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An Internet of Things-Friendly, Plug-and-Play Module for Gathering and Sending Data from Nodes

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Abstract

The creation of a commercial, reconfigurable module for simple node data gathering and transmission in IoT applications is essential in this era of IoT technology breakthroughs. The majority of the systems on offer are application-specific. The goal of this project is to create a plug-and-play module for node data transfer and acquisition in Internet of Things-based applications. It was created a general framework for IoT sensors and controllers. In this study, a plug-and-play device was created to enable the usage of non-IoT sensors and controllers in IoT applications. It was created a software programme to implement the model. The work underwent online validation using an open-source server. Any remote site with a GPRS network can be utilised to collect data using the node. Therefore. The system proposed in this research will reduce the design to market time for IoT systems to two hours. This work will help in the standardization of the backend of remote IoT nodes for easy integration in the larger IoT ecosystem. The work can be commercially produced as generic configurable IoT controller modules by original equipment manufacturers (OEMs) thereby making it simpler to apply IoT technology in several fields of endeavours.

Keywords: Internet of Things, Plug-and-play, Data Acquisition, Data Transmission, IoT controllers, Sensors, Networks

Introduction

The number of gadgets connected to the internet has greatly increased in recent years. It is estimated that there are already roughly 35 billion Internet of Things (IoT) devices connected to the internet, and that number will rise to about 120 billion by the year 2025, producing about 180 billion terabytes of sensors [1]. The Internet of Things (IoT), a key industry 4.0 technology, faces significant difficulties when it comes to remote applications. In the IoT space, a "thing" is expected to carry out at least two tasks: data collection and transmission. Application-specific data acquisition, which typically involves reading and calibrating physical parameters, makes it challenging to create a universal Internet of Things node for sensor data gathering and transmission. Thus, IoT nodes before now are usually application-specific. The implication is that anybody that wants to use an IoT node must have to design and fabricate the required specific IoT node for the task at hand. For example, in a system that requires temperature, humidity, pressure, air quality monitoring at different locations, separate IoT nodes with unique algorithms have to be designed and fabricated for each parameter to be monitored. This does not make for easy and quick implementation of IoT systems. This work aims to develop a universal hardware and software framework for IoT node data acquisition and transmission. This framework will accept sensor readings as inputs while using the universal software framework to achieve automatic sensor calibration, and data transmission using the supplied receiver's address. Basic IoT systems monitor and control physical variables that define the "things" they monitor and control. To design an IoT system, the physical quantities that require monitoring must be defined [3]. The design of the data acquisition system is based on this definition.

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The acquired data must be shared over the Internet with the following constraints: A) minimization of the amount of the exchanged data while maintaining the entirety of the information B) reduction of the time delay required for sharing the data over the network, and an increase in the lifetime of the nodes Some authors have worked on data acquisition and transmission in IoT. The authors in [4] developed a custom IoT data acquisition system. In their approach, raspberry pi was used to demonstrate how a specific sensor can be interfaced to data acquisition hardware. The work gave an insight into how to develop an IoT sensor node. However, it is not a universal product that can be pushed into the IoT market as a solution for data acquisition and transmission at the backend. The work done by [5] is much similar to that of [4]. The major difference is that it was specifically for temperature monitoring. The work by [2] confirmed that before now IoT nodes have always been application-specific. In their approach, an indoor air quality monitoring platform was developed using some selected air quality sensors. A non-invasive, data acquisition system for reliable bio-telemonitoring of pregnant women which used National Instruments (NI) my RIO for data acquisition and transmission of the acquired physiological signals wirelessly to a computer running NI LabView software for real-time signal visualization, processing and data logging was presented in [6].

