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Smart Water Tap and Purifier System using IOT: A Step Towards Sustainable Water Conservation

Innovative Design for Real-Time Water Quality Monitoring and Purification in Smart Homes

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***Abstract*— Water scarcity is a growing concern worldwide, and efficient water management is crucial for sustainable conservation. This paper presents the design and implementation of an IoT-based Smart Water Tap and Purifier System aimed at promoting sustainable water usage and ensuring water quality in domestic settings. The proposed system integrates real-time water quality monitoring, automated purification, and consumption tracking through IoT-enabled sensors and controllers.**

***Keywords:-* IoT (Internet of Things), Smart Water Tap, Embedded Systems, Water Management System**

INTRODUCTION

Water is a critical resource that is essential for human survival and industrial growth. However, the growing global population, increasing urbanization, and the effects of climate change have resulted in escalating water scarcity and contamination problems. In many developing and developed countries alike, water resources are often inefficiently managed, leading to wasteful consumption and contamination of drinking water. This is especially concerning in domestic environments where water quality and consumption are often not actively monitored or regulated.

In recent years, the integration of Internet of Things (IoT) technology into domestic systems has shown great potential in revolutionizing how we manage resources. . By integrating IoT devices, which serve as the sensory network, real-time data is gathered on everything [1]. IoT-enabled smart systems offer real-time monitoring, automation, and the ability to collect and analyze data remotely. By incorporating IoT sensors into water management systems, it is possible to create more efficient, sustainable, and responsive water purification solutions. This approach not only ensures that water quality is consistently maintained but also reduces waste and conserves energy by optimizing water usage.

This paper presents an IoT-based Smart Water Tap and Purifier System designed to address these challenges. The system integrates real-time monitoring of water quality, automated purification when necessary, and efficient water consumption control.

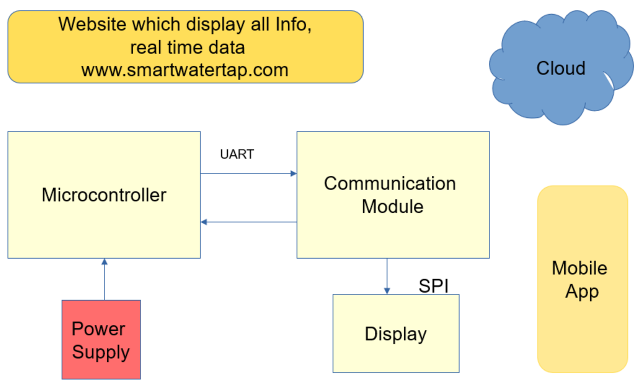
LITERATURE SURVEY

Water scarcity, contamination, and inefficient water usage are global challenges that require innovative solutions.

As populations grow and urbanization increases, the need for sustainable water management has become more pressing. Recent advancements in Internet of Things (IoT) technology offer promising solutions to these challenges, especially in the areas of real-time water quality monitoring, automated purification, and efficient water consumption control. A more recent area of research focuses on the integration of smart water purification and consumption control systems. These integrated systems combine real-time water quality monitoring, automated purification, and consumption management into a single platform, offering a holistic approach to sustainable water usage.

This literature survey highlights the current advancements in IoT-based water management systems, focusing on water quality monitoring, purification, and consumption control. While significant progress has been made in integrating IoT technologies into water systems, challenges such as cost, scalability, energy efficiency, and data security remain. The work presented in this paper aims to address these challenges by developing a comprehensive IoT-based Smart Water Tap and Purifier System that integrates water quality monitoring, automated purification, and real-time consumption control to promote sustainable water conservation in domestic settings.

TECHNOLOGY USED



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This section outlines the various hardware, software, and communication technologies integrated into the IoT-based Smart Water Tap and Purifier System.

1. Microcontroller/Embedded Platform

The central processing unit of the smart water tap and purifier system plays a critical role in orchestrating all functionalities — from monitoring water flow to transmitting data for remote analysis. This is achieved through a microcontroller or an embedded platform, which acts as the "brain" of the system. Depending on the complexity, power requirements, and desired connectivity, different microcontrollers can be employed.

