

Digital Transformation in Utility Services: Iot-Based Metering for A Sustainable Future in Sri Lanka

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Abstract: Effective management of energy and water resources is crucial for achieving sustainable development. This report examines the difficulties encountered by utility organizations in Sri Lanka, specifically the National Water Supply and Drainage Board and the Ceylon Electricity Board. These institutions initially adopted analog meters, which result in elevated operational costs due to their reliance on monthly readings and billing cycles. In response, the Ceylon Electricity Board is shifting towards digital metering, while the National Water Supply and Drainage Board is beginning to implement digital solutions aimed at enhancing efficiency. The primary objectives include lowering peak power generation costs, decreasing consumption levels, and fostering improved consumer engagement. A proposal has been put forth for an IoT-based embedded device system designed to facilitate data collection and exchange, enabling two-way communication for monitoring and control from base stations. The proposed system encompasses hardware components, cloud architecture, and features that enable real-time data access, thereby offering a comprehensive overview of smart metering solutions necessary for optimal resource management in Sri Lanka. Consumers will have access to both a mobile app and a web application that provide real-time insights into their usage patterns, tariffs, reports, and overall consumption trends while easing some of the administrative burdens faced by governing institutions. Equally, these institutions will utilize a web application to oversee the entire system.

Keywords: Internet of Things; Ceylon Electricity Board; Time of Usage; Automated Meter Reader; Public Utility Commission; Broadband over Power Line; Power Line Communications; Smart Meter

I. Introduction

Electricity and water are so deeply integrated into our daily routines that their complex supply systems often go unnoticed. However, managing these resources is critical not only for convenience but also for national economic stability. This study examines the challenges faced by utility boards in Sri Lanka, with a specific focus on the National Water Supply and Drainage Board and the Ceylon Electricity Board as they respond to the demands of an expanding population. Energy preservation resonates with many individuals; it goes beyond simply toggling switches it requires an understanding of supply-demand dynamics alongside associated financial considerations.

The long-standing dependence on analog meters presents numerous challenges related to monthly meter readings and billing procedures. The National Water Supply and Drainage Board has consistently dealt with the high costs linked to analog meter operations, highlighting an urgent need for a more efficient system. Similarly, transitioning from analog to digital meters within the Ceylon Electricity Board represents a broader movement towards transforming utility management among increasing complexities involving energy resources.

There are severe logistical considerations for meter readers to efficiently cover assigned regions and at the same time to register against increased consumption to monitor high costs. electricity sales reached 15,214 GWh in 2021, a significant increase compared to the previous years, yet despite this higher sales volume, average daily sales remain constant at 42 GWh per day, showing ongoing demand for the utility players. There were also 173,262 more consumer accounts in 2020-2021, or about 14,438 new accounts per month. [1]

