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Smart Meter

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Abstract: ***Old-fashioned forms of electricity meter reading are still dependent heavily on manual works and as a result, billing cycles are prolonged, possibilities for energy consumption and management are very few, and errors are commonplace. The problems facing consumers, on the other hand, are nigh endless, for instance, high operational costs, little to no consumption details, and little control over energy usage. This document describes the best in class energy monitoring system that makes use of current and voltage sensors and LoRa based sensor network for hand-held devices and systems within consumer premises. It also makes sure that data flow is accurate and reliable by eliminating human error and data interception by management control, through enabling two way communication between consumer's devices and Metering Service Control Board's (MSCB) services. The improvements in billing accuracy, the efficiency of data gathering and the savings in costs were especially impactful.***

Keywords: ***Improved energy tracking, real time power consumption monitoring, LoRa enabled communication infrastructure, Centralized Metering Control System (CMCS), billing accuracy, information transfer, resource allocation, management optimization.***

I. INTRODUCTION

It is well-known that current energy management systems suffer from significant inefficiencies due to outdated metering technologies, which fail to provide live data. This results in higher costs, energy wastage, and additional stress on the power grid. Traditional methods, heavily reliant on manual data collection, are prone to human errors, delays, and inaccurate billing. To address these challenges, we propose the development of a Smart Meter system.

The system transforms the way of energy consumption and management across residential, commercial, and industrial sectors. By integrating advanced metering infrastructure with IoT technology and the immediate analysis of real-time data, the system will optimize its way toward energy efficiency and cost saving while also encouraging green initiatives. Incorporating current and voltage sensors with a LoRa-based communication network allows for precise monitoring and immediate reporting, eliminating the need for on-site personnel for meter readings and significantly reducing errors in the billing process. The key objective of this program is to make billing more accurate and operations more efficient by automating it and keeping an eye on live data. The Smart Meter system represents a revolutionary leap in energy management technology. By using real-time data and sophisticated analytics, it can potentially change the face of energy usage into one that is more efficient, cost-effective, and sustainable for a better future.

II. LITERATUTRE REVIEW

Gunawan Wibisono et al. conducted a techno-economic analysis to assess the implementation of LoRa-based smart meters in PLN Bali. The study emphasizes the transition from traditional manual meters to smart meters that enable real-time, two-way communication, supporting Bali's Eco Smart Grid initiative. LoRa WAN is highlighted for its long-range, low-power, and cost-effective features, making it more suitable than alternatives like SigFox or NB-IoT.The analysis evaluates three business models—Build Own, Build Operate Transfer (BOT), and leasing—concluding that leasing and BOT reduce financial strain but face challenges like high initial investment and long payback periods. Regulatory compliance with the 923-925 MHz frequency band favors LoRa deployment, though interference and lack of duty cycle regulations pose risks.

Overall, the study demonstrates LoRa's potential to enable scalable and energy-efficient smart metering in Bali, aligning with the region's sustainable energy goals. However, further optimization of financial models and regulatory policies is needed for broader implementation[1].

Santhosh Shetty Chowdary et al. proposed an IoT-based wireless smart metering system utilizing ZigBee technology for smart cities. The system leverages ZigBee's low power consumption, scalability, and self-healing networks to enable real-time energy monitoring and billing. The smart meters, equipped with current and voltage sensors, transmit consumption data via ZigBee to a gateway, which then uploads it to a cloud database for utility providers.

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In this research, star and mesh topologies are considered; mesh topology gives coverage up to 500 meters using router nodes for better functionality. The system works with an accuracy of about 95%, with a reduction of around 25% in power consumption as well as 35% in cost compared to conventional systems. User-friendly features are provided with web interfaces, Android applications for monitoring, and backup data storage via SD cards. The research does conclude that proposed systems provide an energy-efficient and scalable design solution for smart metering in urban areas[2].