The authors in [7] used NodeMCU to push medical parameters to the Thing Speak, and also Message Queuing Telemetry Transport (MQTT) was used to push data to the server, and the Representational State Transfer (REST), while web services were used to provide interoperability between computer systems on the Internet. The authors [8] designed a re-configurable smart sensor interface for industrial wireless sensor networks in an IoT environment that made use of the complex programmable logic device (CPLD) as the core controller. Sentech also developed their 6205DA IoT Data Acquisition System and Protocol Converters which is a platform for exploring architecture, working and design applications of a data acquisition system [9]. The system understands types of protocol converters like serial to Ethernet converter, serial to Wi-Fi converter, and serial to GPRS. In [10] a generic Internet of things(IoT) platform supporting plug-and-play device management was developed based on the semantic web. This work is a major shift from the application specific devices proposed by majority of the authors that have worked in this area. One of the authors used GSM as the only gateway for data transmission. There is no generic plug-and-play device for adapting non-IoT compliant sensors and controllers to IoT environments that has the capability of using multiple data transmission gateways.

Resources and Procedures

Figure 1 depicts the block diagram of the suggested model for data collecting and transmission in IoT-based applications. This paper suggests that a typical IoT remote node can be implemented with just three plug-and-play components. IoT sensor, IoT controller with software configuration, and IoT gateway make up the components. The objective is to create a system that, when put into use, will result in three commercial IoT components that can be set up to collect and send data to any specified receiver via the IoT gateway.

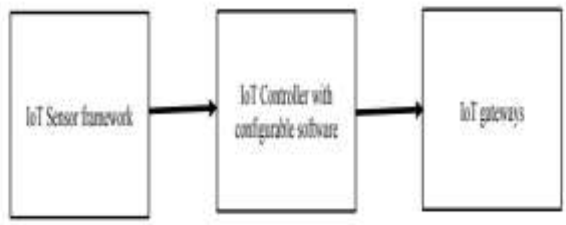
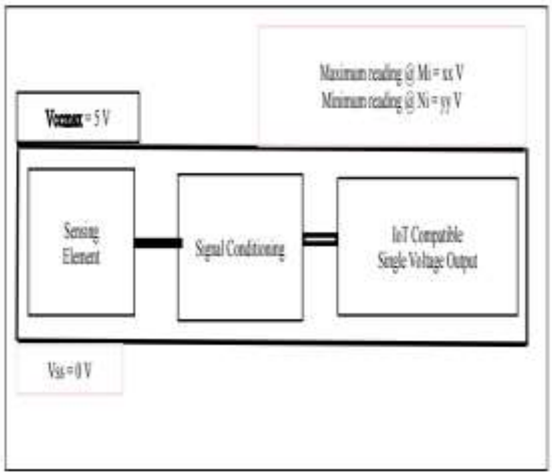


Figure 1: Block Diagram of the Proposed Model

Description of the Sensor Framework

The description of the proposed IoT sensor framework is shown in figure 2. Figure 2: Abstraction of IoT sensor framework



By this abstraction of figure 2, it is being proposed that for any sensor to be classified as an IoT sensor, the following condition must be satisfied:

- Its power supply must have a range between 0 and 5 V.

It must have a signal conditioner that normalizes its output signal to 0-5 V.

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Vol 11, Issue 3 Aug 2021

• Maximum reading xx of the sensor at maximum physical parameter Mi must be stated. For example, if the highest temperature the sensor can measure is 100° C, then the equivalent voltage reading of the sensor at 100° C must be stated by the original equipment manufacturer (OEM)

• Minimum reading yy of the sensor at minimum physical parameter Ni must be stated. With this narrative, it becomes clear that non-IoT-based sensors like thermistors, light-dependent resistors (LDR), and other several sensing elements cannot be classified as IoT sensors since they did not meet up with the above abstraction/standard. However, an original equipment manufacturer, OEM can use an LDR as a sensing element, for example, to produce a standard IoT light sensor. The same applies to thermistors. It can be used to produce a standard IoT temperature sensor. The whole idea of the sensor framework is to have a standard for IoT sensors such that any of such sensors can be interfaced directly to any IoT controller.

Hardware System Implementation

IoT Sensor Framework Implementation

To test the proposed model, the IoT sensor framework was implemented using a case study of light and temperature sensors. The IoT light sensor was designed using a light-dependent resistor (LDR) as a sensing element. The IoT controller architecture was implemented using ATmega328 as the core controller. The pinouts of the IoT architecture are shown in fig.4. It has six sensor channels and four gateway channels: Bluetooth, WIFI, GPRS, and SMS channels. The power supply to the controller is an independent unit.