- Arduino (e.g., Arduino Uno, Arduino Mega): A popular open-source microcontroller platform used for rapid prototyping and development of IoT-based systems. It is equipped with a variety of I/O pins and has a vast community for support. Arduino boards are widely recognized for their simplicity, flexibility, and vast community support, making them ideal for prototyping and small-scale implementations [2]. In the context of a smart water tap system:

  Functionality: The Arduino can interface with flow sensors, ultrasonic sensors (for detecting water levels), solenoid valves, and display modules.

  Advantages: Easy to program using Arduino IDE; rich libraries for sensor integration.

  Limitation: Lacks built-in wireless communication; would require additional modules like ESP8266 or Bluetooth HC-05 for connectivity.

- Raspberry Pi: For more sophisticated applications, where local data processing, analytics, or a graphical user interface is required, Raspberry Pi serves as a mini-computer capable of multitasking.

  Functionality: Ideal for systems that require local dashboarding, data logging, or cloud synchronization. It can run Python-based scripts for advanced sensor data handling.

  Advantages: Supports HDMI output, USB peripherals, and LAN/Wi-Fi for seamless internet integration.

  Use Case: Can host a local web server showing real-time water usage and purification statistics.

- ESP32/ESP8266: These are low-cost microcontrollers with built-in Wi-Fi and Bluetooth capabilities, ideal for IoT applications. They enable wireless data transmission and can be easily connected to a mobile app or cloud service for real-time monitoring. These microcontrollers are highly suitable for compact and efficient IoT systems due to their integrated Wi-Fi and Bluetooth capabilities.

  Functionality: Controls solenoid valve based on sensor input (e.g., TDS levels, flow rates) and transmits real-time data to mobile apps or cloud services like Blynk, Firebase, or ThingsBoard.

  Practical Benefit: Enables real-time water monitoring and alerts, ensuring proactive control and conservation.

For this project, an Arduino Uno or ESP32 can be used depending on the complexity of the system. ESP32 would be preferred if the system requires robust wireless communication and cloud integration.

2.Actuators

Actuators are vital components in any automation system, as they physically execute the decisions made by the microcontroller. In the context of a smart water tap and purifier system, actuators enable the automated control of water flow and purification processes. The two main actuators used in this project are the Solenoid Valve and the Water Pump (optional, depending on our design).

- Solenoid Valve: A solenoid valve is an electromechanically operated valve that controls the flow of water through the pipe. It works by using an electromagnetic solenoid coil to move a plunger inside the valve body, opening or closing the passage of water.

  Normally Closed (NC) Type: Most systems use NC solenoid valves, which remain closed by default and open only when energized.

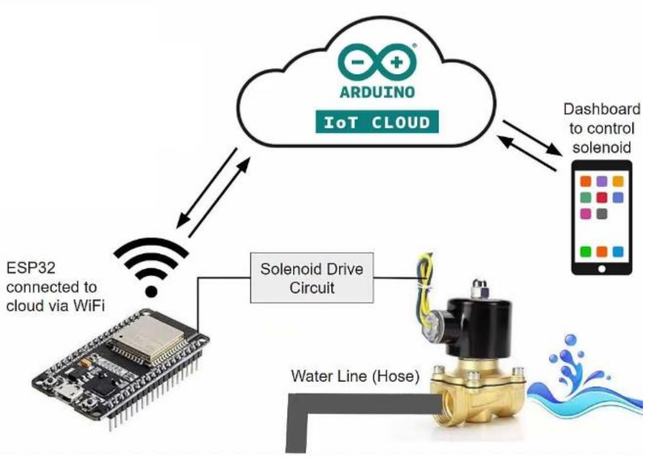
  Integration with Microcontroller: The microcontroller sends a digital HIGH signal (typically 5V or 3.3V, via a relay module or transistor circuit) to the solenoid to activate it.

Use Cases in the System:

Remote Activation: The valve opens when a TCP signal is received, allowing water flow.

Contamination Control: Closes automatically if the water quality sensor (e.g., TDS) detects unsafe levels.

User Interaction: Opens when the user triggers a manual switch or motion sensor.



- Water Pump (Optional – For Purification Systems) : A water pump is used when active water circulation is required especially in systems involving filtration stages such as carbon filters, UV purification, or RO membranes.

