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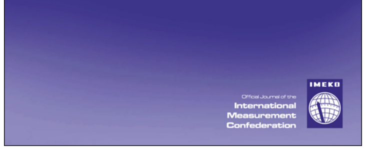

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Internet of Things Cloud Enabled MISSENARD Index Measurement for Indoor Occupants

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Abstract

Thermal comfort is an important factor in human body. It can seriously impact on the livelihood factors of human such as lifestyle, productivity, societal activity, and health of the individual. It holds tremendous adverse affect towards diminishing of tolerance to other environmental hazards too. In this paper, an Internet of Things based Cloud enabled measurement of MISSENARD Index is proposed. A prototype system is implemented based on the proposed novel architecture for measuring thermal comfort of the indoor occupants. The system is developed to apprehend the Internet of Things based multiple cloud services as an important enabler for conferring to MISSENARD index monitoring in real time. The developed system holds a novel way of smarter integration of sensor fueled data analytics with cloud supported visualization at the same time. It further validates the usability of several plug-ins, different Application Programming Interfaces (API), heterogeneous network communications, and low power, memory constrained, yet cost effective processor altogether to testify the underlying theory of Internet of Things to become prevalent into a reality.

Keywords: IoT, Cloud services, MISSENARD Index, Indoor Air Quality, Thermal Comfort.

1. Introduction

1.1 What is IoT?

In recent years, Internet of Things (IoT) has turned into a ground breaking solution to various sectors of civilization. Transportation, healthcare, home automation, agriculture, industry, and environment, IoT has intruded itself into the depth of these fields. It is also envisaged that by 2020, almost 50 billion devices will get connected to the network specifically the internet. Sensor and actuator based network model is the basis of IoT. IoT can be defined as the platform of interconnection of any thing, any time, any where and by any one. In simple words it can be assumed that everything will get connected to each other. The concept become popular by publications from a group of researchers of Auto–ID centre of MIT during early 2000's, who were trying to develop a system implying RFID (Radio Frequency IDentification) integration for industrial automation purpose. But lack of standardized technologies and relevant interests resisted the research of IoT to flourish up to its mandate. The ray of hope is seen after the recent growth in semiconductor sectors where 10nm chip architecture has possibly been built resulting procurement of tiny microcontroller chips and smart sensors along with the open source hardware movement. Fig. 1 presents the growth chart of IoT in recent years. The chart has been generated based on the "Internet of Things" keyword performed over the Web of Science portal. The X-axis represents year starting from 2009 to 2015. No relevant research article was found before 2009. Hence, the data earlier to 2009 are not included. Y-axis presents the number of publication per year in Tier-1 or reputed journals which are indexed by the Web of Science. Current trend of research towards IoT is found to be exponential in nature as expressed by the equation $y = 75.986 * e^{0.3962 * x}$. Popularity of IoT is hereby confirmed by these findings.

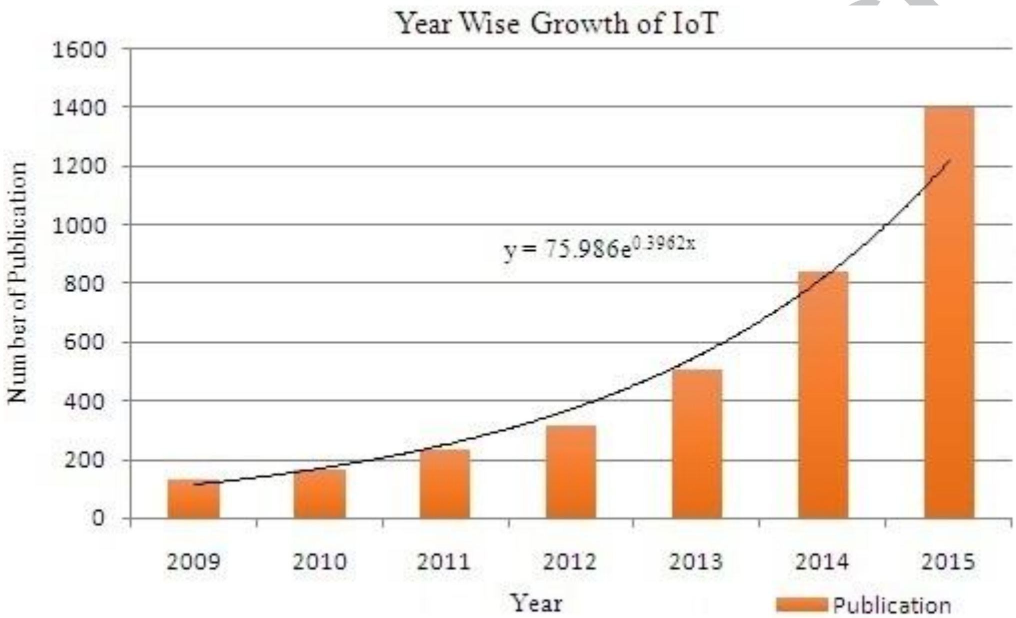

Fig. 1. IoT growth chart.