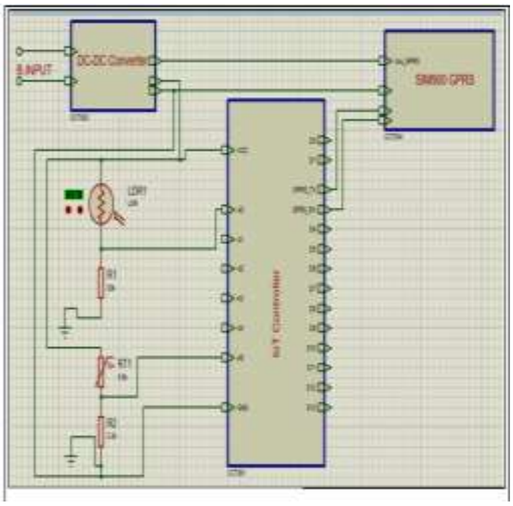

Fig.4: Circuit Diagram of the Integrated Hardware

The software Design

The agile method of software development was used to develop the software embedded in the controller. First, the sensor channel configuration software (SCCS) was developed and tested. Next data computation and automatic calibration software (DCACS) was developed using SCCS output as its input. Finally, the data transmission software (DTS) was developed, and also tested. Equations 5 to 9 were used to develop the software. Figure 5 is the high-level flowchart of the software application.

Results

Table 1 is the output of the UIoTSn when the two IoT sensors designed in this work were connected to channels 0 and 5. The light IoT sensor was connected to channel 0 while the IoT temperature sensor was connected to channel 5. The light intensity on the light sensor was varied by covering the sensing element with hand to a varying degree. Table 1 is the GPRS output of the UIoTSn which was sent to the online Thing Speak server while Figure 7 and 8 are the snapshots of the online server outputs

Table 1: GPRS output of the UIoTSn

S/N	i = 5; s0, s1, s2, s3, s4, s5
1	1000.00,0.00,0.00,0.00,0.00,32.00
2	1000.00,0.00,0.00,0.00,0.00,32.00
3	1000.00,0.00,0.00,0.00,0.00,32.00
4	1000.00,0.00,0.00,0.00,0.00,32.00
5	1000.00,0.00,0.00,0.00,0.00,32.00
6	1000.00,0.00,0.00,0.00,0.00,32.00
7	1000.00,0.00,0.00,0.00,0.00,32.00
8	1000.00,0.00,0.00,0.00,0.00,32.00
9	1000.00,0.00,0.00,0.00,0.00,32.00
10	1000.00,0.00,0.00,0.00,0.00,32.00
11	1000.00,0.00,0.00,0.00,0.00,32.00
12	1000.00,0.00,0.00,0.00,0.00,32.00
13	1000.00,0.00,0.00,0.00,0.00,32.00
14	1000.00,0.00,0.00,0.00,0.00,32.00
15	1000.00,0.00,0.00,0.00,0.00,32.00
16	124.00,0.00,0.00,0.00,0.00,33.00
17	No data received
18	1000.00,0.00,0.00,0.00,0.00,32.00
19	1000.00,0.00,0.00,0.00,0.00,32.00
20	77.00,0.00,0.00,0.00,0.00,33.00

Table 2: Output Data from the Universal IoT Sensor Node (UIoTSn)