Prathik M. et al. ideated an IoT-based smart energy meter system to improve energy monitoring with reduced manual dependency. The system integrates Arduino ESP8266 microcontrollers with GSM modules for real-time transmission of energy consumption data to users and utilities. Important features include daily energy consumption updates, pre-alert for blackout, billing alerts, and key alerts for when consumption exceeds the user's limits. It is also capable of disconnecting remotely through GSM in order to prevent waste of energy whenever the users are landward.

The proposed system is friendly, with an LCD display presenting real-time data and alerts to apartment dwellers, reducing labor costs while improving the billing accuracy. Moreover, the system will promote energy conservation by providing the user detailed insights into consumption. The solution is a good replacement for existing energy meter problems at an inexpensive cost and scalable [3].

The paper "Performance Evaluation of Low-Power Wide Area based on LoRa Technology for Smart Metering" examines the suitability of LoRa technology for smart metering within smart grids, the key component of sustainable smart cities. The urbanization thus increases the need for effective resource management; reliable communication networks are essential in connecting 10 million of smart meters. The performance of LoRa was evaluated using the LoRaSim simulator based on such metrics as Data Extraction Rate (DER) under varying configurations of the network and traffic conditions. Results indicate that while LoRa has a low power level with significant communication range, there will be scalability limitations for high traffic loads involving frequent transmissions and larger packet sizes. Performance degrades quite critically with the increase in the number of nodes connected, suggesting that LoRa is less compatible with large-scale smart metering systems. Still, it is fairly effective for low data-rate applications with small packets and seldom transmissions. Based on these findings, although LoRa is a potentially785 LPWA technology, its limitations call for alternatives or hybrid combinations to address the requirements of large-scale smart grid deployments[4].

This paper proposes the novel energy-efficient approach to smart metering applications on the LoRa network by minimizing energy consumption and communication delays through the introduction of Edge computing integrated with LoRa technology for easy processing and transfer of energy data. A compression-decompression model based on deep learning is proposed to compress energy multivariate time series (EMS) at the Edge device, thereby significantly reducing the data size and energy of transmission. It proposes another algorithm to determine the value of spreading factors in LoRa for energy-efficient communication within a certain time constraint. Through simulations and prototype implementations are presented on the proposed system, showing significant reductions in energy consumption and communication delay without compromising the accuracy of data, making it suitable for large-scale deployments of IoT-based smart metering systems.

III. DESIGN AND METHODOLOGY

The IoT-based smart energy meter system proposed in this paper ensures real-time energy monitoring, automated billing with efficient power management. This combines hardware components consisting of Arduino ESP8266 microcontrollers, GSM modules, current and voltage sensors, and a display unit with cloud-based software tools granting seamless communication between users, energy meters, and utility providers. The system brings to an end human intervention hence allowing monitoring of energy use with precision ways of data access for users. The central processing unit is in charge of the system, governed by an Arduino ESP8266 cooperating in the processes of data acquisition, communication, and control tasks. Parameters such as current, voltage, and power factor are regularly assessed by the ACS712 current sensor, ZMPT101B voltage sensor, and other sensors, while the data undergoes processing to determine real-time energy use and total consumption. In case of disconnection of the IoT service, updates or information alerts are still carried on the GSM module that acts as a backup means of communication. LCD displays provide for energy consumption, such as user detail billing information and alerts.

The system connects to the WiFi via the ESP8266 module with the capability of uploading energy consumption data onto a cloud platform where both the users and utility companies can have remote access to it. Hence, the GSM module ensures uninterrupted communication through the bill reminder notifications and outages notifications sent to the user's mobile phone if WiFi is unavailable. Within the household, the LCD monitor shows real-time data and alerts to the users.

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Alerts are sent to users as SMS messages or app notifications when energy consumption exceeds or nears a critical limit, or when any bills are overdue. Enabled with remote control features, the system now allows users to cut off their energy supply through GSM. During vacations, the user can switch off power via mobile to avoid waste. If energy usage exceeds some preset limit, the system triggers alerts to inform such users on optimizing their consumption. Moreover, users are informed about the scheduled outages beforehand, while notifications are visible on the LCD to allow users to arrange for disruptions. Historical data storage is made possible by the cloud platform - with the added assurance that the data is secure and can be accessible for the analysis of trends and correct billing. The energy meter has an SD card module that allows local backup during power or network failures.

