Summary

This paper discusses the design, construction, and validation of an add-on device for energy/gas/water meters that can transform a traditional meter into a smart meter. The device is unique in its electronic design and utilizes a simple IoT architecture built with Lora WAN technology for direct internet connection, while also being compatible with standard meter enclosures.

The proposed smart meter adaptation will improve the current invoice system, which relies on estimates and periodical readings, by allowing users to track their energy use and compute bills independently, eliminating the need for monthly meter readings by an agent.

Experimentation has shown that the prototype has an absolute percentage error of less than 5% in all readings. Additionally, a real-life application of the device was demonstrated by reading meter data and sending and storing it using a web-deployed application. The use of smart meters will help address the rising energy consumption due to population growth, climate change, urbanization, and the increasing use of electronic devices.

Keywords: smart meter; power meter; internet of things; energy meter; lorawan

Authors: Sorin Istrate; Laurentiu Istrate; Catalin Adam

INTRODUCTION

With the shortage of energy resources, there is a sense of urgency to utilize energy-efficient technologies. Since electricity consumption is growing drastically, energy monitoring and control is very fundamental.

New technologies give electric appliances the ability to be networked through the Internet, to communicate with the consumers and even with manufacturers or other 3rd parties[1] and allows to improve energy consumption based on user preferences.

But what about the electric equipment and appliances that lack the ability to be networked? Here it is a growing need for smart meters roll-out. Smart meters are devices

1 Skarmeta A, Moreno M, Úbeda B, Zamora M. How can we tackle energy efficiency in IoT based smart buildings? Sensors. 2014;14(6):9582-9614.

that collect and measure data at a particular time intervals, communicate electric energy consumptions, and take control actions remotely[2][3].

INTERNET OF THINGS & LoraWAN

The proposed system utilizes IoT technology to connect physical objects, sensors, and actuators through a common network[4]. This involves installing sensors on existing consumer meters to transmit data to the cloud for access by consumers, with the goal of optimizing consumption and automating the transmission of electricity, gas, and water meter readings.

The primary objective of this system is to develop an energy metering system using IoT technology, specifically a LoraWAN module-based smart energy meter that uploads energy consumption in real-time and issues the measured bill at a cloud server. The LoraWAN protocol is chosen for its efficient long-range communication capabilities, both in urban and rural areas. The data transmission module has a coverage radius of 2-3 km in urban areas using the 868 MHz frequency and a radius of 10-15 km in rural areas using the 433 MHz frequency. The data is then transmitted to the user using a software package for managing household utility consumption data, which processes the data transmitted by the reading module.

PROPOSED APPROACH

Design constraints

Designing a smart metering system poses various challenges, many of which are multifaceted. The most significant and challenging constraint is identifying the necessary features for a smart meter based on the specific application requirements. For example, smart meters for residential use have vastly different design specifications compared to those required for industrial or utility applications.[5]

Design modularity and open-source

The company chose Arduino / Arduino-compatible hardware solutions for their cost/compute capacity/connectivity ratio, size, very low power consumption, ability to run an opensource operating system, multiple programming languages that can be used for

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2 Al Zamil MG, Rawashdeh M, Samarah S, Hossain MS. An annota-tion technique for in-home smart monitoring environments. IEEE Access. 2018;6:1471-1479

3 Mois G, Folea S, Sanislav T. Analysis of three IoT-based wireless sensors for environmental Monitoring. IEEE Trans Instrum Meas. 2017;66(8):2056-2064

4 Kurde A, Kulkarni V. IOT based smart power metering. Int J Sci Res Publ. 2016;6(9):411-415.

5 Jaganmohan M, Manikandan K. Challenges in smart meter de-sign. In: Kanjlia V.K., WahiP.P., PatkiS.G. eds. Proceedings 5th International Conference Power System Protection and Automation, 8-9 December 2010. 2010:465-472

development (Python, Java etc.) and their ability to run an application through which sensors can be configured and monitored.

When choosing electrical equipment, it is common practice to compare available instruments in the market and evaluate them based on quantitative criteria for performance. These criteria may include accuracy, operating range, response time, sensitivity, resolution, and linearity[6]. This is particularly important when selecting voltage and current transducers for the signal acquisition stage of a smart meter.

