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Research paper

Design and Implementation of an IoT Ready Smart Sensor for Speed Sensing of a DC Motor using IEEE 802.15.1 and ESP8266

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Abstract

An IoT enabled smart sensor for speed sensing of a DC motor is designed and implemented. This is a generic platform enabled with Wi-Fi, Bluetooth, etc. It can also be used for many other applications. In this paper, we have used cyber-physical aspects for the co-design of hardware and software. Our design is equipped with Bluetooth radio frequency link and TCP/IP stack. The sensor node is able to communicate to both near and far range according to the requirement. IP addresses make it uniquely identifiable. Implementation is done as per the layered architecture which makes it interoperable. A demo setup is made for verification.

Keywords: *Networked control system (NCS), Internet of things (IoT), Sensor design, Geared DC motor, ESP8266.*

1. Introduction

In the present scenario, Internet of things (IoT) is the most buzzing word in the research community. IoT may be defined as the ubiquitous scalable network of heterogeneous uniquely identifiable intelligent objects which can interact interoperability[**Error! Reference source not found.**]. Acquisition of physical data, processing, and communication abilities enable IoT nodes to interact with each other through the internet or other communication networks. These nodes are constrained by their processing capability, bandwidth limitation, power, etc. On the other hand, they need to cater different quality of services for the delay, feedback, and network traffic requirement of a particular application. The present world is blessed with different wireless technologies like 3G, ZigBee, Wi-Fi, Bluetooth, etc. which give rise to ubiquitous sensing. A comparative study of the wireless network is shown in Table 1.

Table 1: A comparative study of some popular network technologies

Technology	IEEE standard	Range covered (Meter)	Maximum data rate (Mbps)	Channel bandwidth (MHz)
WiMax	802.16	1-5K	30-50	1.25-20
Wi-Fi	802.11	100	54	22
UMTS	CDMA TDMA	0.1-10K	0.384-2	5
ZigBee	802.15.4	10-100	.250	0.3/0.6/2
Bluetooth	802.15.1	10-100	1	1

These technologies have converted the static internet into a ubiquitous networked system[**Error! Reference source not found.**]. For storing these data heaps, we also have various cloud platforms on which the data can be analysed and shared among various smart objects[**Error! Reference source not found.**, **Error! Reference source not found.**, **Error! Reference source not found.**, **Error! Reference source not found.**]. To uniquely identify a small node over an IP network and to provide connectivity over the internet with low power requirement, the 6LowPAN protocol is being used in various research areas [**Error! Reference source not found.**]. There are lots of domestic and civil applications where these architectures are being used such as a smart home, smart building, smart energy meters [**Error! Reference source not found.**], smart cities [**Error! Reference source not found.**], smart parking, smart garbage management [**Error! Reference source not found.**, **Error! Reference source not found.**, **Error! Reference source not found.**, **Error! Reference source not found.**, **Error! Reference source not found.**, **Error! Reference source not found.**], etc. On the other hand, Industry 4.0 [**Error! Reference source not found.**] is also in the evolution phase where smart grid [**Error! Reference source not found.**, **Error! Reference source not found.**], factory automation, smart manufacturing[**Error! Reference source not found.**], water quality monitoring[**Error! Reference source not found.**, **Error! Reference source not found.**, **Error! Reference source not found.**, **Error! Reference source not found.**] are being investigated.

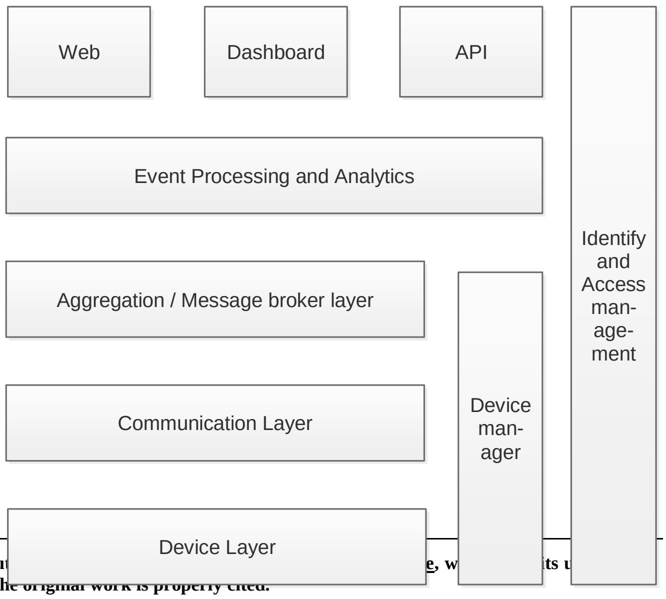

Fig. 1: Reference architecture for an IoT [**Error! Reference source not found.**]