ISSN 2229-6107www.ijpast.in
Vol 11, Issuse 3 Aug 2021

SN	i=0; a0	i=1; a0,a1	i=2; a0,a1,a2	i=3; a0,a1,a2,a3	i=4; a0,a1,a2,a3,a4=	i=5; a0,a1,a2,a3,a4,a5
1	32.00	0.00,32.00	0.00,0.00,32.00	0.00,0.00,0.00,32.00	0.00,0.00,0.00,0.00,32.00	0.00,0.00,0.00,0.00,0.00,32.00
2	32.00	0.00,32.00	0.00,0.00,32.00	0.00,0.00,0.00,32.00	0.00,0.00,0.00,0.00,32.00	0.00,0.00,0.00,0.00,0.00,32.00
3	32.00	0.00,32.00	0.00,0.00,32.00	0.00,0.00,0.00,32.00	0.00,0.00,0.00,0.00,32.00	0.00,0.00,0.00,0.00,0.00,32.00
4	32.00	0.00,32.00	0.00,0.00,32.00	0.00,0.00,0.00,32.00	0.00,0.00,0.00,0.00,32.00	0.00,0.00,0.00,0.00,0.00,32.00
5	32.00	0.00,32.00	0.00,0.00,32.00	0.00,0.00,0.00,32.00	0.00,0.00,0.00,0.00,32.00	0.00,0.00,0.00,0.00,0.00,32.00
6	32.00	0.00,32.00	0.00,0.00,32.00	0.00,0.00,0.00,32.00	0.00,0.00,0.00,0.00,32.00	0.00,0.00,0.00,0.00,0.00,32.00
7	32.00	0.00,32.00	0.00,0.00,32.00	0.00,0.00,0.00,32.00	0.00,0.00,0.00,0.00,32.00	0.00,0.00,0.00,0.00,0.00,32.00
8	32.00	0.00,32.00	0.00,0.00,32.00	0.00,0.00,0.00,32.00	0.00,0.00,0.00,0.00,32.00	0.00,0.00,0.00,0.00,0.00,32.00
9	32.00	0.00,32.00	0.00,0.00,32.00	0.00,0.00,0.00,32.00	0.00,0.00,0.00,0.00,32.00	0.00,0.00,0.00,0.00,0.00,32.00
10	32.00	0.00,32.00	0.00,0.00,32.00	0.00,0.00,0.00,32.00	0.00,0.00,0.00,0.00,32.00	0.00,0.00,0.00,0.00,0.00,32.00
11	32.00	0.00,32.00	0.00,0.00,32.00	0.00,0.00,0.00,32.00	0.00,0.00,0.00,0.00,32.00	0.00,0.00,0.00,0.00,0.00,32.00
12	32.00	0.00,32.00	0.00,0.00,32.00	0.00,0.00,0.00,32.00	0.00,0.00,0.00,0.00,32.00	0.00,0.00,0.00,0.00,0.00,32.00
13	32.00	0.00,32.00	0.00,0.00,32.00	0.00,0.00,0.00,32.00	0.00,0.00,0.00,0.00,32.00	0.00,0.00,0.00,0.00,0.00,32.00
14	32.00	0.00,32.00	0.00,0.00,32.00	0.00,0.00,0.00,32.00	0.00,0.00,0.00,0.00,32.00	0.00,0.00,0.00,0.00,0.00,32.00
15	32.00	0.00,32.00	0.00,0.00,32.00	0.00,0.00,0.00,32.00	0.00,0.00,0.00,0.00,32.00	0.00,0.00,0.00,0.00,0.00,32.00
16	32.00	0.00,32.00	0.00,0.00,32.00	0.00,0.00,0.00,32.00	0.00,0.00,0.00,0.00,32.00	0.00,0.00,0.00,0.00,0.00,32.00
17	32.00	0.00,32.00	0.00,0.00,32.00	0.00,0.00,0.00,32.00	0.00,0.00,0.00,0.00,32.00	0.00,0.00,0.00,0.00,0.00,32.00
18	32.00	0.00,32.00	0.00,0.00,32.00	0.00,0.00,0.00,32.00	0.00,0.00,0.00,0.00,32.00	0.00,0.00,0.00,0.00,0.00,32.00
19	32.00	0.00,32.00	0.00,0.00,32.00	0.00,0.00,0.00,32.00	0.00,0.00,0.00,0.00,32.00	0.00,0.00,0.00,0.00,0.00,32.00
20	32.00	0.00,32.00	0.00,0.00,32.00	0.00,0.00,0.00,32.00	0.00,0.00,0.00,0.00,32.00	0.00,0.00,0.00,0.00,0.00,32.00

