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Environmental Monitoring Using Sense HAT based on IBM Watson IoT Platform

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Abstract – *In recent years, with the introduction of new emerging technologies like IoT, Cloud Computing a new phase of machine-to-machine interaction comes into limelight. In everyday life smart devices like Internet TV, smart-phones, sensors can be connected intelligently through internet using Internet of Things (IoT). The future of IoT based systems need a huge amount of data to be handled and processed where the cloud will play a very vital role. Cloud computing is generalized as a delivery of hosted services like servers, databases, analytics and more over the internet.*

The main aim of the project is to build a system which will sense the environmental parameters and monitor it in real time and sends the data to a cloud that can be further used for analysis. This project describes a complete infrastructure for environmental monitoring, which is based on a cloud architecture. Raspberry Pi is connected to Sense HAT which records the real time data and sends it to IBM Cloud for storage. Cloud data can be accessed in real time through smart-devices and downloaded for further analysis. The IoT platform used in this project is IBM Watson. Sense HAT contains Temperature, Humidity and Barometric pressure sensors inbuilt in it.

***Key Words*: Internet of Things (IoT), Cloud Computing, Raspberry Pi, Sense HAT, IBM Cloud, IBM Watson.**

1. INTRODUCTION

The development of Cloud Computing can be used to store data to a cloud which can be accessed from any parts of the world. With the advancement of sensor technology different sensors are incorporated in a single module to make it more efficient and compact. The Sense HAT is an add-on board for Raspberry Pi [15] which contains different sensors including temperature, humidity and pressure. Environmental Monitoring [2] aims at storing the real time data collected from sensors and processing that data for predictive analytics. IBM Cloud formerly known as IBM Bluemix is a cloud platform as a service which supports several programming languages and services as well as integrated DevOps to build, run, deploy and manage application on the cloud. Node-RED is a flow-based programming for IoT platform. In this project, Node-RED is used for wiring together hardware devices, APIs and online services. The data from the sensors are saved in the Cloudant NoSQL DB which can be further processed for Data Analysis. IBM Watson is a platform where all these above mentioned components can be found. IBM's Watson is at the forefront of a new era of computing which is known as cognitive computing [20].

2. INTERNET OF THINGS (IoT)

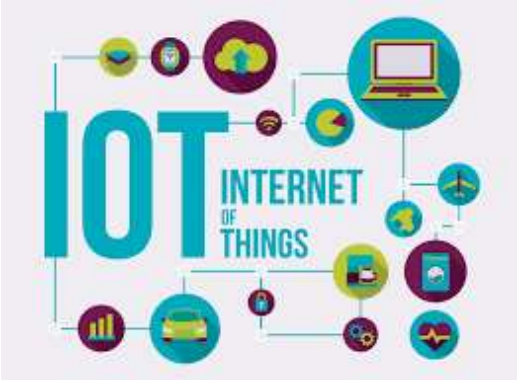

Fig-1: IoT

The Internet of Things [3] [5] is a network of physical objects – vehicles, machines, home appliances, and more – that use sensors and APIs to connect and exchange data over the Internet. The IoT depends on a whole host of technologies – such as application programming interfaces (APIs) that connect devices to the Internet. Other key IoT technologies are Big Data management tools, predictive analytics, AI and machine learning, the cloud, and radio-frequency identification (RFID) [7]. Cloud-based IoT platforms and architecture connect the real and virtual worlds. They help companies manage IoT device connectivity and security – as well as collect device data, link devices to backend systems, ensure IoT interoperability, and build and run IoT applications. Smart devices generate a massive amount of IoT data that needs to be analysed and leveraged in real time. This is where predictive and Big Data analytics [8] come into play. Machine learning is also used to add context to data – and trigger actions without human intervention. In manufacturing, the IoT becomes the Industrial Internet of Things (IIoT) – also known as the Industrial Internet or Industry 4.0. The IIoT uses machine to machine (M2M) technology [4] to support everything from remote monitoring and telemetry to predictive maintenance. IoT involves extending internet connectivity beyond standard devices, such as desktops, laptops, smartphones and tablets, to any range of non-internet-enabled physical devices and everyday

objects. Embedded with technology, these devices can communicate and interact over the internet, and they can be remotely monitored and controlled.

