and durability in different environmental conditions. Overall, the system has met the testing requirements well and is ready for real-world deployment.

❖ **Below is the test table of the functions of the IoT Gas Leak Sensor product:**

STT	Test content	Describe	Implementation process	Expected Results	Actual results	Condition
1	Gas Leak Detection	Check the gas leak detection sensor and trigger the alarm	- Creates a small amount of gas leaking near the sensor - Alert Observation Triggered	Alarm triggers when a gas leak is detected.	The system generates a warning signal when there is a gas leak	Pass

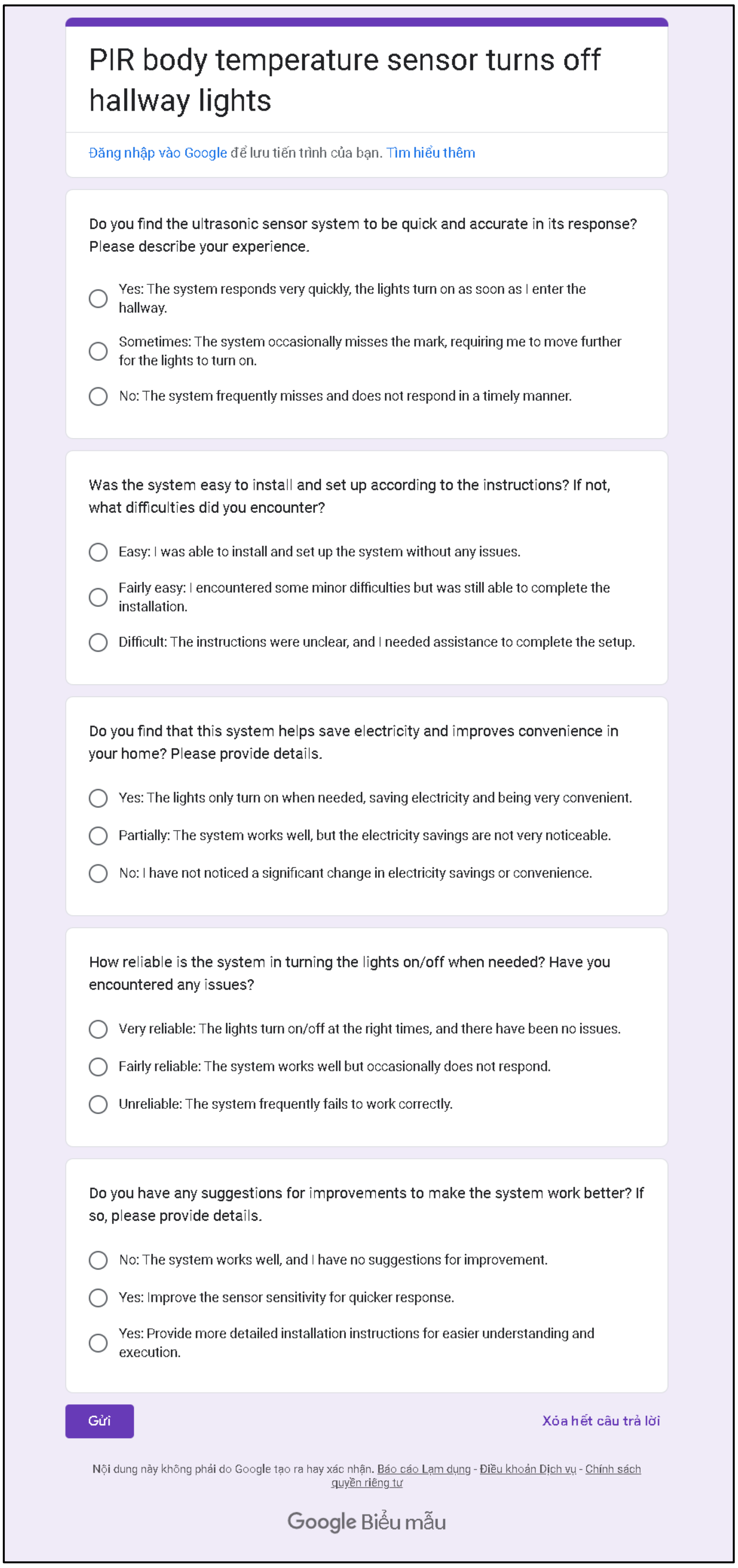
2	Sensor sensitivity	Sensor sensitivity test with different levels of gas leakage	- Creating different levels of gas leaks - Observe the reaction of the sensor	Sensors detect gas leaks at different levels	Sensors detect gas leaks at different degrees	Pass
3	Response time	Check the time from leak detection to alarm activation	- Creating a gas leak near the sensor - Measures the time from detection to when the alarm is triggered	Alerts are triggered during quick response times	Alerts are triggered immediately by the system	Pass
4	Durability in different environmental conditions	Testing the stability and durability of the system under various environmental conditions	- Testing the system under different temperature and humidity conditions - Observe the operation of the system	The system operates stably under various environmental conditions	The system still works well in a variety of environmental conditions	Pass

Table 6-2 Test 2

⇨ **Test conclusions for the above functions:** The test results have confirmed the effectiveness and reliability of the product. The sensor is capable of detecting gas leaks at different levels and triggering alarms quickly, ensuring the safety of users. The system has demonstrated high sensitivity and fast response time, and stable operation under various environmental conditions. Thus, the gas leak sensor system has fully met the testing criteria, showing great potential in improving safety and comfort for smart homes.

6.2. User surveys

To evaluate this product, we collected opinions from 200 customers through online surveys and face-to-face interviews. We created two Google Forms for the system's two main functions and conducted a survey to gather end-user requirements. The data collected will then be presented through charts and statistics.



PIR body temperature sensor turns off hallway lights

Đăng nhập vào Google để lưu tiến trình của bạn. Tìm hiểu thêm

Do you find the ultrasonic sensor system to be quick and accurate in its response? Please describe your experience.

- Yes: The system responds very quickly, the lights turn on as soon as I enter the hallway.
- Sometimes: The system occasionally misses the mark, requiring me to move further for the lights to turn on.
- No: The system frequently misses and does not respond in a timely manner.

Was the system easy to install and set up according to the instructions? If not, what difficulties did you encounter?

- Easy: I was able to install and set up the system without any issues.
- Fairly easy: I encountered some minor difficulties but was still able to complete the installation.
- Difficult: The instructions were unclear, and I needed assistance to complete the setup.

Do you find that this system helps save electricity and improves convenience in your home? Please provide details.