̄Ce billing system is automatic; all information about energy consumption andcost is sent to the user as well as to the utility provider. The user interface canassist in suggesting convenient payment options. In all, the IoT-based smart energymetering system is user-friendly, energy-efficient, reliable, and flexible for modernenergy management, hence conveniently enhancing the utility reliability and serviceconvenience to the consumer.

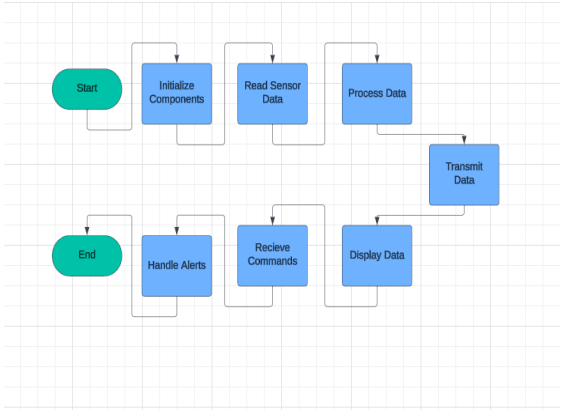


Fig.1- Flow Chart: Basic Working of Smart Meter Technology.

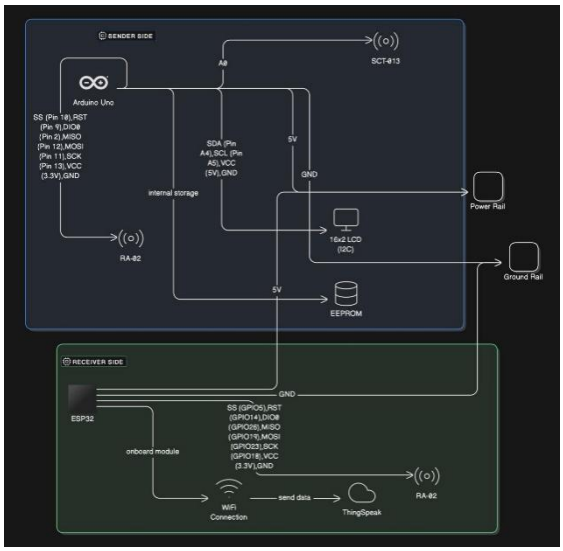


Fig.2- Hardware Circuit Connections.

IV. RESULT AND DISCUSSION

The system performance on LoRa networks during real-time energy monitoring was evaluated based on a smaller test. The tests further stressed the ability of the LoRa network to transmit data over distances of up to 10 km in semi-urban areas with low latency and without excessive energy use. The reporting reiterates the dependability and efficiency of the communication aspects of the system, hence being promising regarding the use in future energy monitoring applications. Data transfer allowed for assessing real-time monitoring over long-distance connection, and the connectivity was smooth throughout the testing without having to pause or open any separate file for it.

The results also confirmed that the data transmission through the LoRa solution was of low power, sustaining the viability of the deployment of the developed system at a larger scale to cover multiple meters. The automatic data gathering mechanism worked well to streamline and lessen manual involvement in the collection of field data. However, the wider impact of this automation, especially for operational efficiencies like reduced time taken in the billing process, was not assessed due to the constraints of the test.