LoRa Gateway

The LoRa Gateway is a crucial component in IoT networks utilizing LoRa technology. It acts as a bridge between devices and The Things Network, allowing low power devices to connect to the Gateway using networks such as LoRaWAN, while the Gateway uses high bandwidth networks such as WiFi, Ethernet, or Cellular to connect to The Things Network. With the ability to serve thousands of devices, the Gateway is a cost-effective and efficient solution for IoT networks. It is equipped with a LoRa concentrator and runs on minimal firmware, making it easy to use and manage. The LoRaWAN protocol, which is built on top of the LoRa modulation, provides a standardized way for connected devices to communicate and exchange data.

LoRaWAN

The LoRaWAN protocol together with LoRa devices has its own advantages compared to the various wireless standards available for IoT such as low power consumption operation, large capacity to handle millions of messages from thousands of gateways, full data security using AES-128 encryption, remote firmware update of connected devices, license-free spectrum, no cost for network usage, good coverage indoors and in multi-storey buildings, range of over 10 kilometres in rural areas and up to 2 kilometres in urban areas, data transfer rates from 0.3 kbps to 50 kbps.

Network implementation required for the application.

The network consists of:

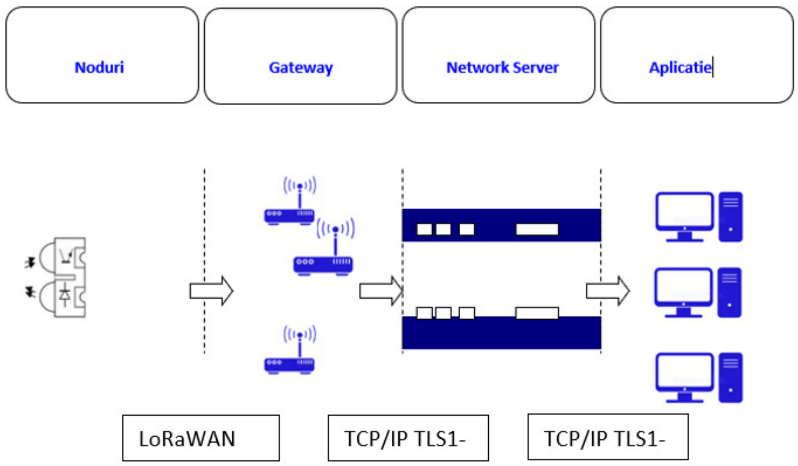
Gateway - the base stations of the network that allow bi-directional communication between end-user nodes. They transmit data to LoRaWAN servers for processing.

Nodes - devices that have one or more sensors that acquire information and send it to the Gateways through their built-in LoRaWAN® communication capability.

[6] Golding E, Widdis F. Electrical Measurements and Measuring Instruments. London: Pitman Publishing; 1963

LoRaWAN Network Server - receives the information transmitted by gateways and takes it to the application and back. It also handles the authentication of devices on the network.

Application Server - embedded software that runs and executes decisions, data views, events, and more with the collected information.



Hardware design

Two versions have been produced: for 5V series (TTL) and 3.3 volts (JEDEC standard) as CMOS logic level voltage, standards agreed to ensure product compatibility

The Arduino microcontroller is utilized in the design of the smart meter because it is easy to program with the Arduino compiler, user-friendly, and has readily available peripheral libraries. Additionally, it offers additional ADC channels, which can be useful if the design is expanded to include three-phase measurements.

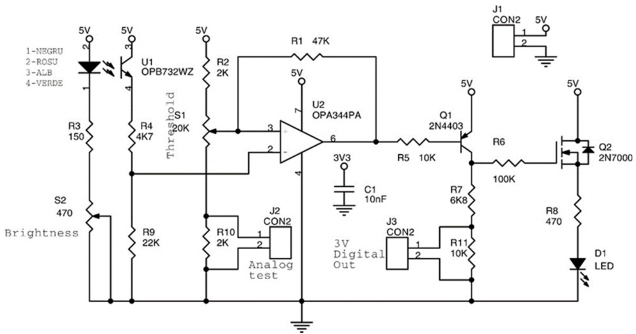
5V version

An optical disk rotation sensor module is used in the meter.