1.2 Understanding Cloud

Cloud is sometimes termed as Cloud computing which is essentially a metaphor that delivers the on demand computing resources – from utilities to data centers on a pay – as – you go basis or free. Various forms of platforms ranging from *public*, *private* or even *hybrid* serve the technical necessities while enabling virtualization and Service Oriented Architecture (SoA) to solve the problem into several smaller units to get processed efficiently. Services (utility programs) help the user applications to get validated. Out of many, three service models are primarily the basic building block of cloud – a) Infrastructure as a Service (IaaS) provides computers (virtual or physical) and other useful resources from designated data centers, b) Platform as a Service (PaaS) typically includes database, system software such as operating system, inbuilt language execution and web server based services and c) Software as a Service (SaaS) is sometimes refereed to as ODS (On Demand Software); as it is usually cumulated as subscription fee. Amazon Web Services (AWS), Google Cloud Platform (GCP), HP cloud, IBM smart cloud, Microsoft Azure Infrastructure Services (WAIS), Oracle cloud computing are the top rated cloud services proving opportunity to work in public, private and hybrid mode to various user applications.

1.3 What is IoT Cloud?

Besides the above mentioned giant corporations, few specialized cloud platforms are also floating in the market which cater the particular needs of the IoT based services, called IoT cloud. According to Ray, 2016 IoT cloud may be described as a model designed to facilitate the information society, enabling advanced services by interconnecting (physical and virtual) things based on, existing and evolving, interoperable information and communication technologies through ennoblement of ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (i.e., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction that leverage the need and heterogeneous connectivity issues of the user centric things in well defined fashion. Xively, ThingSpeak, Plotly, Exosite, GroveStreams, Temboo, ThingWorx, Carriots, Nimbits, KAA, IBM IoT, Oracle Open IoT, Microsoft Research Lab of Things, SensorCloud, Ayla's IoT Cloud Fabric, Arrayent Connect TM, Aer Cloud, thethings,io, SeeControl IoT, Jasper Control Center etc. are to name a few. Generally, these cloud based IoT service platforms provide real time raw data collection and storage, graphical interaction, statistical analytics support, reaction measures, triggering activities, device status messages etc. These platforms are sophisticated enough to incorporate different network communications protocols such as Wi–Fi, ZigBee, WLAN (Wireless local Area Network), BT (Bluetooth), BTLE (Bluetooth Low Energy), RF (Radio Frequency), 6lowpan (IP version 6 low power personal area network) along with many non conventional ones. Open API (Application Programming Interface) and plug–ins strengthen their cumulative architecture to act with the devices that are connected.

1.4 Motivation

Technically speaking, IoT is a service which can serve and disseminate the prolonged needs of unlimited human desires. Thermal comfort is the one which has attracted many researches to derive and establish their thoughts through pen–paper and practical implementations [1,2,3,4,5]. The thermal comfort is defined as a perception to a human body that neither loose nor receive heat from environment. As per the information from the Office of National Statistics (ONS) of United Kingdom, around 25,000 people die from cold each year. The troll of deaths rose up to 45,000 in 2015 [17]. More than 1,100 people of India died from extreme heat this year [18]. Problems may increase in its magnitude if preventive mechanism is not sought due time. Measurement and monitoring of thermal comfort is a way out in such situation. Thermal comfort can be determined by parameters like air temperature, air dynamics, relative humidity, age, health status, clothing style (thickness, color), and activity (physical, psychical). MISSENARD index is one of the most suitable techniques which indulge into a strong impact into finding thermal comfort for indoor occupants as proposed by Krawczyk himself [6]. Though, manual processes are present, but no literature was found till writing of this paper that would have devised an automated procedure to measure and monitor MISSENARD index. Also, IoT oriented approaches were not sought in available libraries of articles. This has motivated me to design and implement an IoT cloud based smart measurement system for MISSENARD index suitable for indoor environment.

1.5 Contribution

One purpose of the monitoring is to develop a smart and novel system to automate the process of mathematical juxtapose of MISSENARD index. Furthermore, monitoring is required to detect the interference between the factors of thermal comfort of indoor occupants with the MISSENARD index. Another purpose of MISSENARD index monitoring is to help determine how IoT cloud platforms integrate services as disclosed on their portals with the open source hardware. Finally, how the sensory inputs significantly enhance the efficiency of the whole system in real time. To achieve all of these goals, monitoring has to be mobile, compact in size, low energy consuming, versatile, and less costly.

This paper presents a novel IoT cloud based measurement system on MISSENARD index, moreover it:

- educates the reader with a overview about IoT and IoT cloud;
- elaborates the experimental methodology to measure MISSENARD index for indoor occupants;
- uses multiple IoT cloud services to monitor MISSENARD index;
- presents real-time visualization and analytics of the fetched data;

The main objective of this work is to provide the reader the complete view of the understanding about how IoT (IoT architectures, technologies in use and specifications) can be incorporated in the measurement science (for example MISSENARD index monitoring). The remainder of the paper is organized as follows. Section 2 provides related works done so far in this field. Section 3 presents the materials used for this experiment. Section 4 shows layered architecture, experimental setup, and determination process which is followed by Section 5 that illustrates results obtained from the study, whereas Section 6 concludes this paper.