A comparison table could be developed using the performance metrics from your tests and compare them with the existing research or similar projects. Here is a typical framework based on key metrics that might be filled using your project's results and data from other sources:

Metric	Proposed System	System A (LoRa IoT-Based Architecture)	System B (ZigBee IoT System)	System C (GSM-Based System)
Communication Range	10 km (Suburban)	~5-8 km (Suburban)	~350-500 meters	Limited to GSM cell coverage
Power Consumption	Low	Low	Moderate	High
Latency	Low	Moderate	Low	High
Data Transmission Method	LoRa	LoRa	ZigBee	GSM
Scalability	High	High	Medium	Low
Cost Efficiency	Cost-Effective	Moderate	Expensive	Expensive
Energy Meter Accuracy	95%	90-95%	~92%	~85%
Backup Features	Local (SD card) + Cloud	Cloud Only	None	None
User Alerts	Real-time (Mobile + LCD)	Cloud-based	Local Display Only	SMS Alerts Only
Pre-Intimation Features	Yes	No	No	Yes

TABLE - ATLTERNATIVE TECHNOLOGY.

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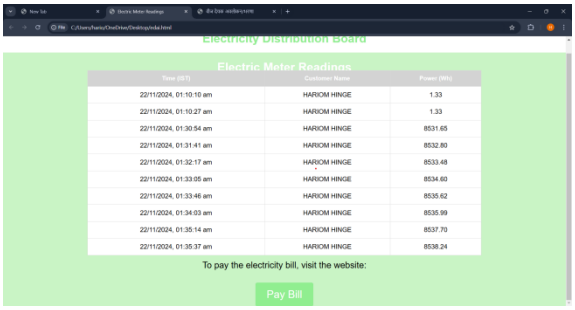


Fig 1.1 - REAL TIME POWER CONSUPMTION DATA

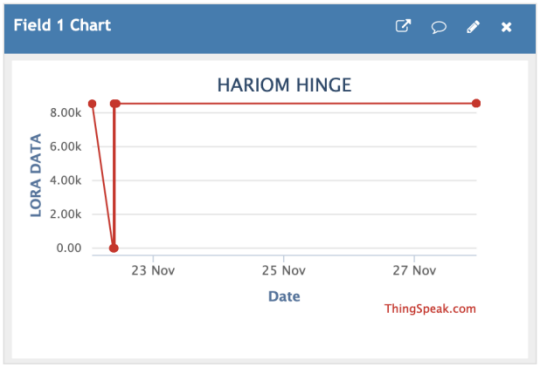


Fig 1.2 - Date v/s LORA DATA.

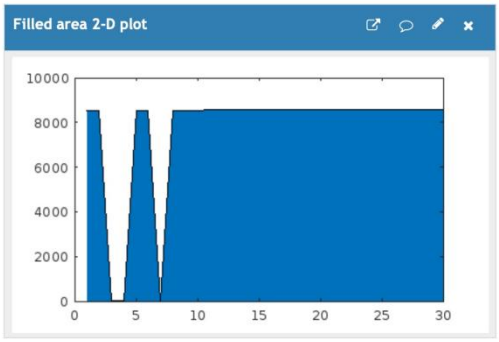


Fig 1.3 - Power v/s Time.

The results included visualizations such as real-time power consumption data and comparisons of date versus LoRa data, which provided insights into the system's functioning. However, it remains to be recognized that the test was not fully representative, and its main aim was to validate the ability of LoRa networks. Further tests need to take place on a larger scale for assessing the system under conditions of congested networks, loaded devices and changing environmental factors.

V. CONCLUSION

The project tackles the shortcomings of the traditional energy monitoring system by providing the means for real-time data acquisition, automatic billing, and effective power management, thanks to IoT-based smart energy meters. The communication technologies used are based on LoRa, offering reliable data transmission over long distances while consuming less power, making it an excellent choice for suburban and rural areas where Internet connectivity is less reliable. Some salient features of the system are remote energy monitoring, billing notifications, and power control, which add to the ease of use and encourage the conservation of energy. Cloud integration allows easy storage and remote portability of the data while performing local backups for safety when live network faults occur.

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Some preliminary tests tried out and confirmed to the system refined communication; data transference without much energy consumption; thus, it is reliable and expandable. Large-scale testing is necessary since the application must be able to be tested under both network-congested conditions and obvious environmental changes. To conclude: the project is heading toward dynamic energy management reforms, scalable, cost-effective, and simplifies the solution towards the fast-approaching sustainable energy practices.