- Yes: The lights only turn on when needed, saving electricity and being very convenient.
- Partially: The system works well, but the electricity savings are not very noticeable.
- No: I have not noticed a significant change in electricity savings or convenience.

How reliable is the system in turning the lights on/off when needed? Have you encountered any issues?

- Very reliable: The lights turn on/off at the right times, and there have been no issues.
- Fairly reliable: The system works well but occasionally does not respond.
- Unreliable: The system frequently fails to work correctly.

Do you have any suggestions for improvements to make the system work better? If so, please provide details.

- No: The system works well, and I have no suggestions for improvement.
- Yes: Improve the sensor sensitivity for quicker response.
- Yes: Provide more detailed installation instructions for easier understanding and execution.

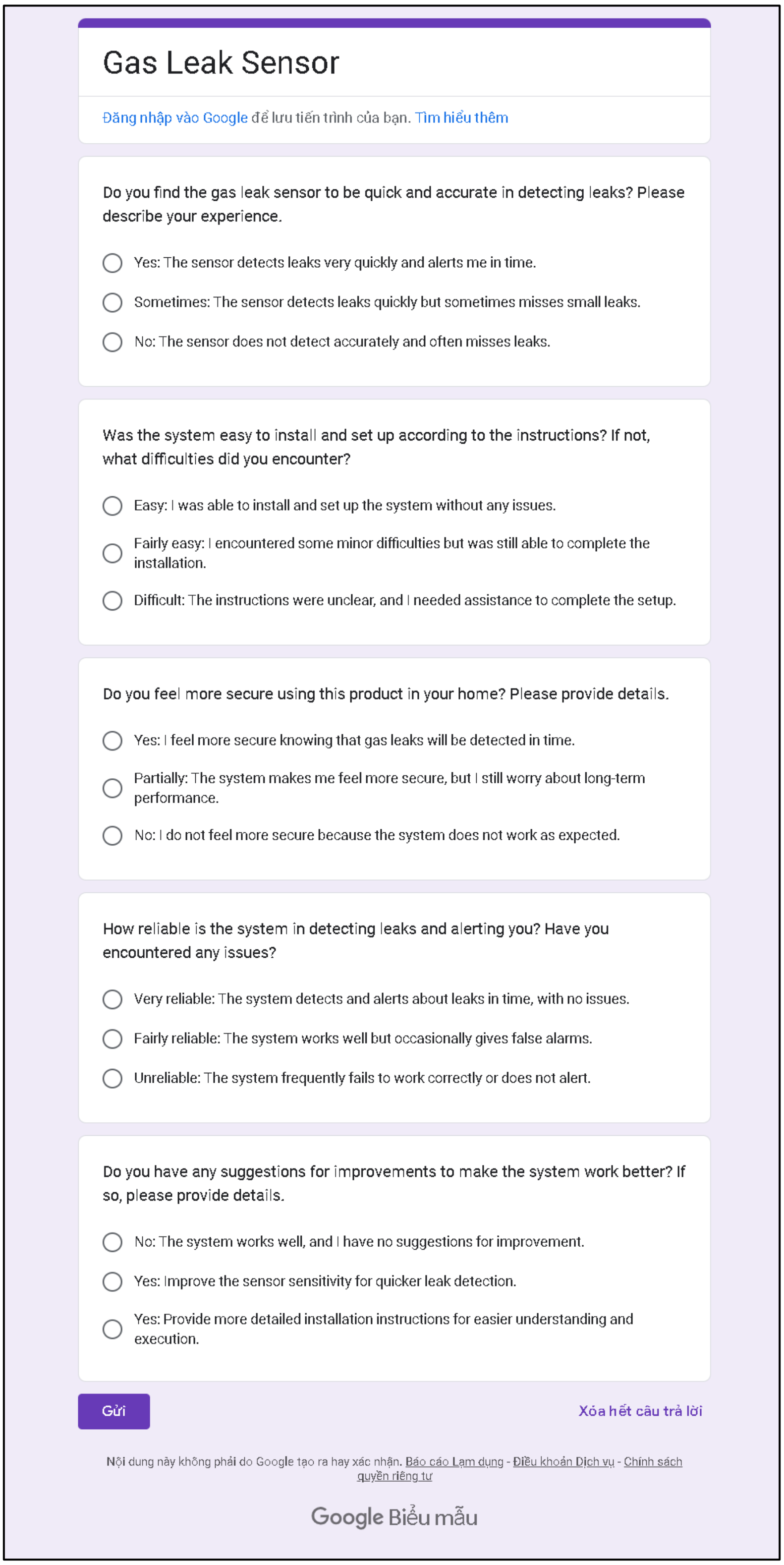
Gửi

Xóa hết câu trả lời

Nội dung này không phải do Google tạo ra hay xác nhận. Báo cáo Lạm dụng - Điều khoản Dịch vụ - Chính sách quyền riêng tư

Google Biểu mẫu

Figure 6-2 Google Forms 1



Gas Leak Sensor

Đăng nhập vào Google để lưu tiến trình của bạn. Tìm hiểu thêm

Do you find the gas leak sensor to be quick and accurate in detecting leaks? Please describe your experience.

- Yes: The sensor detects leaks very quickly and alerts me in time.
- Sometimes: The sensor detects leaks quickly but sometimes misses small leaks.
- No: The sensor does not detect accurately and often misses leaks.

Was the system easy to install and set up according to the instructions? If not, what difficulties did you encounter?

- Easy: I was able to install and set up the system without any issues.
- Fairly easy: I encountered some minor difficulties but was still able to complete the installation.
- Difficult: The instructions were unclear, and I needed assistance to complete the setup.

Do you feel more secure using this product in your home? Please provide details.

- Yes: I feel more secure knowing that gas leaks will be detected in time.
- Partially: The system makes me feel more secure, but I still worry about long-term performance.
- No: I do not feel more secure because the system does not work as expected.

How reliable is the system in detecting leaks and alerting you? Have you encountered any issues?

- Very reliable: The system detects and alerts about leaks in time, with no issues.
- Fairly reliable: The system works well but occasionally gives false alarms.
- Unreliable: The system frequently fails to work correctly or does not alert.

Do you have any suggestions for improvements to make the system work better? If so, please provide details.

- No: The system works well, and I have no suggestions for improvement.
- Yes: Improve the sensor sensitivity for quicker leak detection.
- Yes: Provide more detailed installation instructions for easier understanding and execution.