2. Related Work

At the time of writing, no similar works were found that talk about the MISSENARD index measurement and monitoring using IoT and cloud services. But few researches have shown applications developed to measure environmental and other parameters using IoT and enabled clouds. Physical activity of a person can be measured and monitored using Internet of Things based cloud services. [10] has proposed an architectural framework to handle the information about the physical activity of a human body by involving Bluetooth and IEEE 802.15.4 technologies that measures ECG, number of steps, and dissolved oxygen into the blood. An article presents the measurement of vitals of elder person by architecting the H3IoT (Home Health Hub Internet of Things) at homely atmosphere. It uses Bluetooth, Zig Bee, radio frequency (RF) etc. technologies to monitor ECG, EEG, EMG, tilt, movement,

Fig. 2. Arduino Uno (left), DHT11 sensor (right).

respiration, blood pressure, blood glucose, thermometer, and dissolved oxygen in blood - using cloud services [11]. A recent research has proposed to integrate the body of sport person with the sport equipments to the team management, coach, and even with their fans through social networking [12]. Visualizations along with the IoT based cloud services such as injury risk analysis, compact analysis, and contextual awareness analysis are merged with this solution. [14] has gone one step above and proposed to connect soccer with the footballer through the use of IoT and cloud services. IHoH (Internet of Health of Home) architecture is presented to monitor carbon monoxide, carbon dioxide, humidity, temperature, LPG gas, air pressure, and ambient light at indoor (home) to inform the inhabitants by alarming, digital spraying, switch on/off of air cooler, air conditioner and exhaust fan to save the life of occupants from threats. Here, IoT cloud services are used to serve visualization, heat energy, and other risk analysis [13]. Few other papers do validate the integration of IoT cloud services to monitor heat index of environment, air borne particulate matter of 2.5micron size, and wood equilibrium moisture content (EMC) by [15, 21,16] respectively. It is also found that IoT and cloud enabled agriculture is currently getting its shape to be smarter in near future [22]. Salamone et. al., [9] describes a low-cost and open-source hardware architecture which is able to detect the indoor parametric variables necessary for the Indoor Environmental Quality (IEQ) calculation consisting of some sensors and an Arduino board. This article presents a nano Environmental Monitoring System (nEMoS) that is developed based on inexpensiveness and the consistency of the detected data. AirQualityEgg [23] is a community led sensor network that comprises of a small electronic sensing system which sends environmental data about NO2 and CO concentration to the internet over WiFi. The data is sent to the Opensensors.io based IoT cloud platform which both stores and provides free access to the data to the users. Xively supported visualization and ability to generate triggers for tweets and SMS alerts allow inhabitants to gather knowledge about their peers. Similar solution using private IoT cloud platform has been devised by the Specksensor^{TM} [24], a PM2.5 sensor system. It is designed to measure particulate matter of 2.5 micron borne in its surrounding air. It uses WiFi to send the measured data to its private IoT cloud where user can later on analyze the air condition. Real-time local visualization support has also been provided.

3. Material Used

The components of the study can be classified into four types –

a) Microcontroller system: It is based on Arduino Uno which is an open source physical computing platform having following specifications, such as Atmel ATmega328 microcontroller, 14 digital input/output pins, 6 analog inputs, a 16 MHz quartz crystal oscillator, 32 KB – Flash Memory, 1 KB– EEPROM, 2 KB – SRAM,. It operating voltage

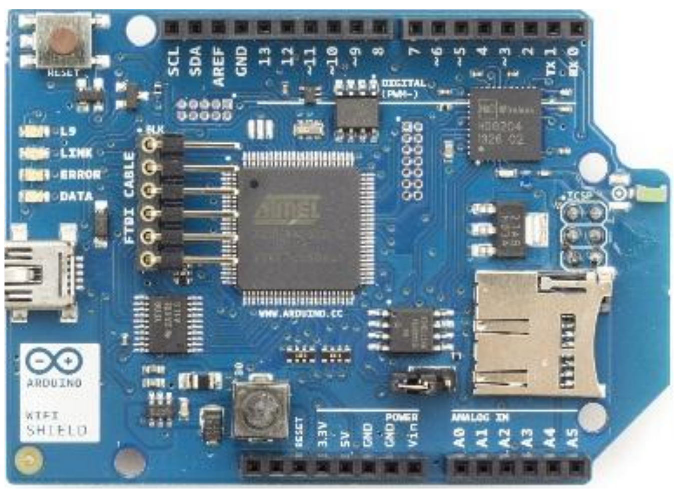

Fig. 3. Arduino WiFi module.

is 5 volt DC. Arduino Uno is easily programmed by an IDE (Integrated Development Environment) that runs on developer's computer, and can be uploaded into its physical board. The IDE uses a simplified version of C++ and the programming is supported by the Wiring language. The IDE is located on *https://www.arduino.cc/en/Main/Software*. Fig. 2 shows the actual Arduino Uno (See left).

b) Sensor: It is a DHT11 sensor which uses a capacitive relative humidity sensor and a thermistor to measure the surrounding air (environment), and spits out a digital signal on the data pin [operating range: temperature 0–50^{o}C, relative humidity 20–90%], DHT11 sensor has been considered in this study due to its compatibility with Arduino Uno, low cost, and low power capabilities, precision and accuracy rates are manageable in laboratory experimental set up, the other specifications are as follows: 3.3 – 5V power and I/O, 2.5mA max current use during conversion, Good for 20–80% humidity readings with 5% accuracy, Good for 0–50°C temperature readings ±2°C accuracy, and 1 Hz sampling rate, Fig. 2 presents the DHT11 sensor (See right), the library is available in GitHub repository on *https://github.com/adafruit/DHT-sensor-library,*

c) Communication protocol: In this study, IEEE 802.11b/g/n protocol based Arduino WiFi shield has been empowered in the experiment has been used for ease of installation, compatibility, and mobility purposes. This is a 2.4 GHz Ultra High Frequency (UHF) connectivity which is most suitable communicating protocol which caters the connectivity to a radius around 100m WiFi access point or router to get accorded to internet, Fig. 3 shows the physical Arduino WiFi shield. The followings are the most important specifications of this shield, such as operating voltage 5V which is directly supplied from the Arduino Uno, supported encryption types: WEP and WPA2 Personal, on-board micro SD slot, ICSP headers, supported by the HDG204 Wireless LAN 802.11b/g System in-Package (SiP), AT32UC3 provides an Internet Protocol stack which is capable of TCP/UDP, FTDI (Future Technology Devices International) connection enables serial communication with the 32U for ease of debugging, WiFi library comes pre-built into the Arduino IDE, and