IoT is a paradigm shift in the machine to machine (M2M) and machine to human interaction.
A layered reference architecture[**Error! Reference source not found.**]for IoT is shown in Fig. 1. Some recent applications are worth mentioning. Reference [**Error! Reference source not found.**]designed a smart sensor which identifies pot material of domestic cooking items. Here inductor is used as a sensing element and spectral method is used for the calculation of impedance using voltage and current waveform across sensing element. A feature set of impedance and power factor is used for learning of pot material. In [**Error! Reference source not found.**], smart recognition and counting of objects using a camera as a sensing element was designed. Reference [**Error! Reference source not found.**]explored an energy efficient model in IoT environment and proposed an architecture for integration of wireless sensor networks with IoT. Reference [**Error! Reference source not found.**]designed a microcontroller-based sensor for measuring water quality in real-time using ZigBee communication protocol. Reference [**Error! Reference source not found.**]presented a wireless sensor network (WSN) based on ISO/IEC/IEEE 21451 for monitoring water bodies to achieve the objective of capturing extreme events. In [**Error! Reference source not found.**], authors proposes a reconfigurable design using complex programmable logic devices (CPLD). They adopted IEEE1451.2 intelligent sensor interface specifications and co-designed hardware and software interface. Apart from these, some works have been reported in environment monitoring [**Error! Reference source not found.**, **Error! Reference source not found.**]. The above literature review reveal that wireless sensor network standards have been established well. They have been applied in many fields. However, lot more can be done in industrial aspects like control, maintenance, real-time decision making, etc.
In this paper, we have mainly concerned with the design of a smart sensor for speed sensing of a DC motor. This design is developed for an end to end solution keeping scalability, interoperability, and extensibility in mind. Our design is capable of processing and transmitting data in a local network as well as in an internetwork scenario. Our proposed design is reconfigurable, versatile, cost effective and modular, and can be used for different other applications. With this design, sensing element could be replaced periodically without disturbing the entire system.
The paper is organised as follows: Section 2 covers all the design issues and architectures of different individual layers. Section 3 describes the implementation procedure of hardware, software, and communication module design. In Section 4, we provide the detailed experimental results. We have concluded the paper in Section 5.

2. System Design

We have worked on the device layer, communication layer and Device management of the IoT architecture as shown in Fig 1. The Proposed layered architecture for our smart sensor node is shown in Fig. 2, where hardware and software co-design is implemented for the speed sensing.

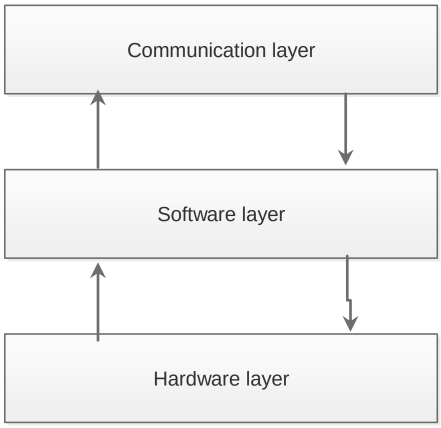

Fig. 2: Proposed layered architecture for sensor node

In a typical industrial scenario, we have to sense either analog or digital signal. A microcontroller can only process digital signals. Hence, usually, we need to convert analog data into digital data using analog to digital converter (ADC). However, in our case, we are generating only digital event to sense. Thus, there is no need of ADC. But for the sack of generalisation, we have kept the provision of an ADC with the hardware implementation. A schematic diagram of hardware implementation design is shown in Fig. 3.

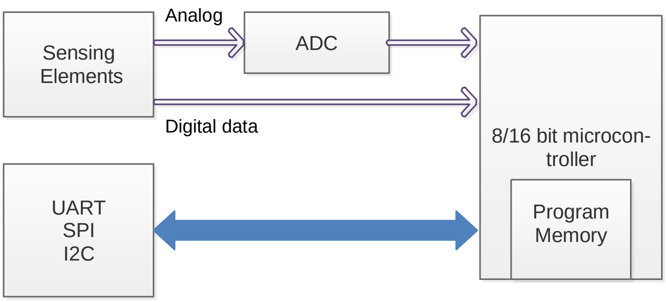

Fig. 3: Hardware design part for the sensor node

After capturing the data in digital format, we run the software algorithm to converts these bits into useful information. The software layer is attached to the hardware layer. A schematic diagram of software design is shown in Fig. 4.