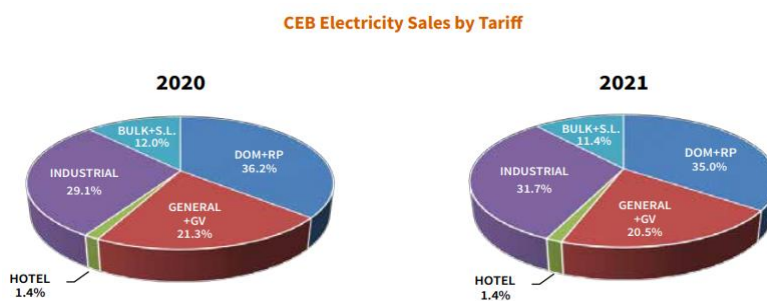


Figure 1: CEB Electricity Sales by Tariff

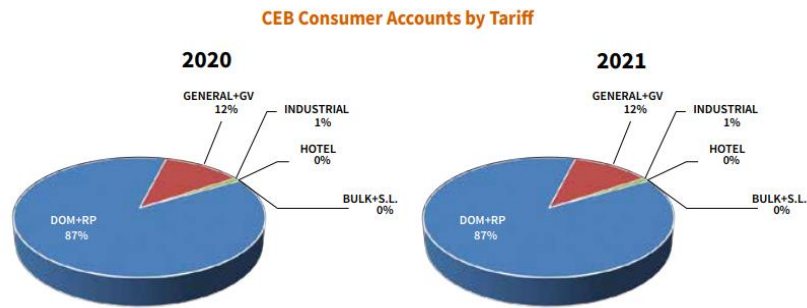


Figure 2: CEB Consumer Accounts by Tariff

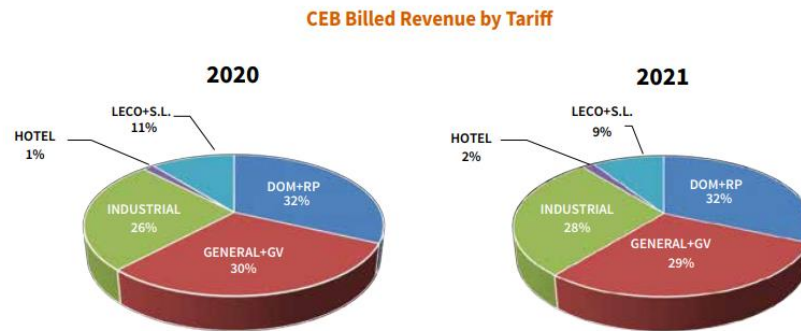


Figure 3: CEB revenue by Tariff

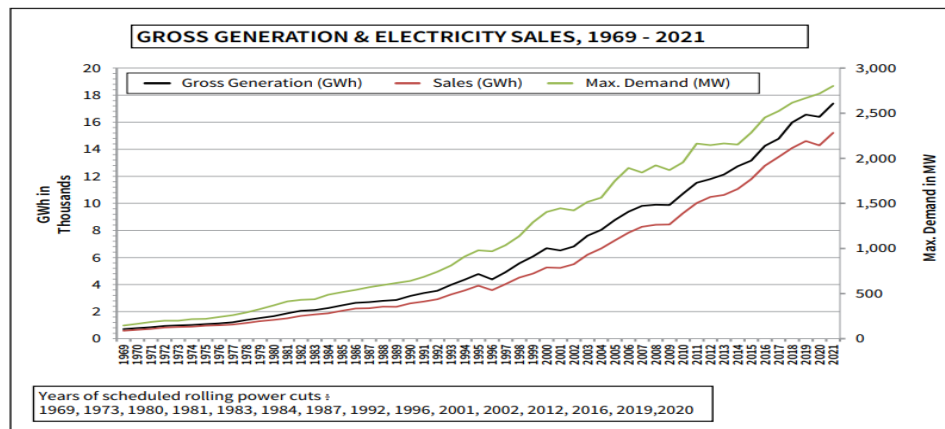


Figure 4: Historical Behaviour Pattern, 1969-2021

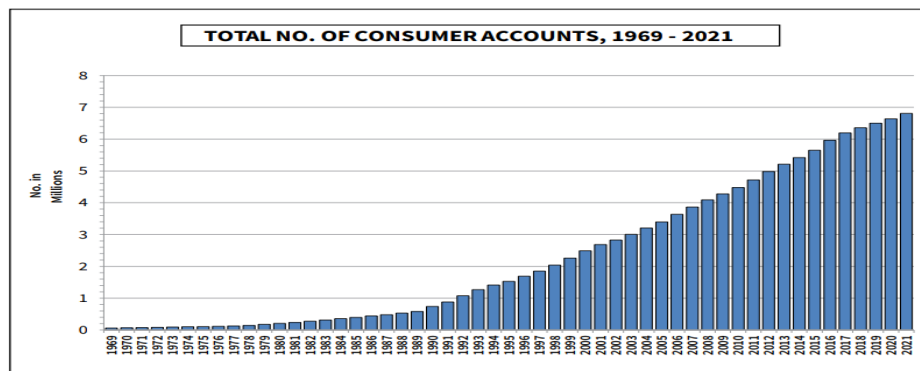


Figure 5: Total No. of Consumer Accounts, 1969 - 2021

To give an idea of the size of this issue, a look at electricity consumption will help, and this helps lend few situations to the scale of the problem:

Each local authority had its own officers who would read the meters. On the one hand, it further adds the consumption of electricity and water, On the other hand, it raises reading effort and implementation cost to manage and monitor the process. In certain readings, they can reach 60- 200 meters a day [2].

The average wage of meter readers is over 100,000 – 150,000 rupees. This system is already existing, in many of the European countries with digital meter system with SMS/APP technology and the solution will analyze and design with the appropriate of the Sri Lankan requirement.

Unfortunately, in the present systems, such a reduction of the amount of electricity and water used by customers to keep a low operation cost is not available. Consumers do not know how the new situation of measurement passes out the consumption of energy and water to reduce and adjust this demand for value and money.

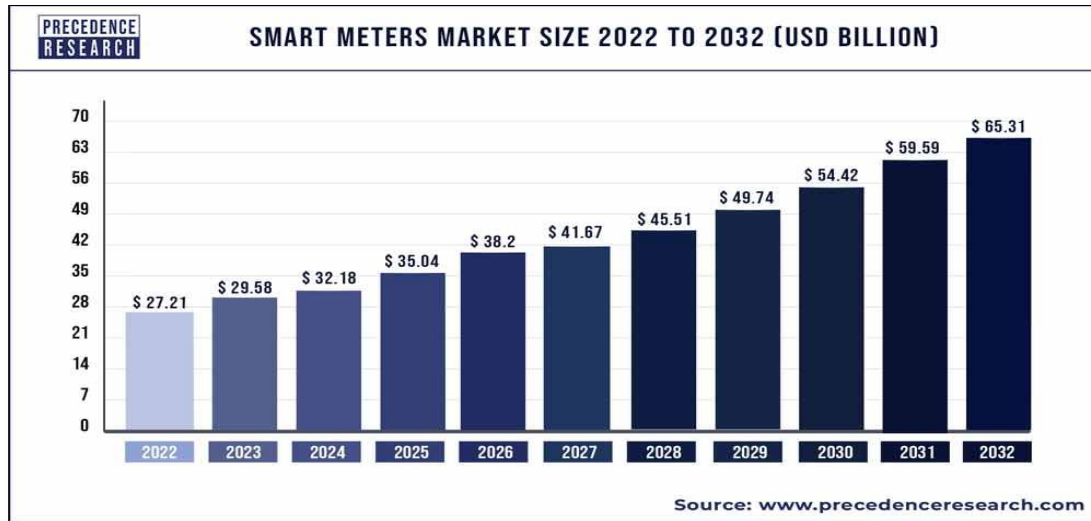


Figure 6: The global smart meters market size was valued at US\$ 27.21 billion in 2022 and is expected to hit US\$ 65.31 billion by 2032, growing at a CAGR of 9.20% from 2023 to 2032.