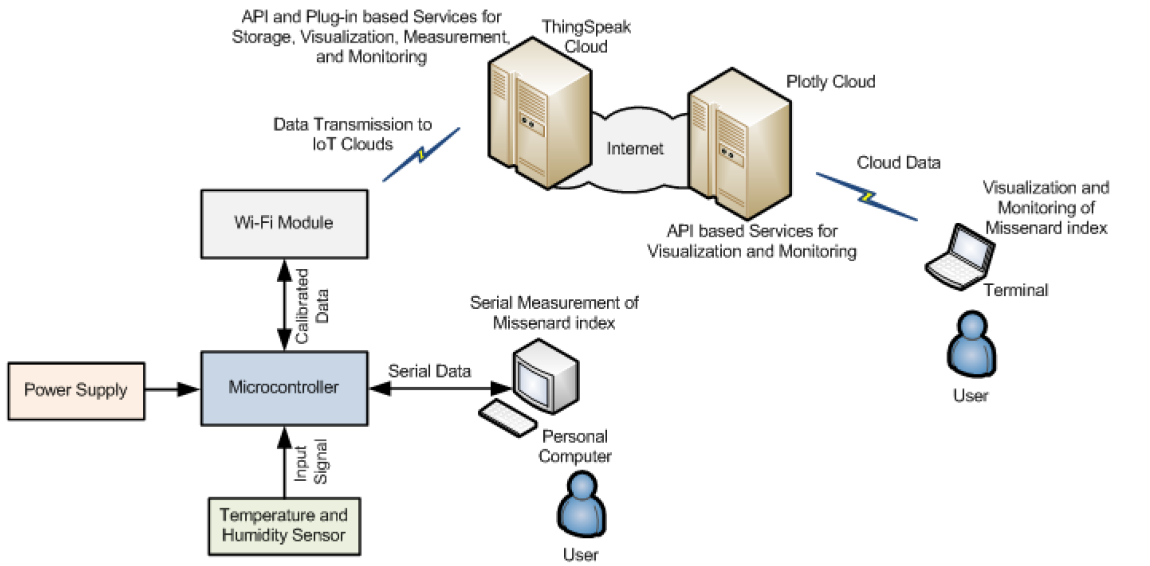

Fig. 4. System model for IoT Cloud based MISSENARD index measurement.

d) IoT Cloud interaction: Two cloud platforms have been chosen for this experiment – i) ThingSpeak and ii) Plotly. Both the clouds provide Application Programming Interface (API) based interconnectivity with the proposed system. API is a set of routines, protocols, and tools for building software applications especially in cloud platforms. This helps the developer to correlate the cloud services with the hardware for data visualization, data storage, data analytics, and triggering purposes. Plotly has made the study of graphical plotting very easy, whereas ThingSpeak provides the plug–in based facility to monitor the present value of MISSENARD index.

```
Input: DHTPIN at port 2
Input: network SSID
Input: network Password
Input: ThingSpeak API Settings
Input: ThingSpeak IP Address
Input: ThingSpeak writeAPIKey
Input: nTraces
Input: Tokens
Input: Plotly APIKey
Input: Plotly Graph Variable
Output: Missenard Index

Step 1. Initialize WiFIClient
Step 2. Serial Connection Begin at 9600 bps
Step 3. Attempt to connect to Local Wifi network
            If Connected  Local WiFi Network
                  Print: Connected to WiFi
                  Begin: DHT Sensor
            Else
                  Print: No Network Available
Step 4. Graph Variable Initialization
Step 5. Graph Variable Open Stream
Step 6. Read:  Temperature (t) in Float and Humidity (h) From DHT11 Sensor
Step 7. Convert:  MISSENARD Index = (t - (0.4 * (t - 10)) * (1 - (h/100) ))
Step 8. Set: Minimum Comfort Level and Maximum Comfort Level
Step 7. If WiFiClient Available
            Print: Update Response to Serial Monitor
Step 9. If WiFiClient is Not Connected
            Print: Disconnect from ThingSpeak Cloud
            Stop: WiFiClient
Step 10.Update ThingSpeak
             If WiFiClient Connected to ThingSpeak at Port 80
                  Print: POST /update HTTP/1.1
                  Print: Host: api.thingspeak.com
                  Print: Connection: close
                  Print: X-THINGSPEAKAPIKEY: "+writeAPIKey+"
                  Print: Content-Type: application/x-www-form-urlencoded
                  Print: Content-Length: ThingSpeak massage data length
                  Print: Data Length
            Else
                  Print: Connection to ThingSpeak failed
Step 11. Stream Data to Plotly
Step 12. Repeat to Step 6
```

Fig 5. Algorithm for sending MISSENARD index value to ThingSpeak and Plotly clouds.

ThingSpeak (https://thingspeak.com) is an open IoT data platform based on public cloud technology. ThingSpeak enables real time data collection, analysis and actuation with an Open API. With apps and plugins, data storage, visualization, monitoring and integration of user's data with a variety of third party platforms, including leading IoT platforms such as ioBridge, Arduino, Twilio, Twitter, ThingHTTP, MATLAB have been made possible. Sensor data is collected into each channel that has eight fields which can hold any type of data, three location fields, and one status field. Various apps such as, TimeControl (automatically perform actions at predetermined times with ThingSpeak app), TweetControl (listen to the Twitterverse and react in real time), React (reacts when channel data meets some certain condition), TalkBack (queue up command for user's device) improve the reaction measures [20].