Gửi

Xóa hết câu trả lời

Nội dung này không phải do Google tạo ra hay xác nhận. Báo cáo Lạm dụng - Điều khoản Dịch vụ - Chính sách quyền riêng tư

Google Biểu mẫu

Figure 6-3 Google Forms 2

Below will be some charts showing opinions from customers as well as potential problems that need attention to be able to improve the finished product when it reaches customers.

❖ **Evaluation of IoT System PIR body temperature sensor turns off hallway lights**

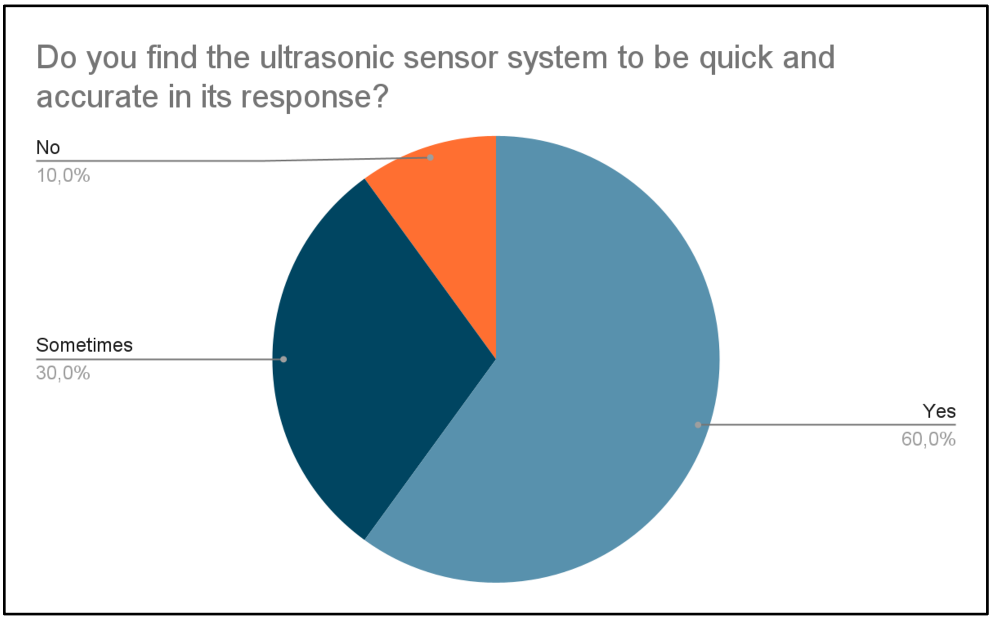


Figure 6-4 Chart 1

Observe:

- Yes (60%): Most customers consider the ultrasonic sensor system to be quick and precise, proving that it fulfills their demands well.
- Sometimes (30%): Some users believe that there are instances of erroneous or delayed replies, and that the system is unstable.
- No (10%): Although there aren't many people that have issues with accuracy and reaction time, it's still vital to remember to make improvements to the product.

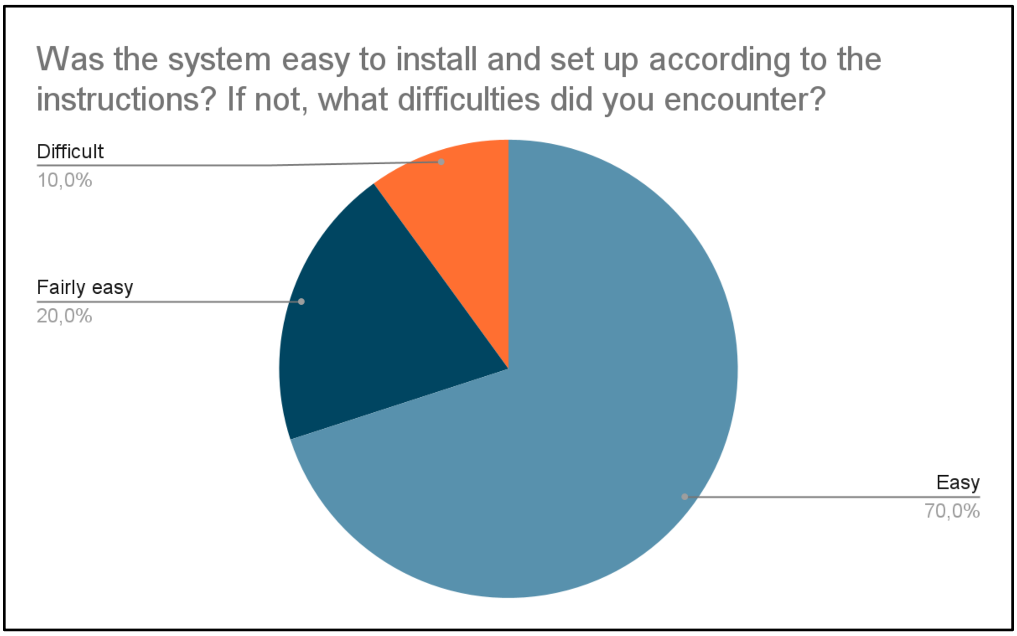


Figure 6-5 Chart 2

Observe:

- Easy (70%): The majority of people believe that installing the system in accordance with the instructions is simple, demonstrating how user-friendly the product is.
- Fairly easy (20%): A small percentage of consumers encounter minor issues but manage to finish the installation procedure.
- Difficult (10%): A tiny portion of customers report difficulty installing, which might be brought on by a lack of technical know-how or inadequately clear instructions.

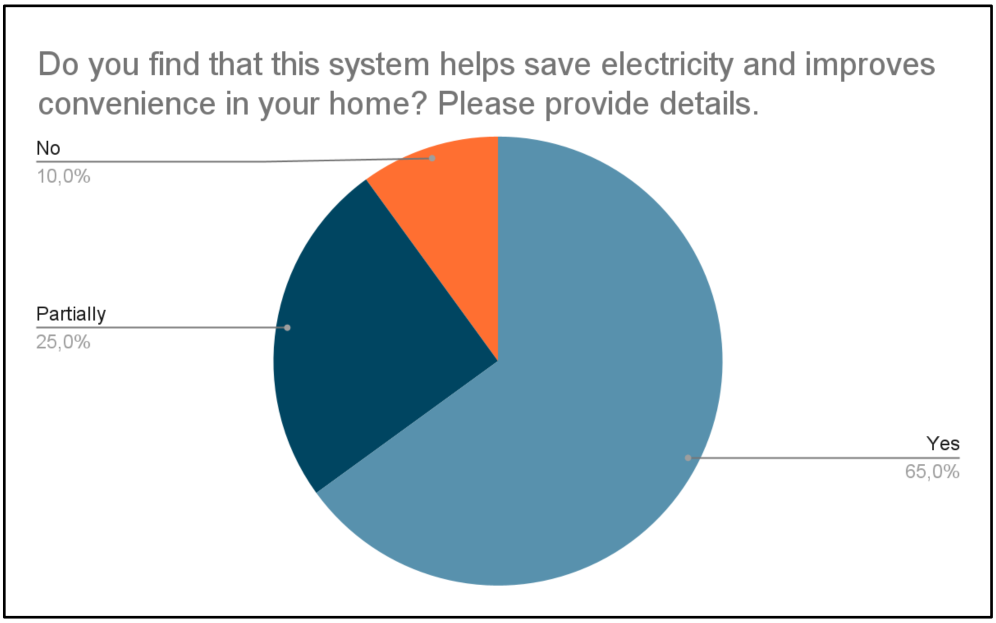


Figure 6-6 Chart 3

Observe:

- Yes (65%): The majority of consumers reported that the system increased convenience and helped save power in the house, suggesting that the device had a high practical value.
- Partially (25%): Owing to certain usage patterns or contextual factors, some users report that the system is only partially functional.
- No (10%): More research is required to improve the product since a tiny percentage of consumers do not see the system's benefits.

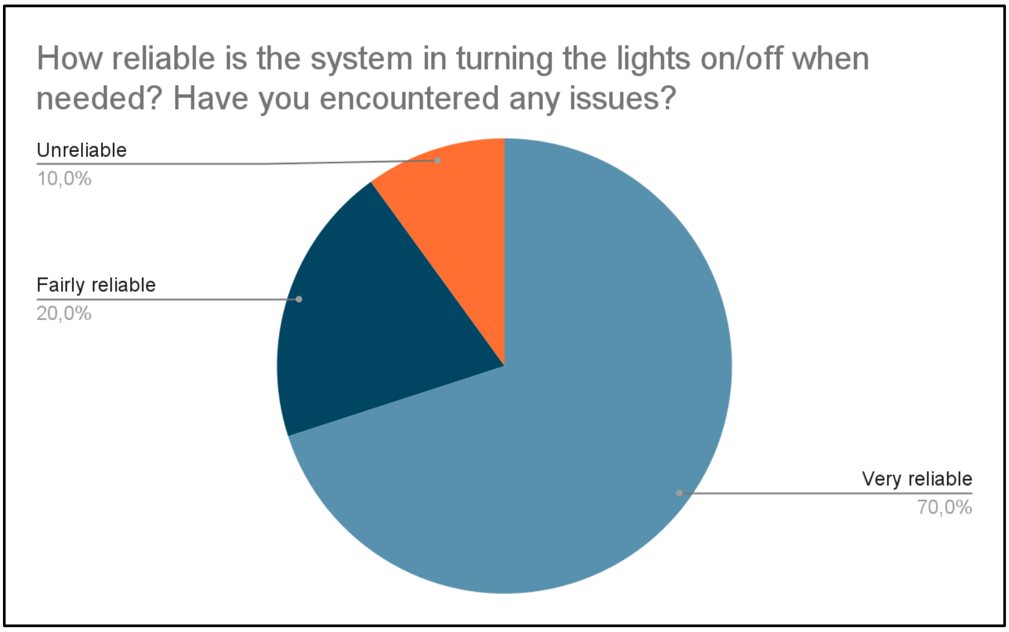


Figure 6-7 Chart 4

Observe:

- Very reliable (70%): A high level of performance is shown by the majority of users rating the system as highly reliable.
- Fairly reliable (20%): Certain users may encounter small dependability difficulties that call for maintenance or changes.
- Unreliable (10%): It's important to recognize that a tiny portion of consumers are dissatisfied with dependability in order to make improvements.

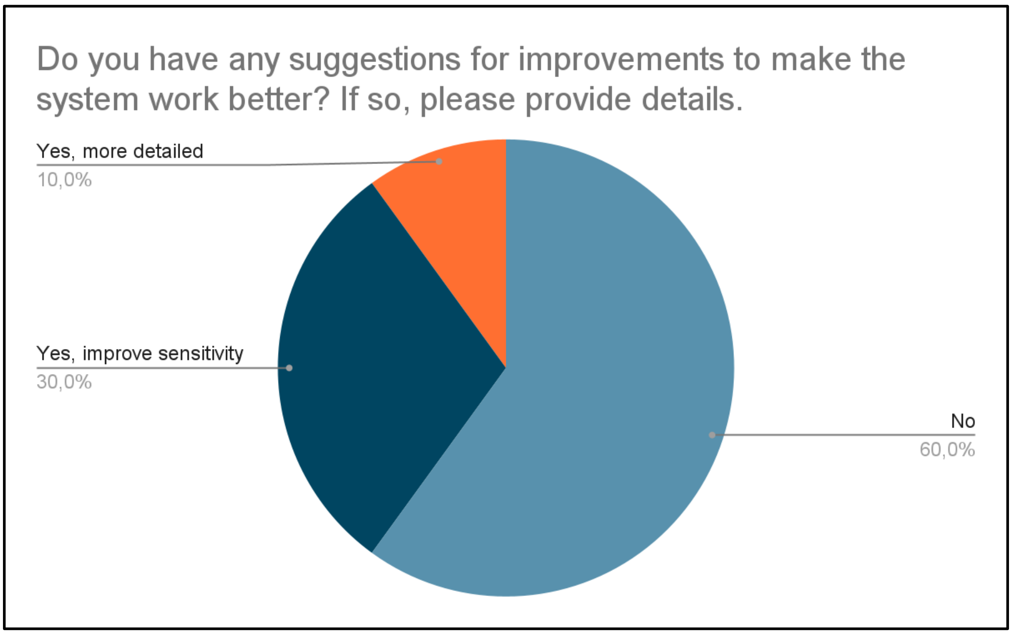


Figure 6-8 Chart 5

Observe:

- No (60%): The majority of consumers are happy with the present product and have no recommendations for improvement.
- Yes, improve sensitivity (30%): A few people have made this suggestion, indicating that there could occasionally be problems with the sensor.
- Yes, more detailed instructions (10%): Some people feel that having more thorough instructions would enhance their installation process.

⇨ Based on the following reviews after conducting a survey of 200 customers, we assessed the potential human impacts:

- **Impact on people:**

Safety and Protection:

Positive: Sensors help avoid collisions in dark corridors, reducing the risk of accidents.

Negative: If the sensor does not respond in time, it can be inconvenient and dangerous in the dark.