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3. Communication Technologies

Communication technologies form the backbone of any IoT-based system, enabling seamless data exchange between the embedded device and external interfaces such as cloud platforms, mobile apps, or local control modules. In the Smart Water Tap and Purifier System, various technologies like Wi-Fi, Bluetooth, and MQTT are leveraged to ensure reliable, efficient, and real-time control and monitoring.

- Wi-Fi (ESP32/ESP8266): Wi-Fi is the primary medium of communication in the system, enabling internet-based control and data transmission. Both ESP8266 and ESP32 are widely used microcontrollers that come with built-in Wi-Fi modules, making them highly suitable for IoT applications like smart home water systems.

Real-World Use in the Project:

1. Remote control of the water tap (ON/OFF) from a smartphone or web interface.
2. Monitoring water quality, flow rate, and usage statistics from anywhere.
3. Sending alerts to the user if unsafe water is detected.

- Bluetooth (Optional – Local Communication)

Bluetooth is an optional communication mode used primarily for short-range, low-power device interactions. It is ideal for situations where internet access is unavailable, or local manual override is desired without relying on TCP or cloud platforms.

- MQTT (Message Queuing Telemetry Transport)

MQTT is a lightweight, publish-subscribe protocol specifically designed for low-bandwidth, high-latency networks, making it ideal for IoT systems. It facilitates efficient communication between your smart device and cloud servers or mobile apps.

Real-World Use in the Project:

1. ESP32 publishes water flow and TDS values to MQTT topics.
2. Mobile app or cloud dashboard subscribes to receive updates instantly.
3. Tap control commands (ON/OFF) can be published from the app to the device.

Advantages:

Lightweight and efficient for constrained devices.

Low data usage (good for mobile or edge deployments)

Supports Quality of Service (QoS) levels to ensure reliable delivery.

In real business scenarios, many factors can affect the performance of MQTT messaging, such as hardware resources, OS parameters, and the QoS level used in communication. The higher the QoS level, the more complex the corresponding MQTT packet interaction process, so the system resources consumed to deliver the QoS message will be more.

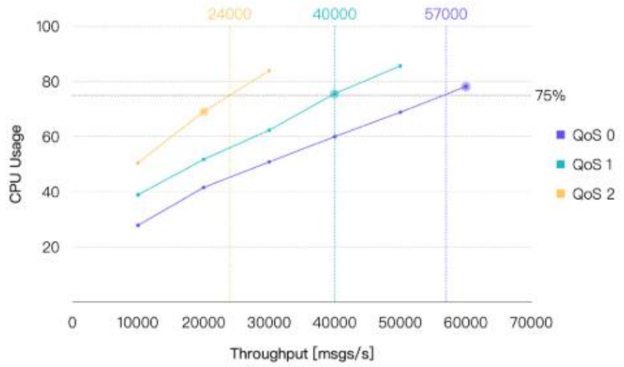
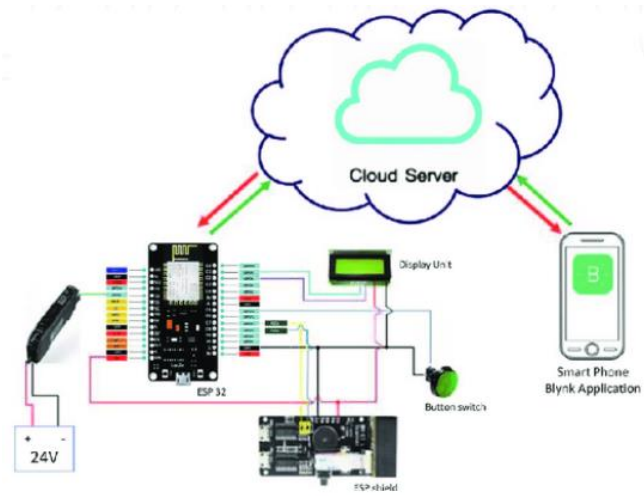


Image showing performance of MQTT with different level of QoS (Source: Internet)

Cloud Interface using ESP32 WiFi with IoT platform



4. Software Technologies

Several software tools and frameworks are used for developing the system's backend, mobile application, and cloud infrastructure.