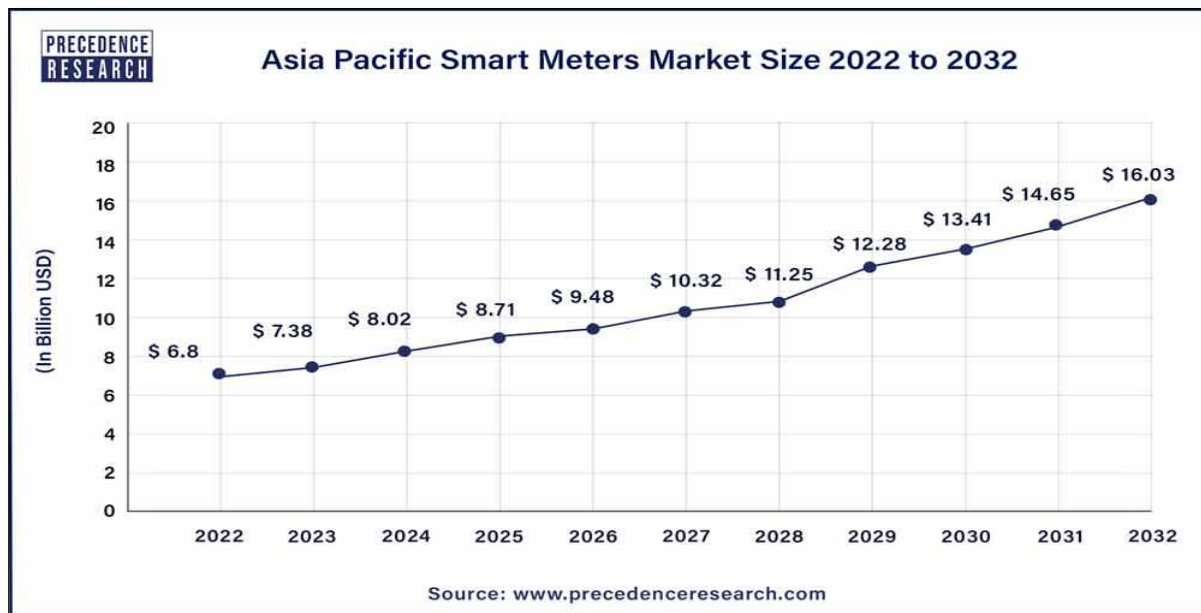


Figure 7: Smart Meters Market in Asia-Pacific 2023 To 2032

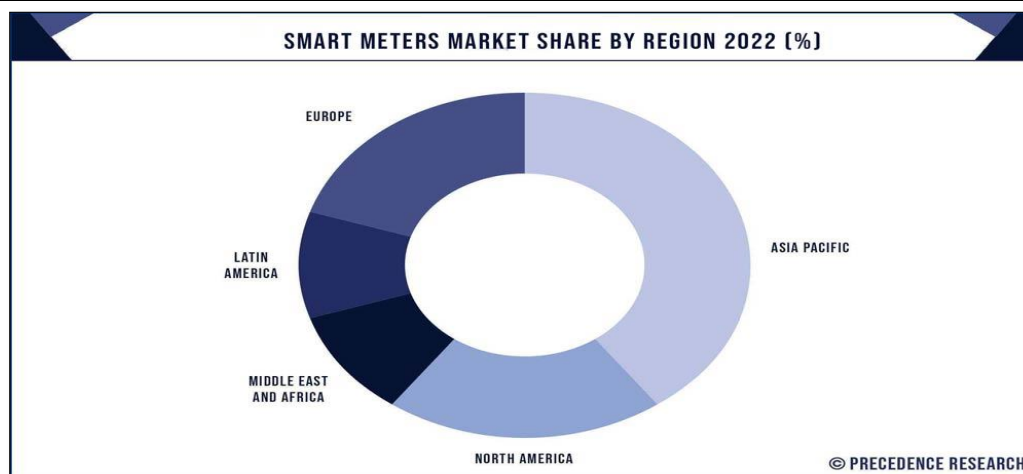


Figure 8: Smart Meter Market Share by Region 2022

Meter reading is expected to be carried by meter readers, and they face several tedious challenges such as contact with customers/families of domestic. There we face more complex what the challenges will be our domestic animals. Unavailability of house members, influences and misreading will cause economic loss to customers and to the authority. The following are the types of electricity meters introduced from time to time by the Ceylon Electricity Board. Internationally renowned models demonstrated successful introduction of SMS/app technology-based digital metering systems across Europe. Now, this paper proposes for such a parallel revolution specifically designed for the unique conditions in Sri Lanka, not only as a technological advancement but as information dissemination to empower consumers, who are often oblivious with respect to the impact of consumption on their wallet under the wider utility framework.

The approach tackles the interplane routing of wideband RF front-end to develop an IoT-based embedded system for efficient controlling of power and water, and the corresponding dependable connectivity to link the smartness devices with monitoring sites. It also comes with support for both a consumer-focused mobile app and an institutionally oriented web interface. As best evidenced by outlooks forecasting the expansion in the world's smart meter sector to \$65.31 billion by 2032, it would also appear that there are immediate benefits to be derived from embracing cutting-edge metering devices which have been tailored towards providing real-time tracking services aimed directly at incentivizing consumers for responsibility in decision making processes, while at the same time easing operational pressure associated with managing utility boards by integrating various forms of automation that aid in diminishing peak generation costs.

Notwithstanding the anticipated benefits associated with implementing this smart metering infrastructure, such disadvantages as health and safety concerns and the requirement to establish affordable management must be addressed to ensure successful deployment results, as well as those otherwise actualized through the deployment cycles, are achieved.