Convenient:

Positive: Automate the on/off of lights, improve comfort in the home.

Negative: An insensitive system can be frustrating for users.

- **Impact on businesses:**

Business Opportunities:

Positive: Create new products to attract customers, expand the market.

Negative: Must invest in research and development to stay competitive.

Costs and Profits:

Positive: Helps save energy, reduce operating costs.

Negative: The cost of system development and maintenance can be high.

- **Social Impact:**

Environmental Protection:

Positive: Reduce power consumption, contributing to environmental protection.

Negative: Manufacturing and disposal of equipment can cause e-waste.

- **Impact on end users**

User Experience:

Positive: Increase convenience, improve quality of life.

Negative: The product does not work properly which can be frustrating.

Cost:

Positive: Save on electricity costs.

Negative: High initial cost for purchase and installation.

- **Potential problems:**

Reliability and maintenance: Regular inspection and maintenance are required.

Security and privacy: It is necessary to protect the system from attacks.

Cost: It is necessary to consider reasonable prices.

Customer Support: Good customer support is needed.

❖ **Gas Leak Sensor IoT System Evaluation**

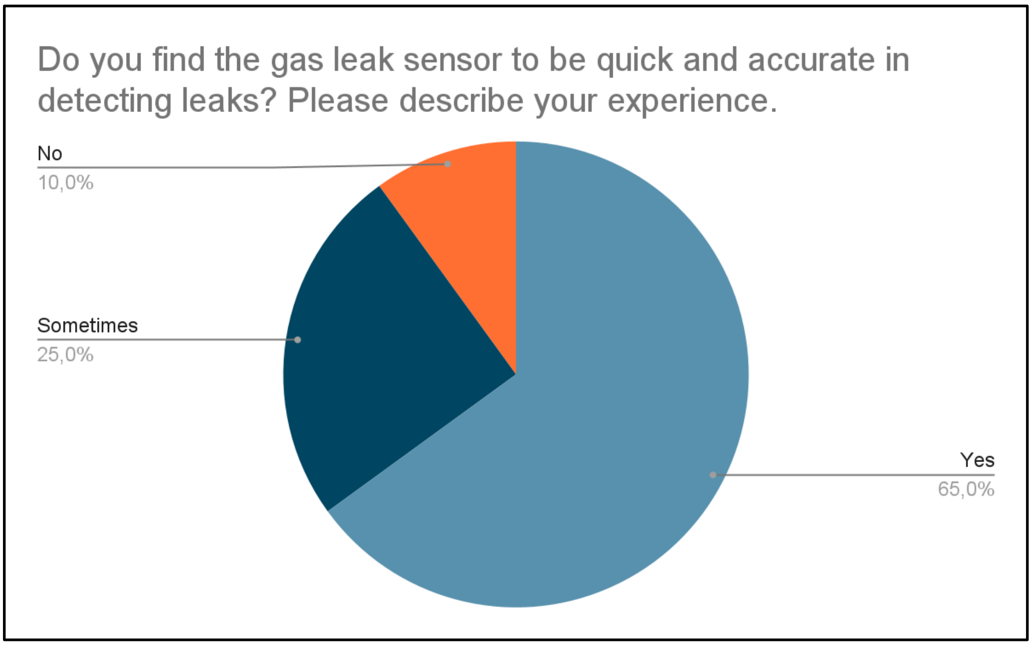


Figure 6-9 Chart 6

Observe:

- Yes (65%): Most users gave the gas leak sensor high marks for quick and precise detection, demonstrating that it satisfies safety requirements.
- Sometimes (25%): A small percentage of users report instances in which the sensor is slow or inaccurate.
- No (10%): To guarantee optimal safety, accuracy has to be enhanced since few people experience accuracy issues.

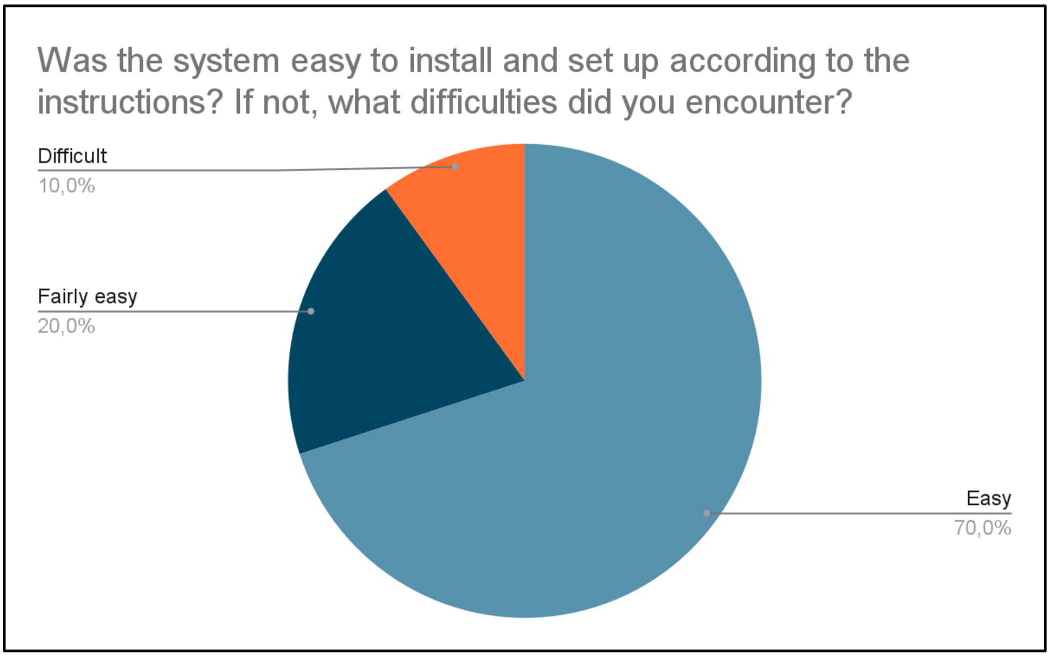


Figure 6-10 Chart 7

Observe:

- Easy (70%): The majority of people believe that installing the system is simple, demonstrating how user-friendly the product is.
- Fairly easy (20%): A small percentage of consumers encounter minor installation-related issues.
- Difficult (10%): A tiny portion of people report difficulty installing; they may require more thorough instructions.