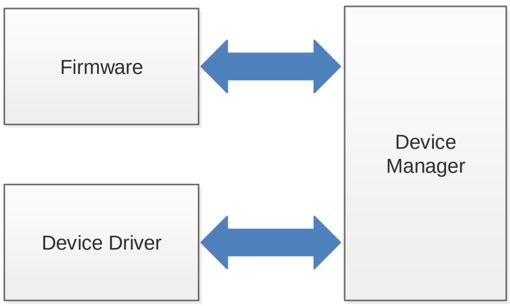

Fig. 4: Software design part for the sensor node

The information obtained from the firmware are sent to the serial port, from where according to demand requirement, the data are sent to near range, far range, or even in the cloud platform. The schematic diagram of the communication layer design is shown in Fig. 5

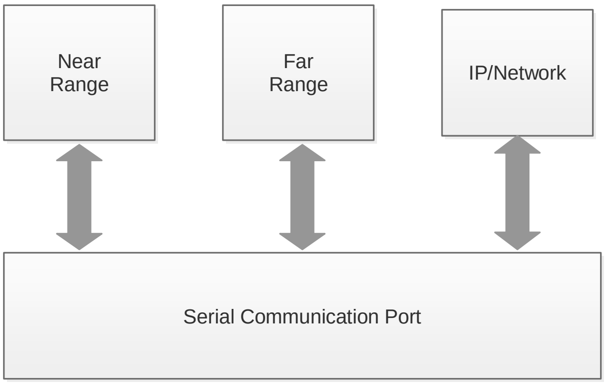

Fig. 5: Communication layer design for sensor node

The objective of the work is to create a reconfigurable interface for different sizes of the motor or other rotating elements. The design is done with a limited data processing ability for observation, estimation, and transmission. The node has a unique identification, radio frequency link, and TCP/IP stack.

3. System Implementation

3.1 Hardware Layer Design

In this design, we have used encoder disc with equally spaced 20 holes. An infrared sensor is mounted in such a way that the disc makes and break the transmission path of infrared. When IR sensor makes the path then an event is generated. ATmega2560 microcontroller is used for timing and event handling.

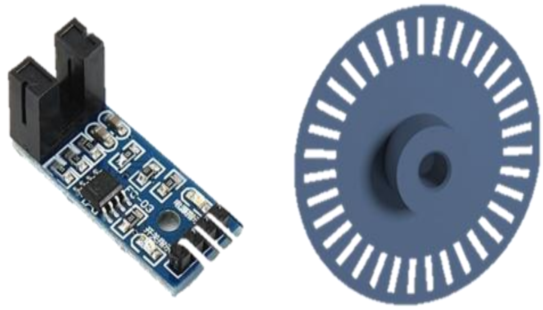

Fig. 6: (a). Infrared sensor (Left) (b). Encoder disc (Right)

3.2 Software Layer Design

Event monitored by the hardware is converted to the useful information, i.e. speed (in RPM) in our case, by our algorithm. An android application is designed to supervise the motor. The flowchart is shown in Fig. 7.

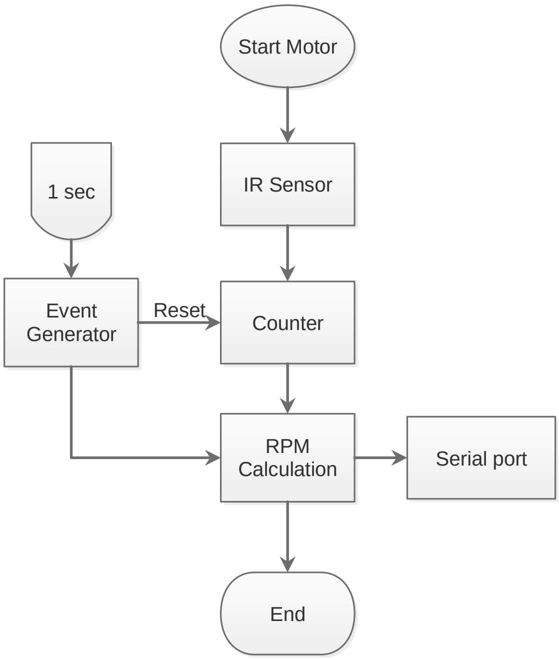

Fig. 7: Communication layer design for the sensor node

3.3 Communication Layer Design

We have divided this layer into three modes. The first mode provides local communication where we have used universal asynchronous receiver transmitter (UART) protocol. The second mode is used for near range communication where we have used Bluetooth protocol. With this mode, we can visualise and supervise the plant where this smart platform is mounted. For the far range communication, we have used Wi-Fi connectivity using esp8266 and for IP communication, we need TCP/IP stack.