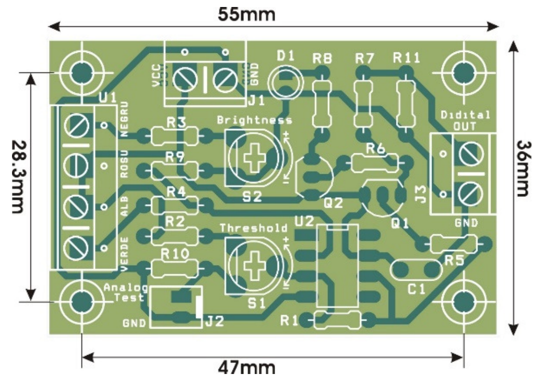
It is realized with a reflective long-distance switch OPB732 which then applies the signal to an amplifier OPA344PA. The sensitivity is regulated by the current through the reflective switch LED set by the S2 half-relay and the switching threshold is regulated by the S2 half-relay.

The signal from the output of the operational amplifier is applied to a class A amplifier realized with transistor Q1, the digital signal is played back to the output, in phase, through connector J2 and optically visualized by the illumination of led D1.

The module is powered at 5V.



Electrical schema – 5V version



Printed Circuit Board - 5V Version

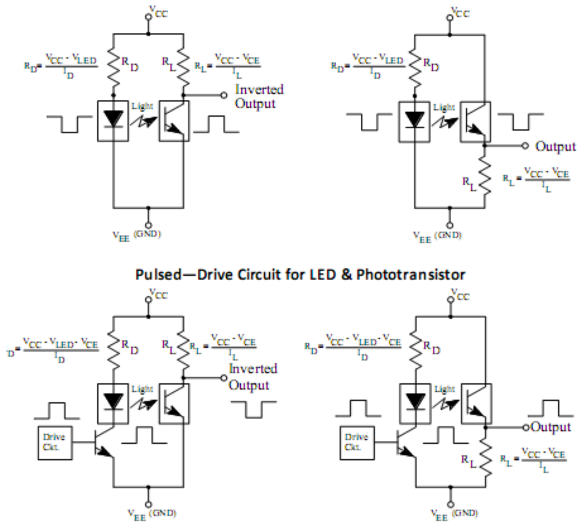
OPB732 reflective long-distance switch, non-contact infrared switch.

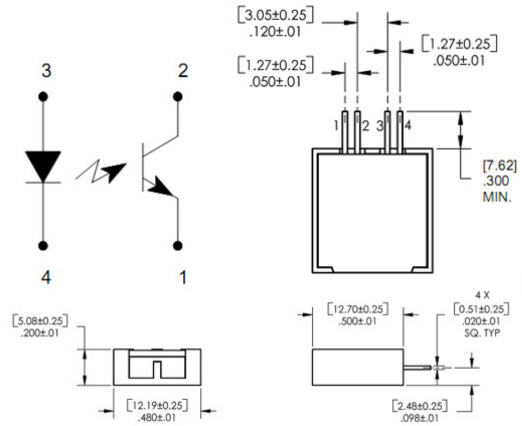
The OPB732 uses an infrared LED and a phototransistor in a reflective switch configuration.

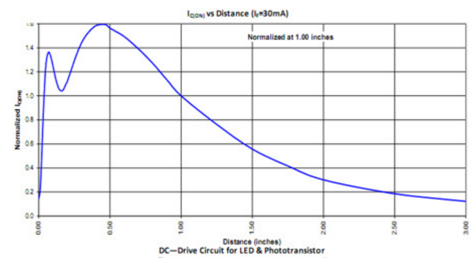
The assembly is made in either a pin version for planting directly on the printed circuit board (OPB732) or with wires (610 mm), 26 AWG (OPB732WZ) and uses an opaque filter to reduce the ambient light sensitivity of the sensor.

The LED and sensor are protected by a transparent window, allowing operation in a dusty environment.

The phototransistor can be configured as a common collector or common emitter device. While an object is in the reflection path of the device, the light from the LED will be reflected to the surface (base) of the phototransistor. When the reflected infrared radiation appears on the base of the phototransistor, the transistor becomes forward biased and is in the "ON" state, providing an IC(ON) current proportional to the light hitting the phototransistor. If the infrared light from the LED is not reflected back to the phototransistor, it blocks, minimizing the IC(ON) current.