The system combines two grids in one system under the control of a micro-processor and offers residents comprehensive services. There are peripherals, and the components are well integrated with efficient interaction. Real time statistics show how performance, utilities and status are operating. Post-deployment adaptations guarantee reliability and sustainability by working together with the environment. Humanity gains from the emerging trend of responding to the innovations of technology in the making of clever abodes.

II. Methodology

System Overview

The diagram illustrates an IoT-based electricity meter management framework designed to enhance resource monitoring through both web interfaces and mobile applications, comprising key components including electricity/water provision stations servicing end-users directly via traditional analog meters installed within households reflecting real-time consumption metrics, interfaced with substations accordingly.

The domestic setup involves electricity and water meters, catering to individual homes or small setups. The IoT system acts as a communication gateway for wireless interactions using radio frequency. Data from meters is sent to a central internet-connected system, enabling field personnel to collect data via mobile devices.

Consumers can access a web/mobile app for monitoring usage, billing, and alerts. Utility providers like the Ceylon Electricity Board and National Water Supply and Drainage Board process this data for accurate monitoring and billing, fostering better resource management between consumers and providers.

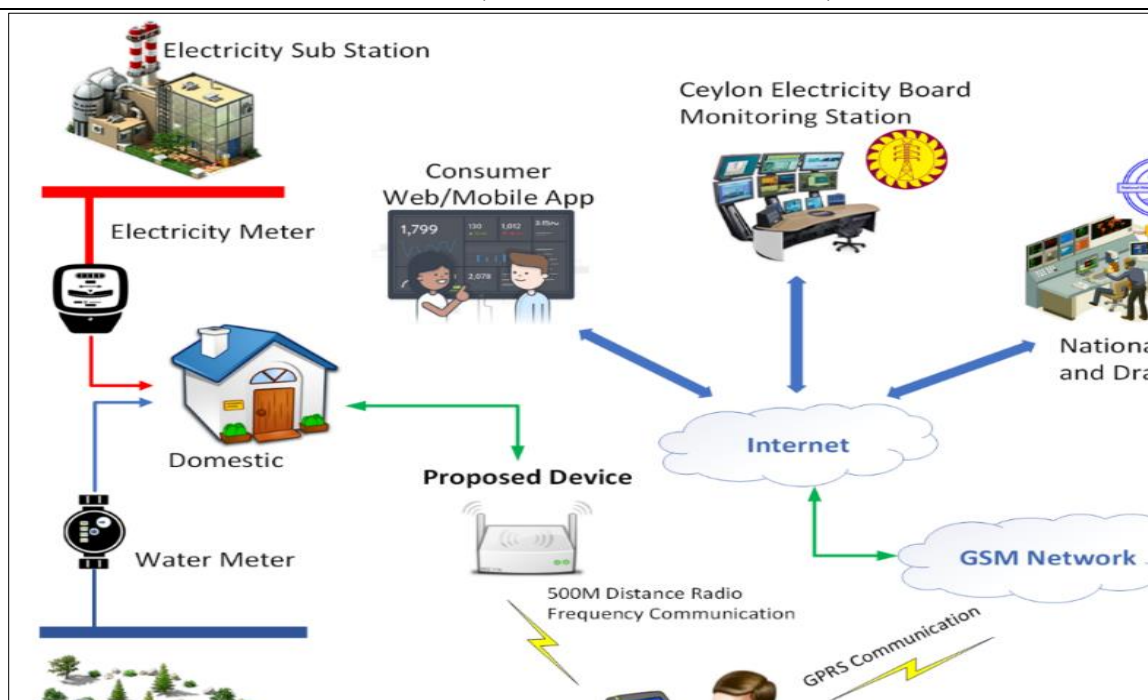


Figure 1: System Overview Diagram

Technology Stack

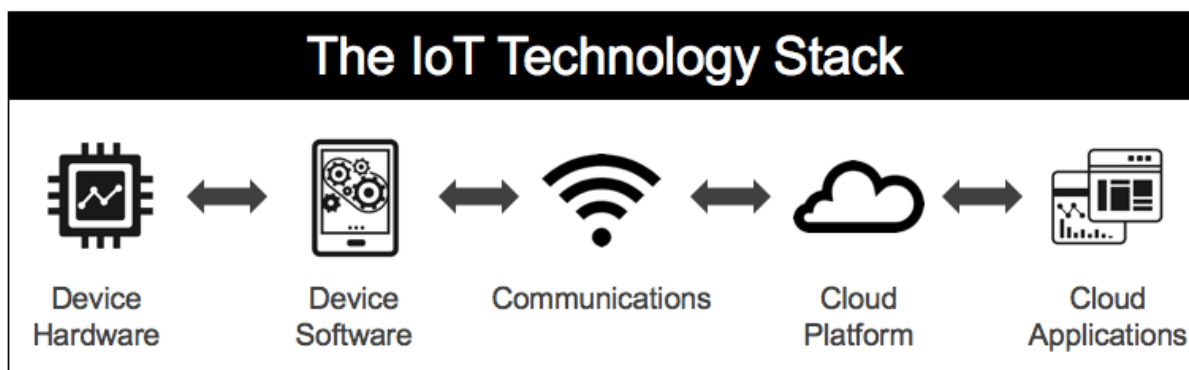


Figure 1: Technology Stack

This diagram outlines critical aspects comprising an IoT ecosystem divided into five layers, each fulfilling distinct functions necessary to ensure seamless operation:

Device Hardware: Represents foundational physical elements such as sensors collecting environmental data (e.g., temperature sensors or smart meters).