Plotly (https://plot.ly) is a popular public data visualization cloud service provider. Plotly provides community, professional and enterprise data storage, visualization and analytics services to the ordinary or IoT applications. Excel, CSV and XML data formats are used to upload the data to its cloud servers. Python, R, MATLAB and Julia based APIs are implemented in Plotly. Graphics libraries such as, ggplot2, matplotlib, MATLAB chart conversion techniques empower the visualization. Among many, HDF5, SAS, SPSS, MS Access and ZIP file formats are used to temporarily store the data before uploading to cloud. Pdf, svg and eps vector exports facilities are incorporated into it. LDAP and directory integration are another pillar of huge popularity behind Plotly. Node.JS supported 3D chart framing enable user data to get suitably processed from Arduino, Raspberry Pi and Electric Imp hardware devices [20].

Fig. 6. Experiment set up for IoT based MISSENARD index measurement. Code running on IDE and serial monitor output (left), ThingSpeak cloud running (right).

The system model for the experiment is presented in Fig. 4. Initially, the microcontroller board is attached with DHT11 sensor and WiFi shield. After giving power to the board, it is connected via serial port of a desktop computer where Arduino IDE is pre installed. At the same time, ThingSpeak and Plotly clouds are made ready with specific APIs for communication with the system. Later on, an appropriate algorithm (see Fig. 5) is coded on the IDE and burned into the board. The rest is based on the algorithm and the communication that is coordinated by the WiFi shield. User sitting at the local desktop machine or remote location can access the real time information from the board and the clouds, respectively. Figure 6 shows the experimental design comprising a laptop, Arduino Uno, Arduino WiFi, a DHT11 placed over a bread board connected by wires. Figure 6 (left) shows the program running on IDE as well as the serial monitor output to its right side. This resembles to the user sitting near the desktop to view serial monitor output in Figure 4. Similarly, Fig. 6. (right) shows the ThingSpeak output resembling the user sitting on the terminal to view the IoT cloud output in Fig. 4.

4. Determination Process

The overall system architecture is shown in Fig. 7, which is based on a five-layered architecture. The layers have specific tasks to do;

a) *Physical layer* is the bottom most layer which senses temperature and relative humidity through DHT11 sensor and sends the digital signal to the upper level, i.e., conceptual layer.

b) *Conceptual layer* is comprised of microcontroller board which receives the digital data from physical layer and does decision making stuffs and perform respective actions. Microcontroller calculates the MISSENARD index from relative humidity and temperature obtained from the sensor using equation (1) as described later. The index data along with temperature and relative humidity are later on passed towards the personal computer (PC) for serial monitoring through of MISENARD index through next higher level using USBasp. The information has another outlet to move forward to internet.

c) *Communication layer* performs information passing tasks that were obtained from conceptual layer to dissemination layer. USBasp and WiFi protocols are efficiently used to act as information pass maker. USBasp is an in circuit programming device to incorporate with the microcontroller board burning up process with help of serial transmission protocol inbuilt.

d) *Internet layer* holds back jobs so that internet can be used to transmit index term perfectly. This layer is the most vital among three which acts as the backbone of the system. Plotly and ThingSpeak clouds act into this layer.

e) *Application layer* is the user oriented layer designed to exercise the needs to graphical visualization, real–time monitoring, and statistical analytics in fully automated manner.

$$ET = T_s - 0.4*(T_s - 10)*(1-\frac{H}{100}), \text{ for wind speed } \leq 1\text{m/s} \quad (1)$$

$$ET = 37 - \frac{37 - T_s}{0.68 + 0.00014*H + \frac{1}{1.76 + 1.4*V^{0.75}}} - 0.29*T_s(1-\frac{H}{100}), \text{ for wind speed } \geq 1\text{m/s} \quad (2)$$

User interacts with just a few clicks and buttons to materialize the expected outcome from the system in real time. Data storage was made possible with inbuilt services provided by the ThingSpeak and Plotly which could be used at any point of time in future. The overall system was programmed and simulated on a Personal Computer (PC). The specifications of the PC are: 32 bit Ubuntu 14.04 LTS, Intel core i5 3230M, 2.6GHz, 4GB RAM. Simulation software used was Arduino IDE 1.0.3. Wiring programming language was used to code the program. The formula for MISSENARD index is given in equation (1–2).

The parameters in the above equations are: ET = MISSENARD Index (unit), T_s = temperature in ^{O}C, H = relative humidity (%) and V = wind velocity of room air (m/sec). According to the report published by the ASHRAE standard 55-2013, the wind speed should be comfortable at $\leq$1m/s in indoor situation (ASHRAE, 2013) (Awbi, 2008). Hence, I have chosen equation (1) as it is appropriate for indoor environment. Average comfort level for MISSENARD index lies within 18 to 22 units. Temperature and relative humidity sensor fetches the environment and sends the raw data to the microcontroller module. The module receives data from sensor and processes according to an embedded program. While finding out the exact information, microcontroller module uses equation (1). Further, the WiFi module linked to the microcontroller is initialized and sets its connectivity to the nearby available network. Once the connection is set microcontroller instructs the WiFi module to transmit the information to ThingSpeak and Plotly IoT clouds based on their respective APIs and Plug–ins through internet. ThingSpeak and Plotly respond in form of acknowledgements and store the received data into the cloud servers. User can visualize and monitor the data in real–time basis. Moreover, the statistical analysis as well as data exportation can be done by the user as and when required in future.