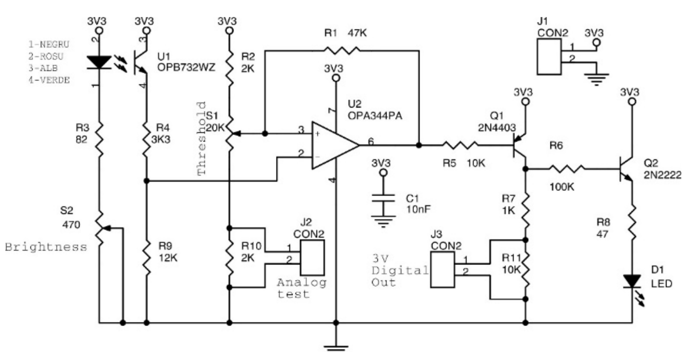




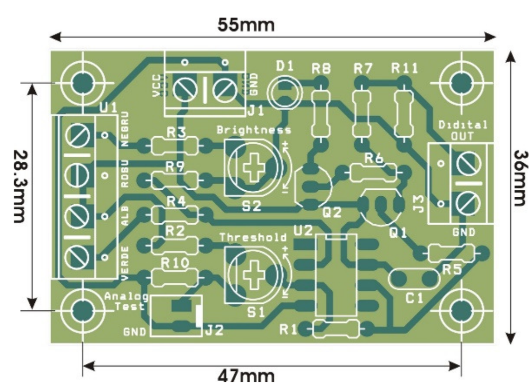


3.3V Version

A 3.3V power supply version of the module has been developed for compatibility with counter Arduino and Pycom modules.