Device Software: Ensures functionalities within devices operate correctly, allowing them to gather data and communicate effectively across respective networks.

Communications: Encompasses protocols like Wi-Fi/Bluetooth/Wireless, facilitating efficient transmission pathways connecting various components throughout the system topology.

Cloud Platform: Centralized repository where all collected data undergoes processing, housed within expansive digital storage infrastructure capable of handling substantial information entry originating from connected devices.

Cloud Applications: Provides actionable insights derived from processed datasets, enabling visual representations (e.g., dashboards illustrating power utilization trends), executing automated functionalities controlling connected devices, accordingly, optimizing user experiences therein, and effectively addressing diverse needs encountered during day-to-day operations.

The diagram captures how these layers come together to create a working IoT system, from collecting data in the real world to processing it in the cloud and using it in meaningful ways.

Implementation

Implementation High-Level Block Diagram

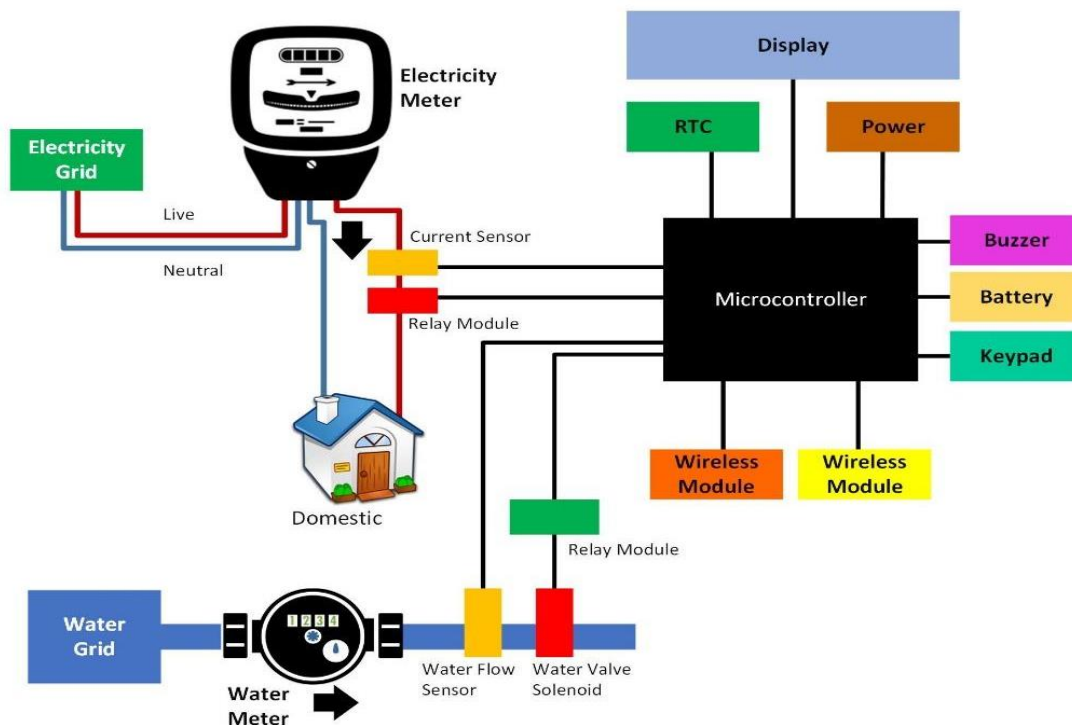


Figure 2: Proposed Architecture

Illustrates architecture devised to monitor/control household-level electric/water consumptions, integrating assorted hardware components alongside communication methodologies, ensuring efficient resource governance, detailed below:

Electricity Grid

Electricity Meter: Quantifies total electrical usage experienced domestically.

Current Sensor: Monitors electrical flow through residential circuitry, permitting instantaneous tracking capabilities.

Module: Acts switch regulated via microcontroller governing energy flow, toggling actions based upon demand requirements established dynamically per utilization scenario presented herein accordingly.

Water Grid

Water Meter: Captures volume metrics corresponding to domestic water utilization, facilitating accurate assessments and maintaining records thereof.

Water Flow Sensor: Monitors liquid dynamics, furnishing relevant insights identifying usage fluctuations/anomalies, detected proactively prevent potential disruptions occurring unexpectedly

Water Valve Solenoid: Controls the water supply, enabling automated flow regulation based on user preferences or system inputs.

Domestic System

The technology, which is managed by a microprocessor, integrates two grids to provide residents with comprehensive services. Peripherals have been integrated, and component interactions are coordinated efficiently. Live statistics display performance metrics, utilities, and operational status. Reliability and sustainability are ensured by collaborative adaptations during post-deployment. Society benefits as the system adapts to new advancements in technology, producing smarter living spaces.

Central Control: Microcontroller

The microcontroller is the brain of the system, coordinating all components:

Connected Modules:

- Display: Shows real-time data such as electricity and water usage.
- RTC (Real-Time Clock): Keeps track of time, useful for scheduled operations.
- Power Supply: Provides power to the microcontroller and connected modules.
- Buzzer: Delivers audible alerts for critical events, such as high consumption levels.
- Battery: Serves as a backup power source, ensuring uninterrupted functionality during outages.
- Keypad: Allows users to input commands or settings manually.
- Wireless Module: Facilitates wireless communication, enabling remote monitoring or control.