Universal IoT Sensor Node Functionality

Any of the input channels of the UIoTSn, which serves as a Proof of Concept (POC), can be configured to accept IoT sensors' output. The results showed that the temperature readings of the IoT sensor were consistent with all the channels. Also from Table 1 and other generated data, it can be seen that the UIoTSn can be configured to accept IoT sensors with different bandwidths of maximum and minimum readings without interfering with one another's readings. The UIoTSn was

able to send data to the remote online server. What it means is that this node can be used to acquire data from any remote location that has a GPRS network, and a good enough GPRS network covers a wide geographical range just as a GSM network. The implication is that the UIoTSn can be applied in many areas of IoT automation for remote data acquisition.

Throughput of the UIoTSn

Throughput in this work can be defined as the ratio of data sent from the UIoTSn to that of the data successfully received at the server end. A total of 20 sampled data were sent. There was only one failure. So, the throughput of the UIoTSn in percentage is

$$\left(\frac{19}{20}\right) \times 100 = 95\%$$

This is much acceptable for any data acquisition system!

Latency of the UIoTSn

The latency of the system is defined as the time it takes data to move from UIoTSn to the online server. Experimentally the latency of the node was found to be 3 seconds, while the processing time of the node was 135 seconds.

The integrity of the UIoTSn

The integrity of the data acquisition system has to do with delivering the exact data acquired by the system. A comparison of data sent with that received showed that the UIoTSn has 100% integrity.

System Validation

One of the major achievements in this work is the automatic calibration of sensor readings which usually takes time for any data acquisition system. But this work overcame the challenge by specifying the maximum and minimum readings of the IoT sensor nodes, a method being proposed that IoT sensor node OEMs should adopt. So the maximum and minimum readings of the developed IoT temperature sensor were supplied as part of the inputs to the configuration software. The temperature output was compared with that of a standard analog thermometer placed within the same environment as the IoT temperature sensor. While the thermometer read 32.2° C, the UIoTSn measured 32° C, giving a difference of 0.2 i.e 99.4% accuracy. As proof of concept for the data acquisition and transmission system, the designed integrated system was implemented.

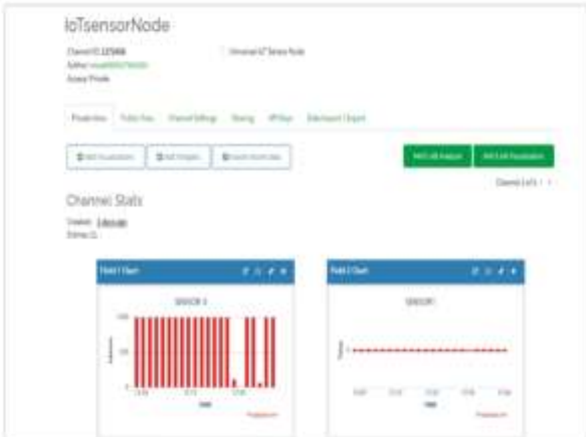

Figure 6: Snapshot of the Online Server Output of the UIoTSn

Software Implementation

The SCCS and DCACS were integrated and tested. The data were sampled at intervals of 2 seconds. The data transmission software (DTS) was developed for the case of Gi=3 due to the time factor. To test the DTS, a real-time online server was configured using the ThingSpeak open-source server.

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Vol 11, Issuse 3 Aug 2021

Conclusion

The goals of this research project were successfully met. A model for the collection and transmission of IoT data was created. Software applications were created, and the test results were within reasonable bounds. The system can be set up to accept IoT sensors with a range of maximum and minimum readings without affecting the readings from the other sensors. Furthermore, it was able to transmit data to the distant online server. This means that any remote site with a GPRS network can be utilised to collect data using this node. As a result, the UIoTSn system can be used for remote data collecting in numerous IoT automation domains. Additionally, the system's throughput is 95%. The node's latency was discovered to be 3

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