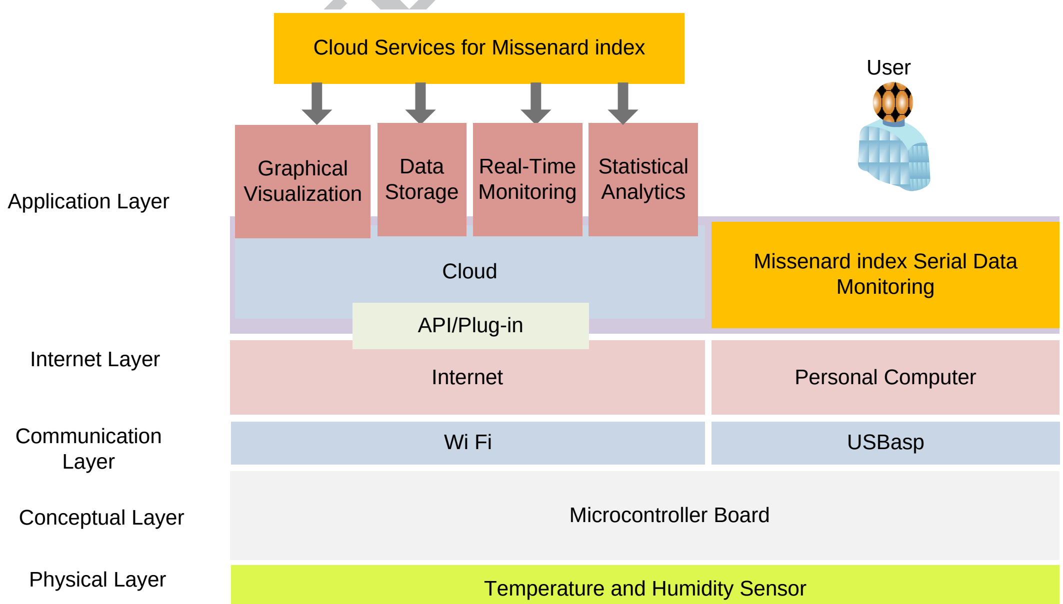

Fig. 7. Architecture for IoT based MISSENARD index measurement.

5. Results

The results are segregated into three parts – a) ThingSpeak output, b) Plotly output, and c) Serial output as presented below. The actual experiment was carried out for 24 hours. The snaps were taken on various time gaps.

a) ThingSpeak output: Fig. 8 represents the output from ThingSpeak cloud. Top left of Fig. 7 is a plug–in based on Google Gauge, showing MISSENARD index (ET index). Top right illustrates the plug–in of MISSENARD index (red) in comparison with relative humidity (%) (green), temperature (^{o}C) (blue), and two straight lines: maximum comfort level (black) and minimum comfort level (yellow). Field chart 1 and 2 are API based indications measuring temperature and relative humidity with respect to time (bottom left and right), respectively. The MISSENARD index lies just above the comfort level on the day of experiment.