Proposed Sub-Solution for Electricity Meter Reading System

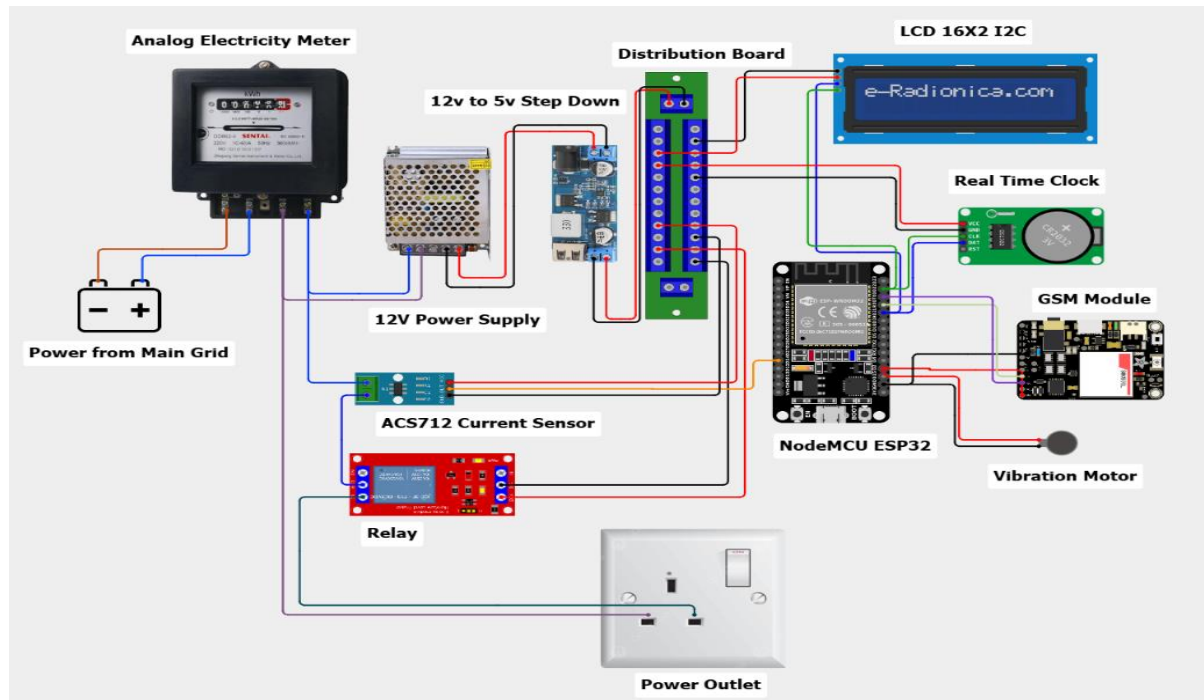


Figure 3: Schematic Diagram Electricity Meter Subsystem

This schematic illustrates fundamental objectives underpinning reading mechanisms employed across diverse types utilized measuring electric consumptions accurately captured relaying associated statuses due payments. Authorities involved overseeing processes governing functionality implemented successfully executed tracking experiences gathered. Utilizing NodeMCU prototype board equipped ESP32 microcontroller performing necessary calculations and retrievals accomplished periodically every minute aided RTC (Real Time Clock) module utilized concurrently guaranteeing timeliness responses provided promptly resolving matters arising swiftly. Addressing concerns raised maintaining integrity preserved intact ensuring consistency throughout lifecycle observed comprehensively inspected evaluating results obtained and reaching positive outcomes.

Proposed Sub-Solution for Water Meter Reading System

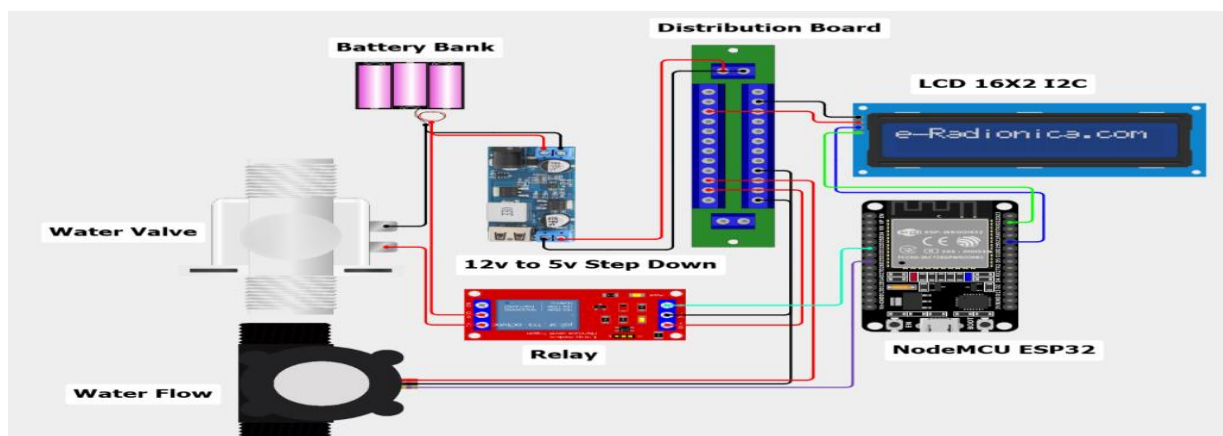


Figure 4: Schematic Diagram of Water Meter Subsystem

The above diagram is the subsystem that will connect to the main system (electricity component). This diagram shows that the water flow sensor will measure the flow of water, and the solenoid valve is used to disconnect the water flow from the main source. The system will be powered by the battery bank and converted to 5 volts. The LCD will display the values of the meter reading and the node MCU ESP 32 will be used as the processing device and connected to the main unit over Wi-Fi.

