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HIGH PERFORMANCE OF LAST METER SMART GRID EMBEDDED IN AN IOT PLATFORM

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Abstract
In recent times, there has been growing interest in integrating the last-meter smart grid with an Internet of Things (IoT) system. This integration aims to save energy and enhance the reliability of your home or business's electricity grid. It achieves this through advanced technologies such as smart meters, which measure your electricity usage, sensors that gather data, and real-time monitoring to control better and optimize energy consumption. This paper provides an overview of how this integration functions. It covers essential components, the advantages it offers, and the challenges it may face. We seek to understand what is required for it to work effectively, how to design it for practical use, and what it's like in real-world applications. We also explore issues related to safeguarding your data and ensuring privacy, making different components work together seamlessly, expanding its functionality to serve more users, and complying with relevant regulations. This research contributes to our understanding of how this integrated approach can conserve energy, bolster the electricity grid's reliability, and engage people in more efficient and sustainable energy management. It's like a step forward in using energy intelligently and responsibly.

Keywords: Internet of Things, smart grid, power meter, Zigbee

Introduction
An electrical grid is a highly remarkable achievement in the field of engineering. It generates electrical power, and transmits it over long distances, and delivers it to end-users. An electrical power network consists of a vast, interconnected system of power generation facilities, energy conversion devices, high-voltage transmission lines, distribution lines, and consumers. Typically, power plants are situated at a considerable distance from areas with high demand and are interconnected through the electric grid. The major electricity is generated by burning coal and utilizing uranium-based fuels, which is associated with low efficiency, environmental pollution, substantial energy wastage, and subsequent financial losses. In addition to these challenges, issues such as inefficient routing and distribution of electricity, unreliable communication, and a lack of efficient energy storage mechanisms also exist. In addition, the grid faces mounting pressure due to a rapidly increasing demand for energy, aging infrastructure, and security concerns.

1.1 Smart Grid
In order to address the aforementioned constraints, the concept of a smart grid has emerged as a crucial solution, combining elements of both communication networks and information technology. The smart grid is a comprehensive system encompassing both wired and wireless communication infrastructure. The key advantage of the smart grid lies in its ability to establish a two-way flow of both energy and communication signals. Within a smart grid, the integrated communication network empowers it to sense and relay any modifications or updates in the power system, as well as within consumers' premises. This capability is enabled through sensor networks and controllers distributed throughout every section of the power grid. The smart grid concept involves a critical examination of the limitations of traditional grids, leading to the identification of load-side demands, improved management, and the evolution of conventional grid systems. [2,3]

The inception of the smart grid concept initially aimed to enhance demand-side management, boost energy efficiency, and build resilience against unforeseen events, destruction, and disasters. [4] To be more specific, the smart grid can be defined as an electrical grid that leverages information networks, bidirectional communication, cybersecurity, and computational intelligence to ensure the generation, transmission, distribution, and recovery of electricity in a manner that is safe, reliable, environmentally friendly, efficient, and economically viable. [5]

The "last meter" smart grid, situated in proximity to consumers' premises, serves the primary purpose of facilitating the two-way exchange of both power and data between consumers and energy service providers. In doing so, it shifts the prevailing approach from one centered on energy distributors to a consumer-centric paradigm. This can be seen as an expanded manifestation of smart homes and smart buildings. The system integrates supervisory control and data acquisition (SCADA), advanced metering infrastructure (AMI), smart meters, fault detection, resilience, detection of unauthorized usage, load stabilization, and self-recovery mechanisms.[6-8]

Table 1 provides a comparative analysis between the smart grid and conventional grid systems.