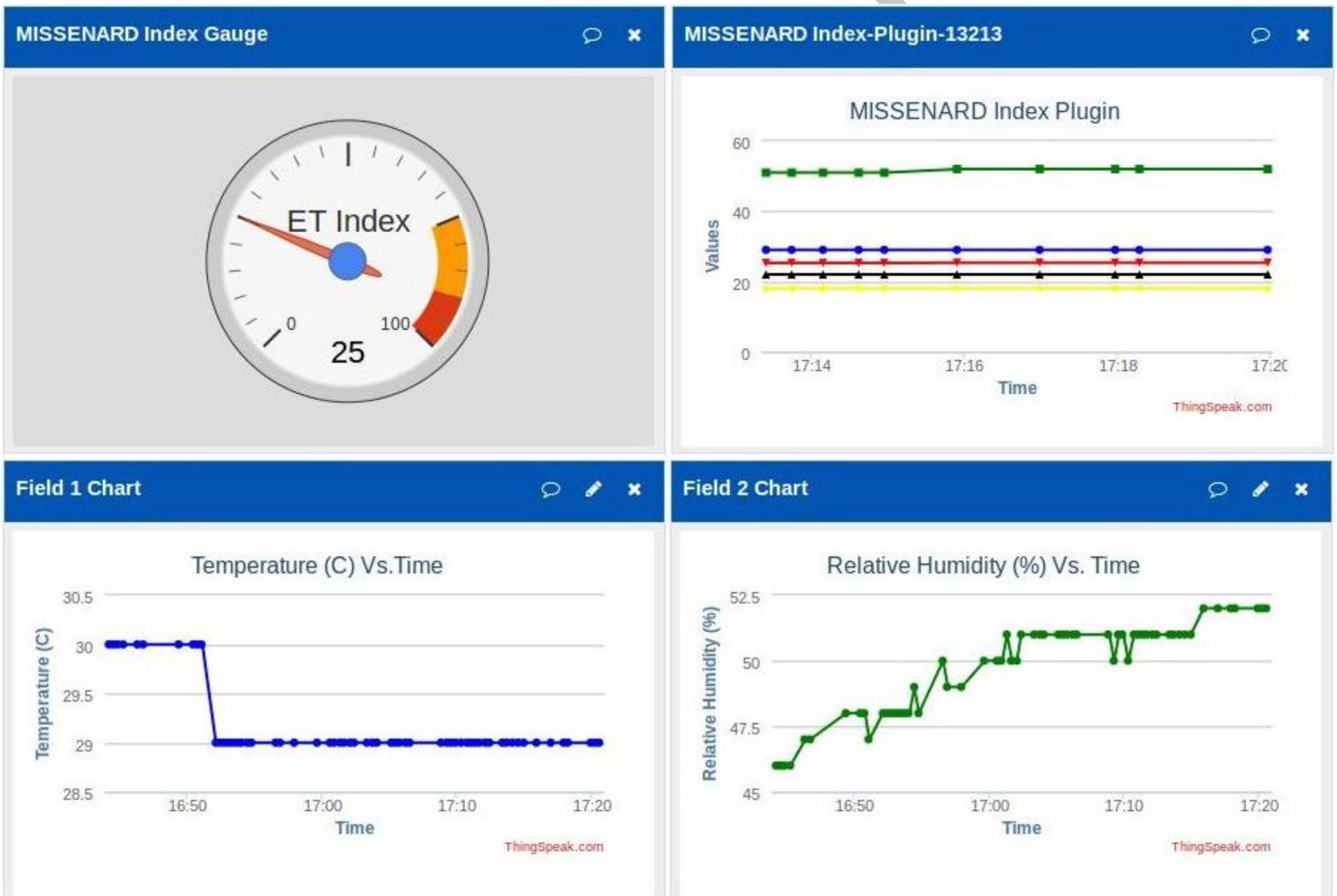

Fig. 8. Output from the ThingSpeak based IoT cloud platform.

The code fragments for the plug-ins are shown below.
MISSENARD index gauge plug in 13226
<iframe width="450" height="260" style="border: 1px solid #cccccc;" src="http://api.thingspeak.com/plugins/13226" ></iframe>
MISSENARD index plug in 13213
<iframe width="450" height="260" style="border: 1px solid #cccccc;" src="http://api.thingspeak.com/plugins/13213" ></iframe>

b) Plotly output: Fig. 9 shows the bar chart (top) and histogram (bottom) of MISSENARD index monitoring from the Plotly cloud. The screen shots were taken on 10th May, 2015 during 14.10 to 14.25 P.M. The Y–axis presents the value (amplitude) while the X–axis is time in *hour:minute* format. The parameters are shown on the graphs besides MISSEANRD index. MISSENARD index was always above the comfort level during the time of experiment. The bar graphs are used to display data by using a horizontal or vertical rectangular bar that levels off at the appropriate level. Among other characteristics, bar