Hardware & Software Tools

The following components and software are being used to complete the proposed solution. The main

Components

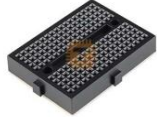
NodeMCU ESP32-WROOM	20X4 LCD	Single channel 5V DC Relay Module	Nextion 3.2-inch Serial LCD
			
Electric Solenoid Valve	YF-S201 Water Flow Sensor 1-30L	Current Sensor ACS712 30A	801S Vibration Sensor
			
4x4 Numeric Ribbon Keypad	12v to 5v Step Down Power Converter	12V 2000mAh Rechargeable	Breadboard
			

Figure 5: Components used to develop

Data gathered from sensors, including water flow and current sensors, will be processed by the NodeMCU, a Node microcontroller unit equipped with an ESP32 wireless chipset for bidirectional communication. The water solenoid valve and the system's electrical output are activated by a relay module. A vibration sensor module is utilised to identify any irregularities or signs of tampering and to notify and buzz the user. Key data, such as consumption by units and tariff, will be displayed on the LCD and GLCD. Rechargeable batteries will power the entire system, and a keypad will be used to interface with it.

Software Platforms



Figure 6 Required Software

Arduino IDE and SDK are the key development platforms for the proposed IoT device. PHP and MySQL used in the development of web applications. Additionally, the Amazon AWS RDS cloud platform contained the MySQL database. The ESP32 module programmed coded using the Python programming language.

III. Results and Discussions

Functional outcomes

Use Case	Functionality
Smart Meter	Real-time data transmission from smart meters to the system. Remote Connect/Disconnect functionality for operational control.
Web Application	View consumer data on web applications. The ability to generate reports to aid the service provider in system evaluation and planning. Monitoring meter status for maintenance or issue detection. Enhanced Tariff Management capabilities for customizing and applying dynamic pricing. Features like predictive maintenance or advanced analytics are outside the current project scope. Integration with third-party services for additional insights into usage patterns.
Mobile Application	Consumers' ability to receive notifications regarding critical updates. Billing history provides access for consumers to better manage their finances. Advanced consumer notifications like predictive usage alerts or savings tips. Visualization tools in the mobile application for easier data interpretation.

Artefact Prototype

Prototype



Figure 7: Smart Device for Electricity and Water Metering

The above prototype consists of 3 units. Mater unit will be managed and monitor the other two subunits which is electricity and water over wireless. The master unit will communicate with the base station over Wi-Fi.

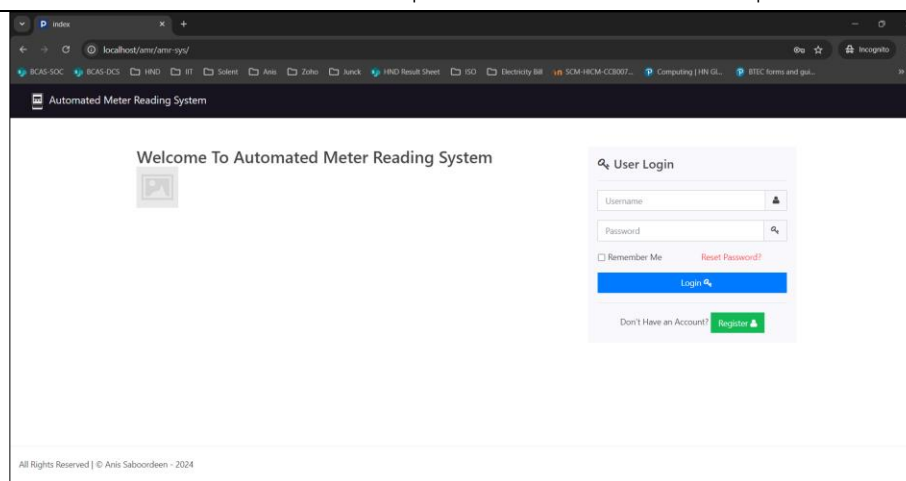


Figure 8: Web Application

The web application will be used by the utility companies and will monitor the entire grid. The application consists of connectivity and dysconnectivity option. Tariff updated via OTA (over the air) and all required reports and charts for predictions.