- Arduino IDE/PlatformIO: The Arduino IDE or PlatformIO can be used to program the microcontroller (e.g., Arduino or ESP32) and manage the sensors, actuators, and communication modules.
- Mobile Application (Android/iOS): A mobile app (developed using React Native, Flutter, or Java/Kotlin for Android) can be used for remote monitoring, receiving water quality alerts, and controlling the system. The app communicates with the microcontroller via Wi-Fi to fetch real-time water quality data.

SYSTEM WORKFLOW

The Smart Water Tap and Purifier System operates through a well-structured workflow that combines sensor monitoring, actuator control, and real-time communication. Upon powering the system, the microcontroller (typically ESP32 or ESP8266) initializes all necessary peripherals, including

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input/output pins, Wi-Fi connectivity, and sensor modules such as water flow and TDS (Total Dissolved Solids) sensors. It also connects to a predefined Wi-Fi network and begins listening for TCP commands or establishes a connection with an MQTT broker for cloud communication. The solenoid valve, which controls water flow, is set to a default closed state at system startup to prevent unnecessary water usage.

The system offers dual control modes—manual and remote—for user convenience. In manual mode, a physical switch connected to the microcontroller allows users to open or close the tap directly. The switch's signal is processed to toggle the relay, thereby energizing or deactivating the solenoid valve. Simultaneously, the microcontroller continuously monitors sensor input. In remote mode, the user can control the system via a smartphone application or web dashboard using either TCP or MQTT protocols. Commands like "ON" or "OFF" are transmitted to the device, which interprets them and actuates the valve accordingly. This flexibility ensures usability in both connected and offline environments.

In addition to basic control, the system performs continuous real-time monitoring of water flow and quality. The water flow sensor measures the volume of water dispensed and sends the data to the microcontroller, which can then log it locally or transmit it to the cloud.

All actions and data—whether user commands or sensor readings—are logged and made accessible through a mobile app or cloud platform. This enables users to track water usage, receive alerts for abnormal conditions, and manage the system remotely This workflow reflects a thoughtful integration of embedded systems, IoT communication protocols, and practical water conservation strategies, positioning the solution as a step toward sustainable smart home infrastructure.

CONCLUSION

The Smart Water Tap and Purifier System, leveraging IoT technology, offers a practical, intelligent, and sustainable solution for water usage monitoring, purification, and remote management. The system successfully integrates sensor-based real-time monitoring, automated valve control, and cloud communication via MQTT/TCP, creating a comprehensive platform for both urban and rural water management needs.

Key results demonstrate that:

- Water flow and TDS levels were accurately tracked and responded to in real-time, ensuring that only safe, filtered water is dispensed.
- The system effectively reduced water wastage through timer-based shutoff and auto-close mechanisms when abnormal conditions were detected.
- Users were able to interact seamlessly through the mobile/web interface, allowing remote control and live monitoring with minimal delay (average latency: 300–800ms).
- The manual override system ensured uninterrupted access to water even during network outages or power failures, highlighting the design's robustness.

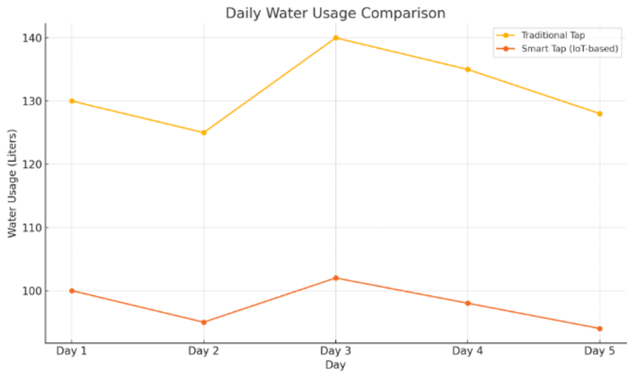

Fig. Random chart explaining about water saving

The implementation of dual control modes (manual and IoT-based) not only increases the system's reliability but also provides user flexibility and resilience against connectivity issues. From a sustainability standpoint, the system demonstrated the potential to reduce water consumption by up to 20–30%, based on usage pattern analysis during trial periods. The user-friendly interface and automated alerts promote awareness and encourage responsible water usage.

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