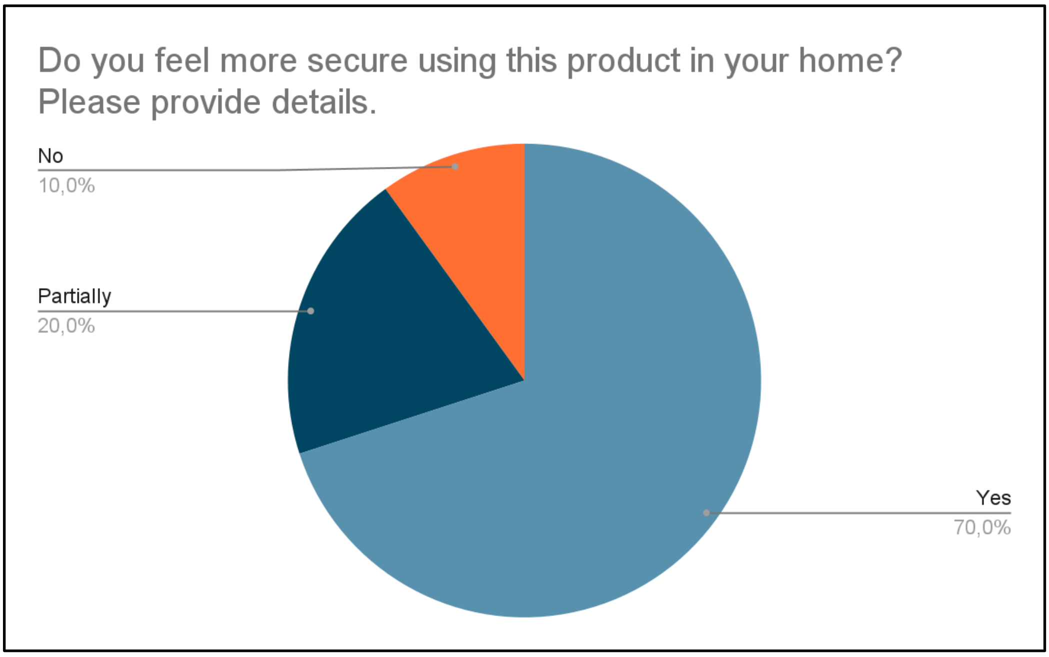


Figure 6-11 Chart 8

Observe:

- Yes (70%): The majority of users feel safer when using the product, indicating that the safety features of the product are high.
- Partially (20%): Some users feel only partially safe, possibly because the sensor is not working optimally in all situations.
- No (10%): A few users do not feel safe, which should be noted to improve the product.

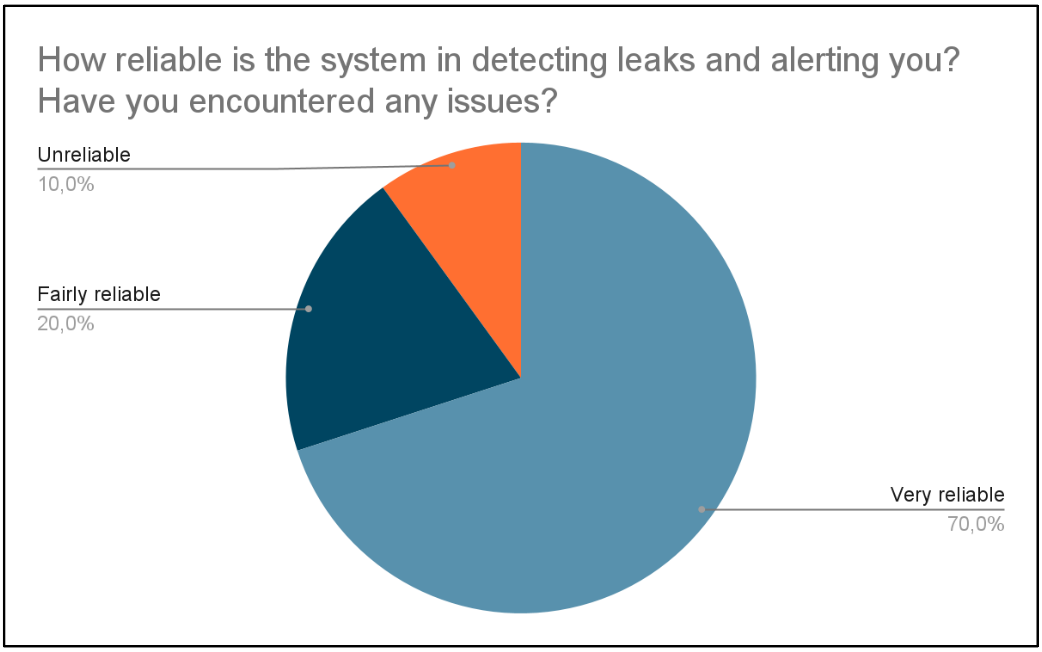


Figure 6-12 Chart 9

Observe:

- Very reliable (70%): The majority of users rate the system as very reliable in detecting leaks and alerting.
- Fairly reliable (20%): Some users have minor issues with reliability.
- Unreliable (10%): A small percentage of users are not satisfied with reliability, which needs to be improved to ensure safety.

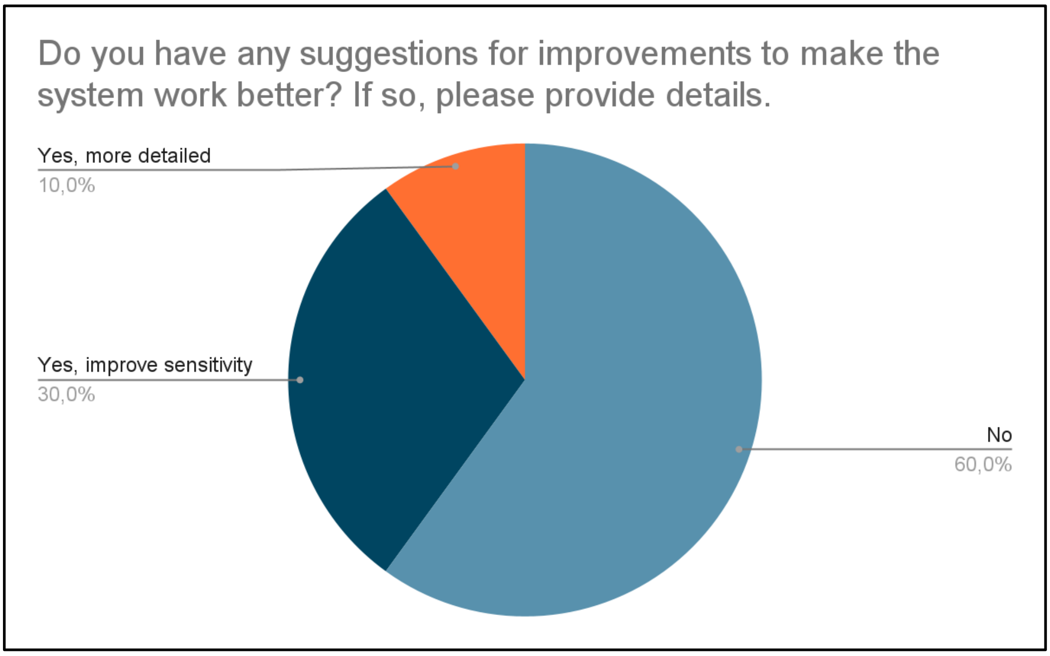


Figure 6-13 Chart 10

Observe:

- No (60%): The majority of users have no suggestions for improvement, indicating that they are satisfied with the current product.
- Yes, improve sensitivity (30%): Some users suggest improving sensitivity, which suggests that there may be sensor issues in some cases.
- Yes, more detailed instructions (10%): A few users require more detailed instructions, which can improve the installation experience.

⇨ Based on the following evaluations after conducting a survey of 200 customers, we evaluated the potential human impacts of our IoT product:

- **Impact on people**

Safety and Protection:

Positive: Early detection of gas leaks, preventing accidents and protecting health.

Negative: If the sensor is incorrect, the risk of accidents still exists.

Convenient:

Positive: Enhance safety, help users feel more secure.

Negative: A malfunctioning sensor can cause confusion and anxiety.

- **Impact on businesses**

Business Opportunities:

Positive: Safe, essential products attract many customers.

Negative: High competition requires continuous quality improvement.

Costs and Profits:

Positive: Helps minimize the risks and costs associated with accidents.

Negative: The cost of developing and maintaining the system can be high.

- **Social Impact**

Environmental Protection:

Positive: Reduce the risk of fire and explosion, protect the living environment.

Negative: Disposal of e-waste from sensors needs to be properly managed.

Technology Development:

Positive: Promote research and development of safety technology.

Negative: Cybersecurity and privacy systems need to be ensured.

- **Impact on end users**

User Experience:

Positive: Enhance safety, help users feel more secure.

Negative: Sensors not working correctly cause anxiety and frustration.

Cost:

Positive: Investing in safety is reasonable and necessary.

Negative: The initial purchase and installation costs can be high.

- **Potential problems**

Reliability and maintenance: Regular inspection and maintenance are required.

Security and privacy: Protect systems from cyberattacks.

Cost: It is necessary to consider reasonable prices to reach more users.

Customer Support: It is necessary to provide good and timely customer support.

LO4: EVALUATE YOUR IOT APPLICATION AND THE PROBLEMS IT MIGHT ENCOUNTER WHEN INTEGRATING INTO THE WIDER IOT ECOSYSTEM.

7. Review the IoT application, detailing the problems it solves. (P7)

7.1. Operation of IoT application

❖ **Gas Alarm System**

- MQ-2 or MQ-5 Sensor: The sensor detects gases (such as LPG, propane, methane) and sends data to the Arduino Uno for processing.
- Gas sensors (MQ-2/MQ-5) continuously measure the concentration of gases in the air.

❖ **Ultrasonic sensor turns hallway lights on/off**

- PIR Motion Sensor: Detects the movement of people in the hallway to turn on/off the lights automatically.
- PIR Motion Sensor detects movement in the corridor.

❖ **Sensors and control systems.**

- MS48-LR LoRaWAN: Wireless communication between the sensor and the control system.
- WiFi Module and MS48-LR LoRaWAN can be used to send status data and enable remote control over the internet.

❖ **User Alerts**

- LED: Visual indication of the status of the system (green LED indicates normal, red LED indicates gas detection).
- When a gas leak is detected, the Arduino Uno activates the Alarm Buzzer and LED to alert the user.

❖ **Remote system monitoring and control**

- The router provides a network connection to monitor and control the system remotely through a mobile app or web interface.

7.2. The problem it solves

❖ **Real-world problems our project solves**

- Minimize health risks: Long-term exposure to toxic gases can be harmful to human health. This system can detect gas concentrations exceeding safe levels and warn users in time
- Energy Management: In industrial facilities and factories, continuous gas monitoring helps to detect leaks early, thereby reducing energy loss and optimizing costs.
- Energy Saving: Corridor lights are often turned on continuously, resulting in wasted electricity.

The system automatically turns lights on/off only when necessary, helping to minimize power consumption and costs.

- Extend Lamp Life: Using the lamp only when necessary helps to extend the life of the lamp, minimizing maintenance and replacement costs.
- Safety and Security: The system can be integrated with other security solutions to detect and alert to abnormal activity or unauthorized intrusion in the surveillance area.

Both projects bring great benefits to both households and businesses, helping to improve safety, comfort, and energy efficiency.

❖ **The impact of the system on life**

These two IoT systems bring many positive impacts to human life by enhancing safety and convenience in daily living. The gas alarm system plays a crucial role in protecting the health and safety of families and businesses by detecting and providing early warnings about hazardous gas leaks, thereby minimizing the risk of fires and accidents. This not only safeguards human lives but also reduces property damage. Meanwhile, the ultrasonic sensor system for turning hallway lights on and off helps save energy and optimize costs by using lights only when necessary. This not only provides economic benefits but also contributes to environmental protection. The system also improves convenience and safety for users, especially at night, creating a smarter and more modern living environment. Overall, both systems contribute to making human life safer, more convenient, and more efficient.

- **Energy and Cost Savings**
  + Energy efficiency: When someone enters or leaves, the system automatically turns the lights on and off, saving energy and reducing electricity costs.
  + Environmental protection: Saving energy also helps protect natural resources and the environment.
- **Convenient and Easy to Use**
  + Manage light bulbs in the house easily: Users can easily monitor and manage light bulbs in the house
  + Remote control: Remote connection and control capabilities allow users to manage their smart home system more conveniently and flexibly.
- **Enhance Family Safety**

+ Safety when leaving the house: Gas detection sensors and turning lights on and off before leaving the house will help prevent accidents and protect all family members.

+ Emergency response: Gas alarm systems protect the home by allowing users to quickly identify and respond to dangerous situations.

- **Smart Home Integration**

  + Create a smart ecosystem: When you can connect with other smart devices in your home, you can create a smarter, more convenient, and safer environment.

  + Centralized control: By using a single device, users can manage and monitor the entire system, saving them more money.