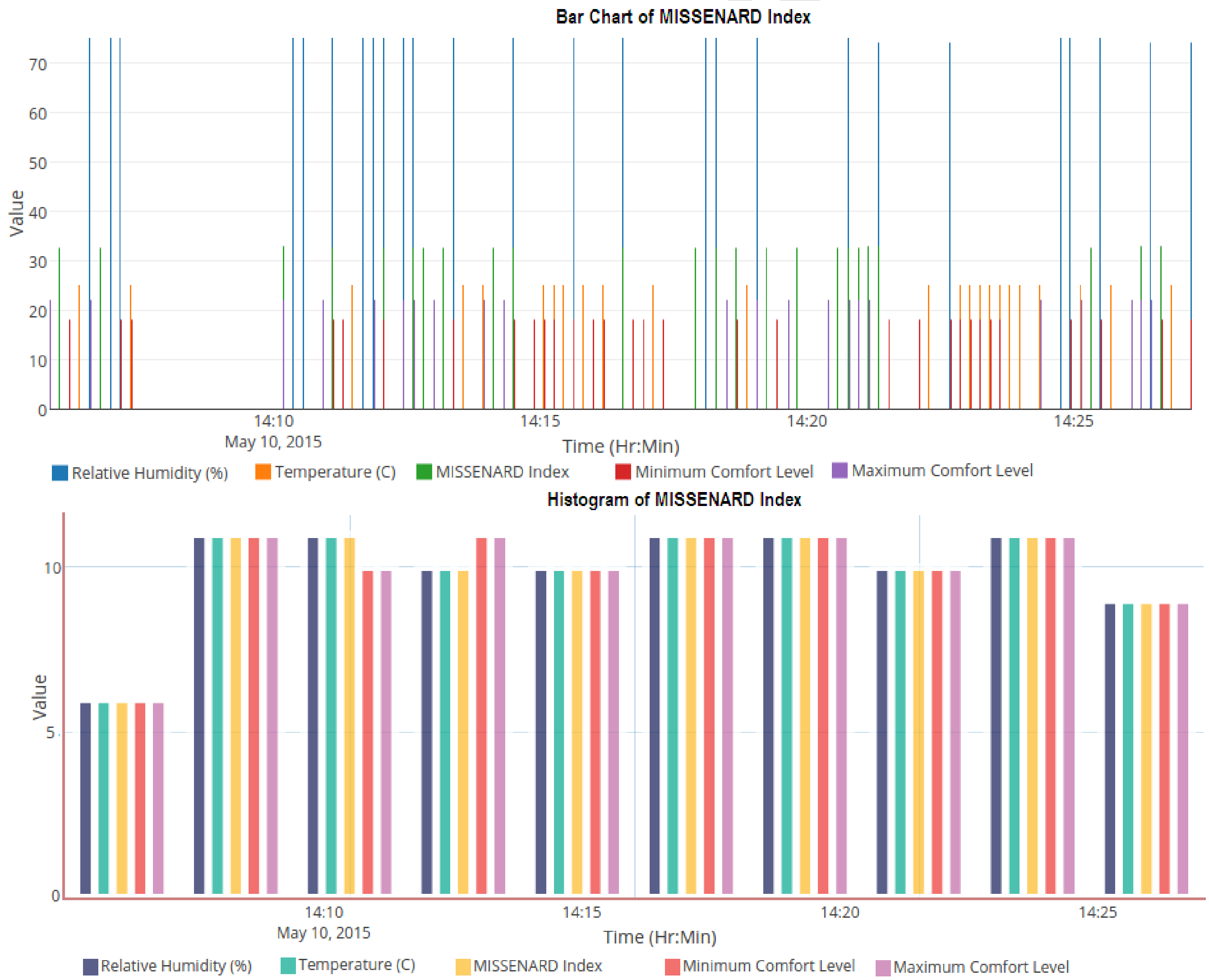

Fig. 9. Output from the Plotly based IoT cloud platform.

graph provides facility for comparing quantities in different categories while showing their relationships. Similarly, histogram charts are used to assess the current state of a system while comparing this state with the historical data and possibly makes the inferences about how the system is likely to get evolved. Due to the stated benefits, bar and histogram charts are used in this study. The data acquisition was done during 10th May, 2015. It can be seen that the bar chart shows some data lost between the beginning and the first timestamp - 14:10 May 10, 2015. This has happened due to the momentous connection loss and other system related delays.

c) Serial output: Fig. 10 presents the serial data output from the port into the desktop computer which was attached to the system. The output clearly demonstrates the connection establishments with WiFi network, available in local vicinity; later on connecting the system with the REST servers of ThingSpeak and Plotly based IoT clouds for preparing of start of transmission of data to the clouds.

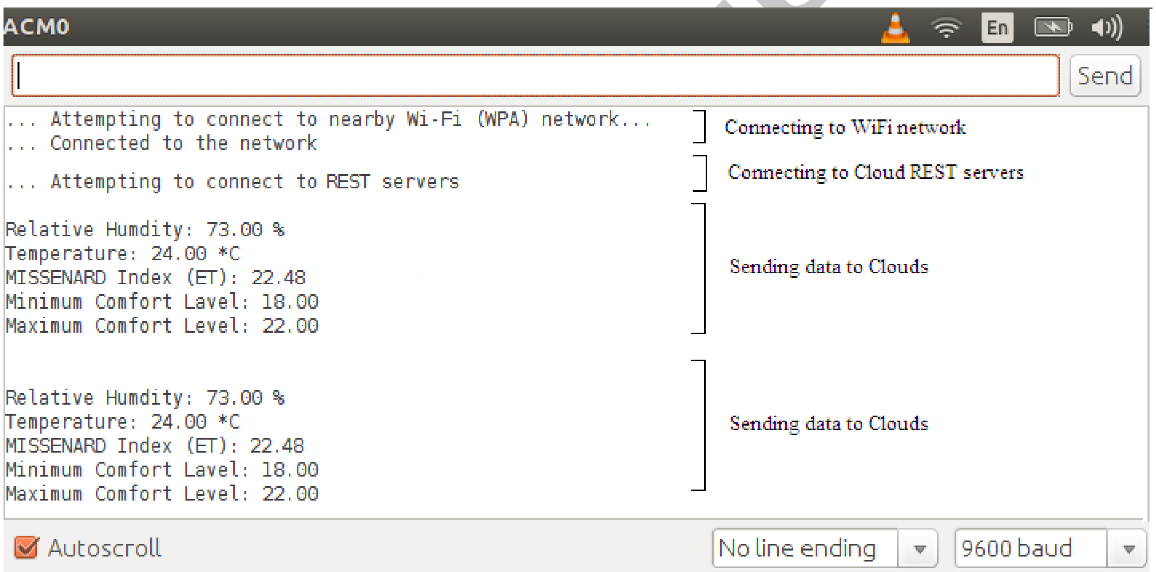

Fig. 10. Output from the serial port.

6. Conclusions

In this paper, I have proposed an Internet of Things based novel approach which comprises real–time integration with cloud through APIs to monitor the MISSENARD index. Physical implementation was done and the results obtained from the system clearly indicate the level of thermal comfort in terms of MISSENARD index. Plug–in based approach was successfully executed with the involvement of ThingSpeak and Plotly, i.e., multiple clouds together. This smart measurement system advocates the monitoring of thermal comfort in terms of MISSENARD index resulting direct benefits to human lives towards comfort level. IoT based implementation to find out MISSENARD index is an unforeseen methodology which is used for the first time for the measurement and monitoring purpose that will backup the scientific community involved in measurement science. Besides, this system is capable enough to run anywhere, be it indoor or outdoor while consumes very less power. The system size is reduced to palm which is why suitable to put in pocket of user. Industries which are related to the development of consumer electronics products and appliances would be interested into producing this system to enhance the smartness of human comfort. The proposed system can also be modified to generate alert messages to the user to notify about the hazard present in form of comfort level, prior getting into the environment. Continuous transmission of dataflow might cause burden in the server memory. Solutions should be sought out to culminate this big data problem in near future.

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Highlights

- A novel methodology to measure MISSENARD index for indoor occupants is proposed.
- Multiple IoT cloud services are used to monitor MISSENARD index remotely.
- Real-time visualization and analytics services of IoT clouds are facilitated.
- Open source hardware platforms are incorporated to measure thermal comfort.