Electrical schema – 3.3V version

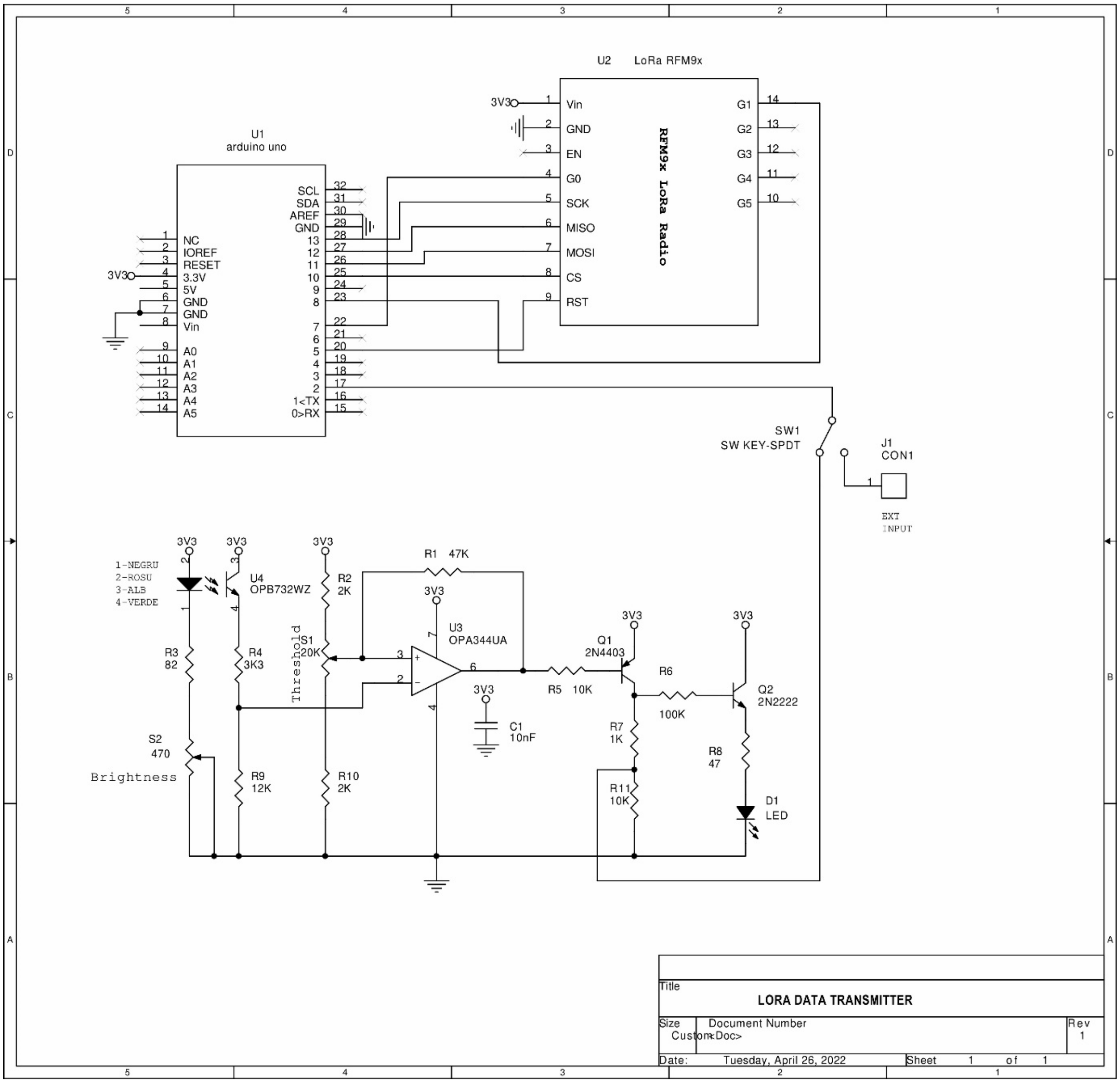


Printed Circuit Board – 3.3V Version

LoraWAN Protocol

Connecting the optical reader to the water meter - LoPy version.

Coupling Arduino Uno and LoRa RFM9x



Software Design

The Arduino compiler provides a user-friendly interface, making it easy to write, upload, and debug code. Additionally, it has a large community of users who share and contribute to a wide range of libraries and resources, making it easy to find solutions to common programming problems and expand the capabilities of the microcontroller.

Arduino boards come with a bootloader that allows new code to be loaded onto it without using an external hardware programmer. Communicate using the original STK500 protocol reference. If we do not use the bootloader, we can program the microcontroller via ICSP (In-Circuit Serial Programming) using Arduino ISP or similar.

The Arduino software includes a serial monitor that allows simple text data to be sent to and from the Arduino board.

The RX and TX LEDs on the board will signal when data is being transmitted through the FTDI chip and USB connection to the computer (but not for serial communication on pins 0 and 1). A Serial Software library allows serial communication on any of the Nano's digital pins. The ATmega328 also supports I2C (TWI) and SPI communications. The Arduino software includes a Wire library to simplify the use of the I2C bus.

For the 5V version we use the Arduino Nano board and for the 3.3V version we use Arduino Pro Mini board.

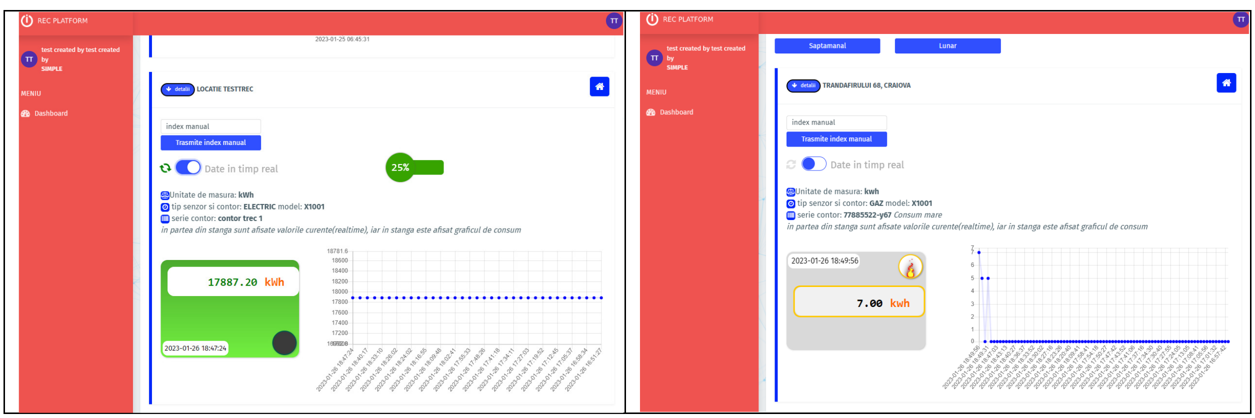
Nano modules are programmed from the editor with the MicroPython language, an implementation of the Python programming language, scripts are uploaded directly to the Arduino boards. MicroPython is designed to run on microcontrollers.