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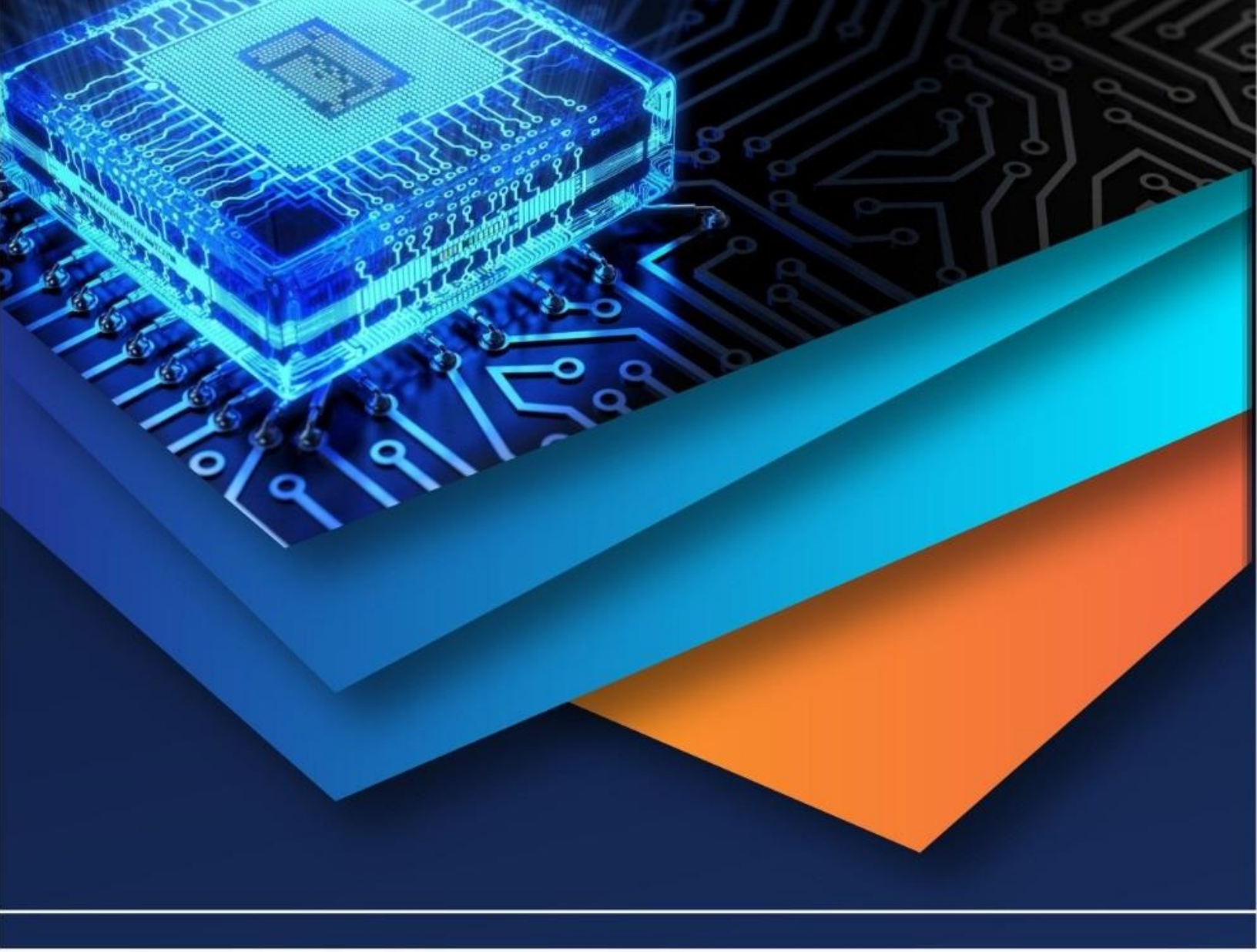
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