	Conventional Grids	**Smart Grids**
Network flow	One-way energy flow	Highly integrated energy, information and business flow
Grid structure	Electric network	Electric network & communication network
Dispatching strategy	According to load forecasting	According to real-time load feedback
Price mechanism	Fixed, tiered or time-dependent price	Sufficient price information, real-time price
Crisis management	Load shedding	Load active avoidance

Table 1: Differentiation between Traditional Grid and Conventional Grid

1.2 Internet of Things (IOT)

Internet of Things, termed by Kevin Ashton in 1999, can be defined as interconnection of many devices (nodes) through embedded technology to communicate with each other or to the main server.[9] The IoT has gained significant advantages over various applications by interconnecting internet to different embedded devices. The architecture of Internet of Things is broadly divided into three main sections:- a) Smart devices and sensors- The main purpose of smart devices, sensors and actuator is to continuously gather the data from the surrounding and transfer it to next layer. These devices form device connectivity layer and are connected to IoT platform with the help of communication network which can be wired (CAN,PLC etc.) and wireless (ZigBee, WiFi, Bluetooth module etc.). b) IP

Gateway- Gateway is a medium which connects the sensors and smart devices to the IoT platform and hence promotes the bidirectional traffic between users and providers. Whenever a device sends any information to the server, gateway converts its network address into an unique ID and vice versa.[10] c) User Interfaces- Consumers, power suppliers and application developers interact on IoT platform with the help of user interfaces which can be web based or API based . In this section, a user can approach the data uploaded on the cloud, web page or an android app by simply logging in and can use the API to obtain information.[1]

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Table 2 Components of IoT

IOT Components			
Basic Components		Detailed Component	
Symbol	*Name*	*Name*	*Examples*
A	**Sensing**	MICRO-SENSORS	Pressure, air quality, Temperature
		TAGS	RFID, NFC, Quick Response codes (QR)
B	**Communication**	ENERGY EFFICIENT COMMUNICATION	Personal Area network (PAN), Bluetooth, ZigBee
		MICRO-COMPUTING	Micro multi-core chips, Raspberry Pi, Intel
C	**Computation**	CLOUD COMPUTING	Little or no local computing (SAAS,etc)
		OPEN/ SMALL OPERATING SYSTEMS	Linux

APPLICATION OF IOT IN SMART GRID

The primary goal of this paper is to emphasize the "last meter" smart grid and its communication system, exploring associated technologies, applications, challenges, issues, and future prospects. This section is structured into three key subsections: "Smart Grid and Advanced Energy Infrastructure," "Innovations in Measurement and Metering," and "Cutting-Edge Communication Technologies." The current state and anticipated future developments within each of these subsections are detailed in this section.

2.1 Smart grid and smart energy infrastructure

As the name indicates, traditional grid produces electricity using fossil fuels, hydro or nuclear in centralised power plants. A conventional power plant generates electricity, transmit it using high voltage line and distribute it among the consumers. Thus it is considered as unidirectional flow of energy. For last meter smart grid, researchers should focus more on end user, for which smart grid has emerged as most promising solution. In smart grid every consumer is able to access their data uploaded in a web page or cloud server. Also smart grid facilitates each consumer to install low voltage generation plants and feed back to the grid, resulting in bidirectional flow of energy and information. The improvement of smart energy infrastructure requires smart measurement system, improved metering devices and efficient communication system

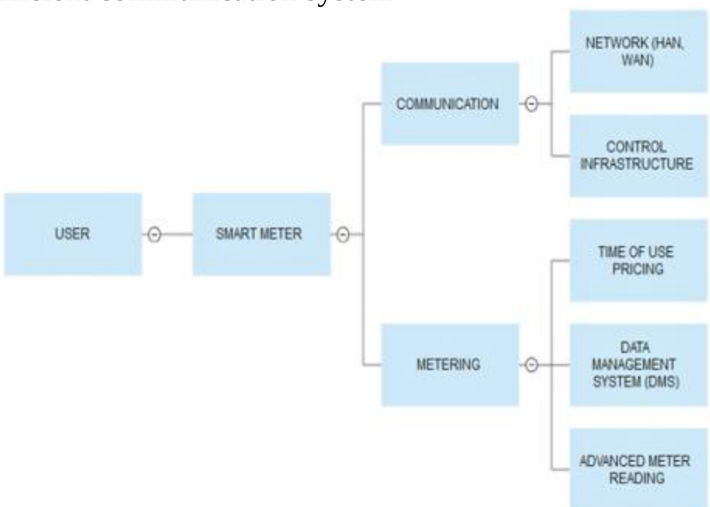

Figure 1 Smart grid perspective

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2.2 Smart measurement and metering