MicroPython is an implementation of the Python programming language that comes with a subset of the Python standard library and is designed to run on microcontrollers.

A great advantage of using MicroPython is that it is easy to learn and has great documentation for a few boards. Now, there are four boards that can be used together with MicroPython, you can read more about them in the compatible boards section. Arduino also supports OpenMV's branch of MicroPython, and through the OpenMV IDE you can install MicroPython, connect/disconnect your board and upload your scripts[7].

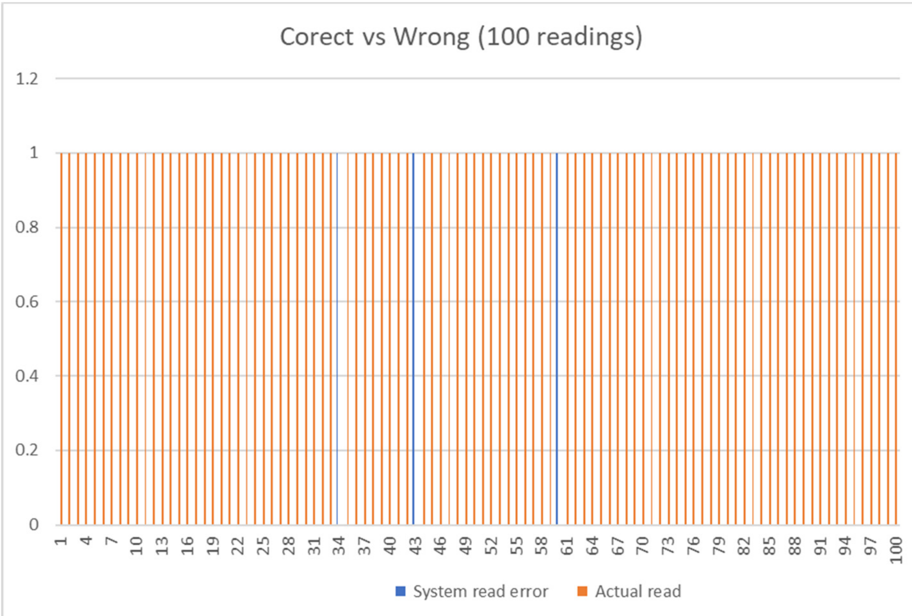
Results

The smart electric meter uses the Arduino IDE software to send as measurement output data through LoRaWAN to Internet (Cloud application) where they are saved there as JSON and displayed to users via the responsive web-application.



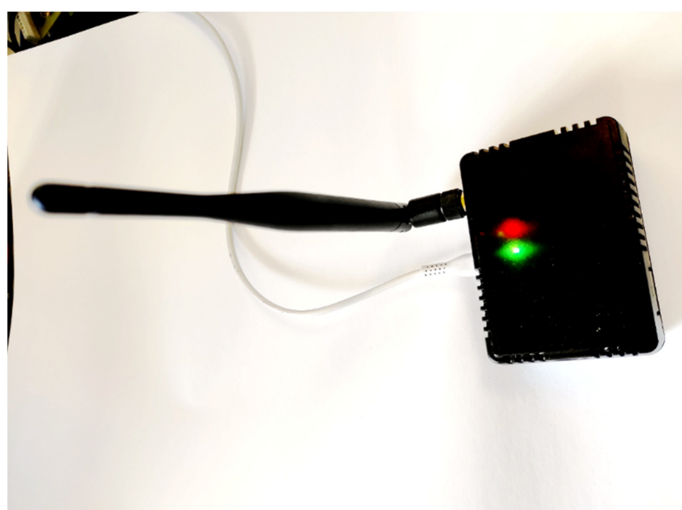
[7] https://docs.arduino.cc/learn/programming/arduino-and-python#compatible-boards

Our system's readings have an accuracy of above 95% compared to human readings. However, accuracy may vary depending on sudden changes in dial, intense light changes in the environment. However, with subsequent readings, the errors are averaged out.



>95% Accuracy

To summarize, this paper presented a design and implementation of an open-source and modular smart meter add-on based on Arduino, LoRa and free to use / open web technologies.



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