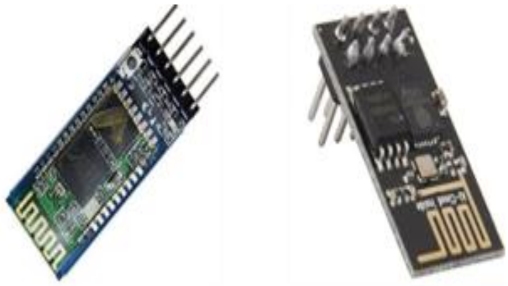

Fig. 7: (a). Bluetooth module (b). Wi-Fi module

4. Experimental setup and Results

We have conducted the experiment to measure the revolution per minute online over the network. The assembly used for this experiment can be seen in Fig 8. The cyber part of the experimental setup is shown in Fig. 9. Due to the wireless network, the responsiveness of the sensor may vary at different locations which depend on the distance between the plant and mobile location.

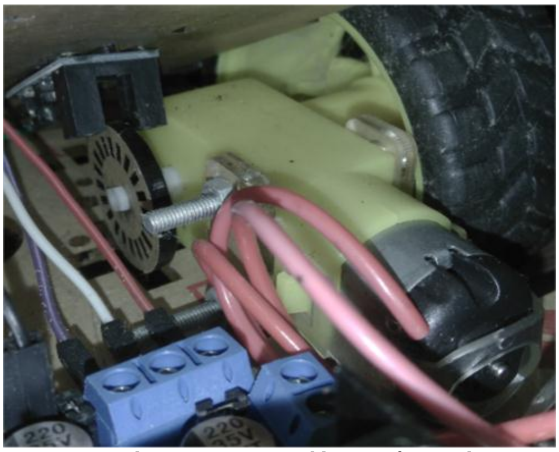

Fig. 8: Experimental smart sensor assembly setup for speed measurement

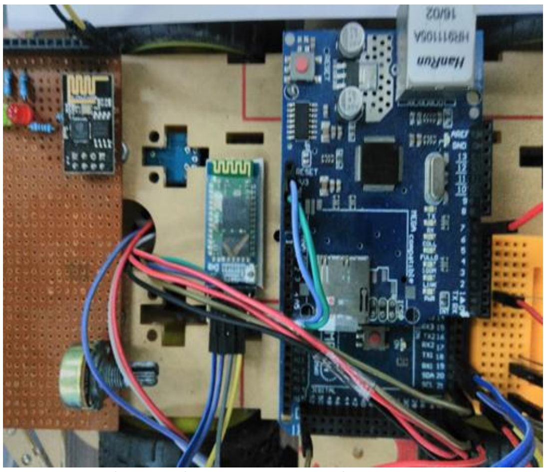

Fig. 9: Interfacing of various modules for speed measurement

An android application is used for sending the reference command to run the motor at different speeds and receiving the value of revolution per minute of the motor. It is displayed locally on a mobile and web interface, which can be seen in Fig 9. The verification of the accuracy of the proposed smart sensor is done using a tachometer (dot-791) to measure the speed locally. The results are given in Table 2. The speed reading by the proposed smart sensor is closely matching with the reading of the tachometer. Thus, the proposed smart sensor is working satisfactorily within the experimental limitation.

Table 2: Observation table for determinationaccuracy of the sensor

Voltage applied (V)	Duty cycle (%)	RPM* determined (Sensor)	RPM* measured (Tachometer)	Error (in %)
2.4	20	0	0	0
4.8	40	~238	241	1.2
7.2	60	~304	310	1.9
9.5	80	~333	338	1.4
12	100	~356	365	2.4

*Revolution per minute, ~ approximately

5. Conclusions

In this paper, we have presented the design and experimental setup of an IoT-based smart sensor for measurement of the speed of a DC motor. The proposed sensor node has communication feature which enables it to transmit measurement data successfully. The accuracy of the proposed smart sensor is compared with the measurement of a tachometer. The experimental results reveal that the proposed smart sensor is able to measure the speed correctly within the experimental limitation. In future, we will extend our design for cloud interfacing.

6. Acknowledgement

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