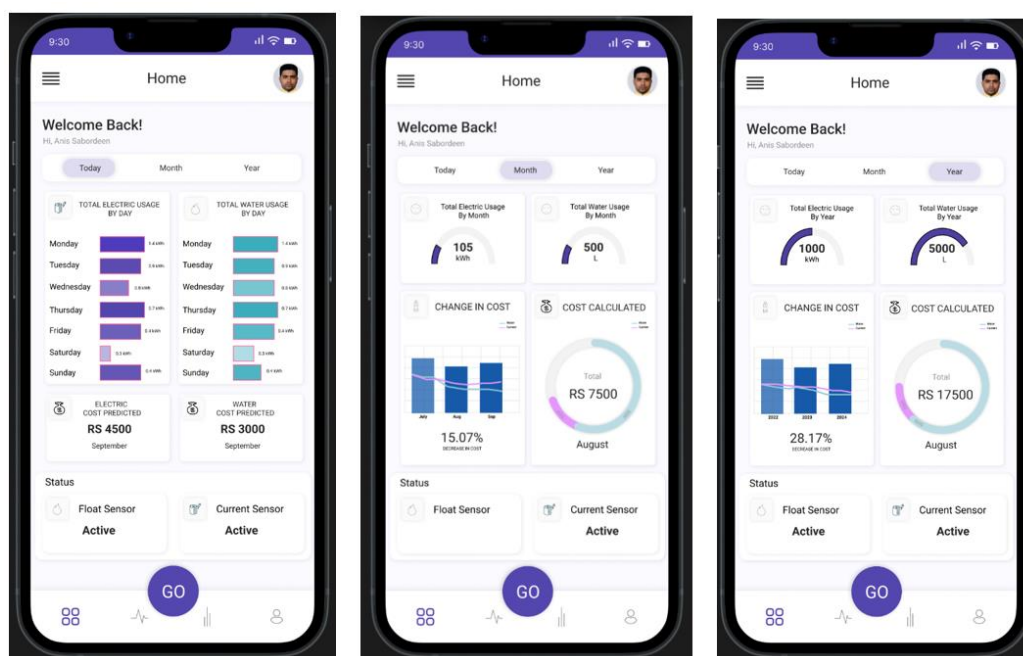


Figure 9: Mobile Application

The mobile application is intended for consumers. Read the current usage in terms of units and tariff, special notifications from the utility companies. Predictions and the sentimental analytics features provide awareness of the usage to the consumers.

Technical Challenges

Throughout the implementation process, challenges related to communication protocols and processing capabilities were encountered. However, these issues were successfully addressed through the integration of NRF wireless modules and the optimization of code, enhancing the overall performance of the system. The resulting architecture not only supports automated billing and unauthorized activity detection but also empowers users with remote management capabilities, thereby promoting energy efficiency and cost savings.

IV. Conclusion

In conclusion, the implementation of the proposed IoT-based utility monitoring system represents a significant advancement in the management of electricity and water resources within households. By integrating a robust technology stack that encompasses device hardware, software, communication protocols, cloud platforms, and applications, the system effectively facilitates real-time monitoring and control of utility consumption. The use of the NodeMCU ESP32 microcontroller, along with sensors such as the ACS712 for electricity and flow sensors for water, ensures accurate data collection and efficient resource management.

The system's design and functionality underscore the transformative potential of IoT technology in utility management, paving the way for smarter, more sustainable living environments. As we move forward, further testing and refinement will be essential to ensure reliability and user satisfaction, contributing to the broader adoption of smart home technologies

References

1. Bandara, M. (2020). Automated Meter Reading System for CEB. Retrieved from <https://dl.ucsc.cmb.ac.lk/jspui/bitstream/123456789/4438/1/2015%20MIT%20006.pdf>
2. Ceylon Electricity Board. (2021). Statistical Unit, Corporate Strategy & Regulatory Affairs Branch, & Ceylon Electricity Board. (2021). [SALES & GENERATION DATA BOOK - 2021]. Retrieved from https://www.ceb.lk/front_img/img_reports/1664784123Sales_and_Generation_Data_Book_20211.pdf
3. Dialog and LECO to Launch Sri Lanka's First IoT-Based Smart-. (2019). Retrieved May 27, 2025, from Dialog Axiata PLC website: <https://dialog.lk/news/Dialog-and-LECO-to-Launch-Sri-Lankas-First-IoT-Based-Smart-Grid-Solution-to-Support-Prepaid-Electricity-Metering>
4. InterlinkKnight. (2017). Nextion Arduino Tutorial #1: Beginner's Guide. Retrieved from <https://www.youtube.com/watch?v=wIWxSLVAAQE>
5. LBO. (2016, January 8). Sri Lanka introduces Smart Metering to reduce electricity generation costs. Retrieved May 27, 2025, from Lanka Business Online website: <https://www.lankabusinessonline.com/sri-lanka-introduces-smart-metering-to-reduce-electricity-generation-costs>
6. Measure AC by interfacing the ACS712 sensor with Arduino – Circuit Schools. (2021). Retrieved May 27, 2025, from Circuitschools.com website: <https://www.circuitschools.com/measure-ac-current-by-interfacing-ac712-sensor-with-arduino/>
7. Migrating connected device fleets to AWS with Custom Domains for AWS IoT Core | Amazon Web Services. (2021, July 28). Retrieved May 27, 2025, from Amazon Web Services website: <https://aws.amazon.com/blogs/iot/migrating-devices-aws-iot-custom-domains/>
8. Pitiyage, J. (2017). Smart water meter for Decision Support. Retrieved from <http://dl.lib.uom.lk/bitstream/handle/123/13050/TH3403-1.pdf?sequence=1&isAllowed=y>
9. PUCSL. (2020). Applicability of Smart Metering Technology in Sri Lanka Prepared By: Public Utilities Commission of Sri Lanka Content. Retrieved from <https://www.pucsl.gov.lk/wp-content/uploads/2020/06/Smart-Metering-in-Sri-Lanka-Final.pdf>
10. Santos, S. (2018, November 6). ESP32 Flash Memory - Save Permanent Data | Random Nerd Tutorials. Retrieved May 27, 2025, from Random Nerd Tutorials website: <https://randomnerdtutorials.com/esp32-flash-memory>
11. Shihar Aneez. (2024, July 11). Sri Lanka's NWSDB considers smart to cut cost on expensive water meter readers. Retrieved April 27, 2025, from EconomyNext website: <https://economynext.com/sri-lankas-nwsdb-considers-smart-to-cut-cost-on-expensive-water-meter-readers-171773/>
12. Sri Lanka's CEB meter readers show how to use unionized power. (2017, September 19). Retrieved from <https://economynext.com/sri-lankas-ceb-meter-readers-show-how-to-use-unionized-power-8379/>