- **Improve Quality of Life**

  + Reduce stress: Feeling safe and saving energy helps users reduce stress and focus on other activities.

  + Increase convenience: The system's smart and automatic features make life more convenient and comfortable.

8. Investigate the potential problems the IoT application might encounter when integrating into the wider system. (P8)

When bringing two IoT products, PIR body temperature sensor turns off hallway lights and a gas leak sensor, to the market, there are a number of potential problems that IoT applications may encounter when integrated into broader systems. Here are the important issues to keep in mind:

- **Security and Privacy**
  - Problem: IoT devices can become targets of cyberattacks, posing the risk of leaking personal information or sensitive data.
  - Potential: If not properly secured, data from the sensor can be hijacked by hackers, leading to unsafety for users, especially in gas leak sensors.
- **Compatibility and integration**
  - Problem: IoT products need to integrate with different systems and platforms, which can experience compatibility issues.
  - Potential: If the sensor system is not compatible with existing devices or applications, this can lead to a poor user experience and make it difficult to implement.
- **Connectivity and reliability**

- Problem: Relying on an internet connection to function efficiently can cause problems if the network goes down.
- Potential: If the sensor system does not work without an internet connection, this can be dangerous, especially for gas leak sensors, where timely detection is critical.

- **Maintenance and technical support costs**
  - Problem: IoT products often require routine maintenance and technical support to ensure optimal performance.
  - Potential: High maintenance costs and technical support requirements can burden users and reduce the appeal of the product.
- **Data management and analysis**
  - Problem: IoT products often collect large amounts of data, requiring an effective data management and analysis system.
  - Potential: Without the right data analysis solution, users may not be able to extract value from the collected data, reducing the value of the product.
- **Scalability**
  - Problem: When users want to expand their IoT system by adding new sensors or devices, the system needs to be well scalable.
  - Potential: If the product does not support scalability, this can lead to difficulty in upgrading the system and lost time for users.
- **Competition and market**
  - Problem: The IoT market is becoming increasingly competitive with many similar products.
  - Potential: If the product can't stand out from the competition, it may struggle to attract customers and retain them.

Cost and functionality of the two IoT products compared to devices of the same type:

- **Ultrasonic sensor system to turn corridor lights on and off**

Cost and functionality:

Initial Cost:

- PIR body temperature sensor turns off hallway lights: $30 - $50
- Traditional Light Switch: $5 - $10
- Standard Motion Sensor System: $20 - $40

- **Operating costs:**

- PIR body temperature sensor turns off hallway lights: Save energy, reduce monthly electricity costs.
- Traditional light switch: Not energy saving.
- Standard Motion Sensor System: Saves power, but may not be as efficient as ultrasonic sensors.

- **Cost and functional advantages:**
  - PIR body temperature sensor turns off hallway lights: Although the initial cost is higher than a traditional light switch, it saves energy and enhances safety, which reduces long-term costs.
  - Comparison with standard temperature sensor: The initial cost is similar, but if your ultrasonic sensor has higher sensitivity and accuracy, it will have advantages in efficiency and reliability.
- **Gas Leak Sensor:**

Cost and functionality:

Initial Cost:

- Your Gas Leak Sensor: $50 - $80
- Simple Gas Leak Detection Device: $20 - $40
- Premium Gas Leak Detection System: $100 - $150

Operating costs:

- Your Gas Leak Sensor: Maintenance Costs and Routine Inspections.
- Simple Gas Leak Detection Device: Low maintenance cost, but low detection efficiency.
- High-end gas leak detection system: Higher maintenance cost, but high detection efficiency.

Cost and functional advantages:

- Your Gas Leak Sensor: Provides accuracy and fast response, at a more reasonable initial cost than high-end systems. Integrated smart features such as automatic gas shut-off and multi-channel alerts enhance safety and convenience for users.
- Comparison with simple equipment: The initial cost is higher but provides better detection features and efficiency, reducing the risk and cost associated with accidents.

When compared to devices of the same type, both of your IoT products have a functional advantage over cost:

PIR body temperature sensor turns off hallway lights although the initial cost is higher than traditional light switches, it saves energy and enhances safety, helping to reduce long-term costs. Compared to standard motion sensor systems, your ultrasonic sensor can have the advantage of higher sensitivity and accuracy, providing high efficiency and reliability.

Gas Leak Sensors provides accuracy and fast response at a more reasonable initial cost than high-end systems. Integrated smart features such as automatic gas shut-off and multi-channel alerts enhance safety and convenience for users. Compared with simple equipment, the initial cost is higher but provides better detection features and efficiency, reducing the risk and cost associated with accidents. This helps your product stand out and compete more in the market, attracting users with a balance between functionality and cost.

With the Iot Smart Home project, specifically our PIR body temperature sensor turns off hallway lights and gas leak sensors, the initial cost is from $30 to $50, higher than the switch light system $5 - $10 and standard motion sensor ($20 - $40). However, our system provides long-term benefits in terms of energy savings, reduced electricity bills and increased safety. Despite the higher initial cost, ultrasound thanks provides greater efficiency and reliability, especially in continuous interface detection, which makes it a better solution than other another choice. With the era of modernization and technological development, our smart devices will contribute to making your home modern and especially convenient, making your home safer. more complete and informative.

CONCLUSION

The Internet of Things (IoT) is revolutionizing how we interact with technology, enhancing connectivity and efficiency across various domains. This assignment explored key aspects of IoT, including its protocols, communication models, and design principles, as well as practical applications and hardware like Arduino and Raspberry Pi.

We highlighted the importance of selecting appropriate protocols and models to ensure low power consumption, real-time communication, and reliability. The study of IoT levels and deployment templates provides a structured approach to building scalable IoT solutions.

Overall, the insights gained equip us to develop effective IoT systems, driving innovation and improving quality of life in fields such as healthcare, agriculture, and smart cities. Continued learning and adaptation to new advancements will be crucial in leveraging IoT's full potential.

EVALUATION

This assignment provided a comprehensive overview of the Internet of Things (IoT), covering essential aspects such as protocols, communication models, and practical applications. By examining protocols like MQTT, CoAP, and HTTP/HTTPS, we learned how to choose the right protocol for different use cases.

The exploration of communication models and IoT hardware, such as Arduino and Raspberry Pi, highlighted the importance of flexible, scalable architectures and hands-on prototyping. Studying deployment templates and communication APIs further deepened our understanding of building robust IoT systems.

Overall, this assignment effectively prepared us to address real-world IoT challenges, equipping us with the knowledge to develop innovative IoT solutions across various fields.

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