The measurement side of a smart grid includes energy management system (EMS). An energy management system is a computer aided system used by energy utilities to control, manage and optimize the performance of power grid by measuring and estimating active and reactive power. The EMS system is divided into two categories: centralized and decentralized. Centralized EMS consists intelligent algorithm and software whereas decentralized EMS uses logical operations. The smart measurement is executed by using smart meter. A smart meter is a device which captures the real time energy consumption by measuring voltage, phase angle and frequency. As shown in above figure 1, the smart metering comprises time of use pricing, data management system and advanced meter reading.

2.3 Communication Network

Smart grid's pivotal achievement lies in its integration of communication technologies. This section provides a comprehensive overview of various communication technologies, categorizing them into IoT and non-IoT communication technologies. Non-IoT technology is further divided into non-IoT wireless (e.g., Bluetooth, Cellular, WiMax) and non-IoT wired (e.g., Powerline, DSL, optical), while IoT wireless includes Z-wave, 6LoWPAN, LoRaWAN, and Zigbee. Table 3 summarizes these technologies, aiming to guide appropriate technology selection.Upon table review, it's evident that most technologies cater to Home Automation Networks (HAN), with LoRaWAN being the sole option for Neighborhood Area Networks (NAN) and Wide Area Networks (WAN).

on-IoT wired options, like DSL, power, and optical communication, are costlier and suitable for high-security, high-efficiency applications. In contrast, wireless technologies are cost-effective and simple but have limited bandwidth, suitable only for short distances and susceptible to interference. In summary, the choice of communication technology should align with specific scenarios and needs.

Table 3
Various Communication Technologies

Technology	Speed	Coverage Area	Frequency Operation	Limitations	Applications
Bluetooth (802.15.1)	3 Mbps	1–100 m	2.4–2.48 GHz	Short range, high interference	AMI, HAN
WiFi (802.11n)	300 Mbps	100 m	2.4–5.4 GHz	Short range, high interference	AMI, HAN
ZigBee	250 Kbps	75 m	2.4 GHz	Low data rate, Short range, high interference	AMI, HAN
Z-Wave	40 Kbps	30 m	EEUU: 908.42 MHz Europa: 868.42 MHz	Low data rate, Short range	AMI, HAN
GPRS	Up to 170 Kbps	1–10 km	900–1800 MHz	Low data rate	AMI, Demand Response, HAN
3G	384 Kbps- 2 Mbps	1–10 km	1.92–1.98 GHz 2.11–2.17 GHz (Licensed)	Costly spectrum fees	AMI, Demand Response, HAN
WiMAX	Up to 75 Mbps	10–50 km (LOS) 1–5 km (NLOS)	2.5 GHz, 3.5 GHz, 5.8 GHz	Not widespread	AMI, Demand Response
PLC	2–3 Mbps	1–3 km	1–30 MHz	Harsh and noisy channel environment	AMI, Fraud Detection

Proposed System

The proposed system, which integrates the las-meter smart grid with an IoT platform, addresses the limitations of the existing system by enabling real-time monitoring and control of energy consumption at the last-meter level. This is achieved through the deployment of smart meters and sensors, which collect data on energy usage, environmental conditions, occupancy, and appliance-level energy consumption. The data is then transmitted to the IoT platform for analysis and processing.

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The IoT platform forms the backbone of the proposed system, providing a centralized dashboard for utilities and customers to visualize and manage energy consumption patterns, access real-time insights, and make informed decisions. The platform also enables the implementation of demand response programs and personalized energy management services. Utilities can send real-time alerts and incentives to customers to reduce energy usage during peak demand periods, while customers can actively participate in load management and adjust their energy consumption patterns to contribute to grid stability.
The proposed system also facilitates the seamless integration of renewable energy sources into the grid infrastructure. With real-time visibility into energy generation and consumption, utilities can effectively manage the variability of renewable energy sources, optimize their utilization, and balance supply and demand.

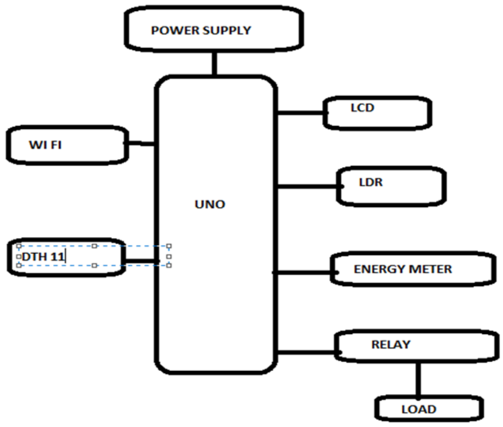

Figure 2: Block diagram of proposed system

3.1 Arduino UNO

In proposed model, arduino serves as the central processing unit or microcontroller of the project. It receives data from various sensors, processes that data, and controls the relay module and LCD display based on the received information. It is the brain of the project, managing the decision-making and communication with the IoT platform
Arduino is an open-source electronics platform based on easy-to-use hardware and software. Arduino boards are able to read inputs - light on a sensor, a finger on a button, or a Twitter message - and turn it into an output - activating a motor, turning on an LED, or publishing something online. You can tell your board what to do by sending a set of instructions to the microcontroller on the board. To do so you use the Arduino programming language (based on Wiring), and the Arduino Software (IDE).

3.2 DHT11 Sensor

Table 2.1: Arduino Uno specifications

Microcontroller	Atmega328
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limits)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
Analog Input Pins	6
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB (Atmega328) of which 0.5 KB used by bootloader
SRAM	2 KB (Atmega328)
EEPROM	1 KB (Atmega328)
Clock Speed	16 MHz

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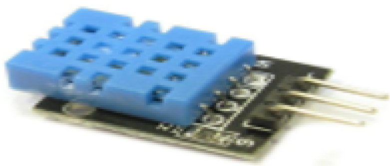
The DHT11 sensor is used to measure temperature and humidity. It provides environmental data that can be used to make informed decisions about energy consumption or to monitor conditions in the last meter of the smart grid.

3.3 Relay module

The relay module allows the Arduino to control electrical devices. In the context of your project, it can be used to turn devices on or off remotely. For example, you could use it to control the power supply to certain appliances or components of the smart grid.

ITEM	SYMBOL	LEVEL	FUNCTIONS
1	VSS	0V	Power Ground
2	VDD	+5V	Power supply for logic
3	V0	—	Contrast adjust
4	RS	H/L	H:data L:command
5	R/W	H/L	H:read L:write
6	E	H.H→L	Enable signal
7-14	DB0-DB7	H/L	Data Bus
15	LEDA	+5V	Power supply for LED Backlight
16	LEDK	0V	



Parameters	Specification
Input Output Voltage	3V 5V
Humidity Range	20-80 perc
Temperature Range	0-50 deg C
Sampling Rate	1Hz
Response time	50ms

3.4 LCD Display

The LCD display serves as the user interface for the project. It can show real-time data, system status, or other information to users. This can be particularly helpful for visualizing data or providing feedback to users about the status of the last meter smart grid

Conclusion

After going through several observations, it is concluded that Internet of Things brings a great accord of upgrade to the last meter smart grid. The usage of WSN in smart network improves the presentation and guideline of the framework. End users can approach above web services and operate them to manage their home load. It also increases consciousness and involvement of non-technical end users granting them better interaction and control. With the increase in development, many new technologies will emerge which will make smart grid interoperable, cost effective and secure system.

Parameter	Rating
Supply voltage	3.75V to 6V
Trigger current	5mA
Active relay current level	70mA (one relay), 600mA (eight relays)
Relay maximum contact voltage	250VAC, 30VDC
Relay maximum current	10A

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