3. IBM WATSON

Fig-2: IBM Watson IoT Platform

Powered by the latest innovations in machine learning, Watson lets us learn more with less data. We can integrate AI into our most important business processes, informed by IBM's rich industry expertise. We can build models from scratch, or leverage our APIs and pre-trained business solutions. No matter how we use Watson, our data and insights belong to us – and only us. IBM Watson [1] [9] is a system based on cognitive computing. Cognitive computing is a technique which is a mixture of different techniques such as machine learning, natural language processing, artificial intelligence, human interaction, reasoning etc. Machine learning [21] is a technique where system tries to get better day by day by learning new things, just like we humans do. Natural language processing [19] is a way in which human can interact with computers with a language we speak daily. Artificial intelligence [18] is the way by which computers perform some tasks which actually need human intelligence. Human interaction is the way in which computers can interact with humans, yes we can say natural language processing as a subset of human interaction. Reasoning is the part where system actually think like humans & produces answers to the questions. So, overall IBM Watson is made up of these techniques. IBM Watson can think like us, it can learn & yes, it gives answers to our questions.

3.1 IBM Cloud

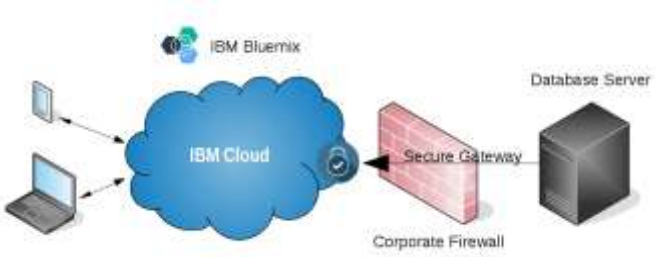

Fig-3: IBM Cloud

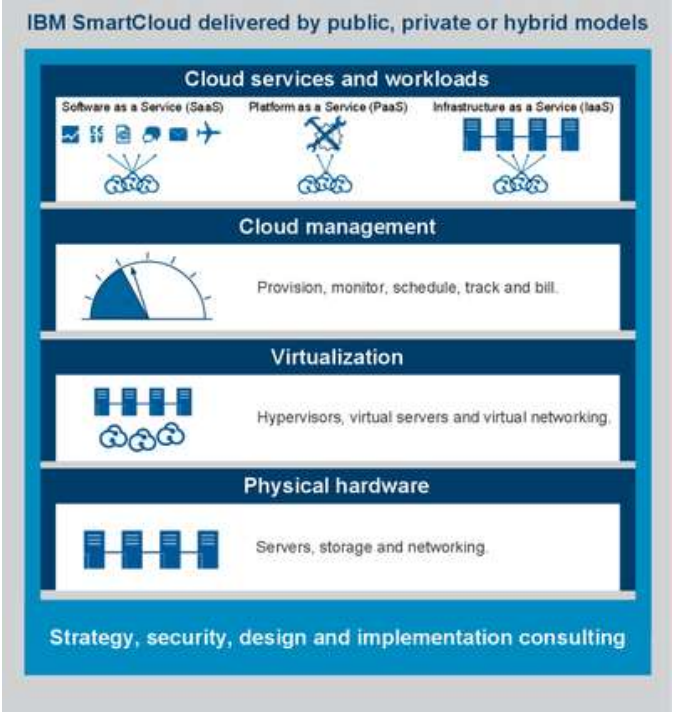

Fig-4: IBM Cloud Services

IBM Cloud formerly known as IBM Bluemix [11] is a cloud platform as a service which supports several programming languages and services as well as integrated DevOps to build, run, deploy and manage applications on the cloud. IBM Cloud is a suite of cloud computing services from IBM that offers both platform as a service (PaaS) and infrastructure as a service (IaaS). With IBM Cloud IaaS, organizations can deploy and access virtualized IT resources such as compute power, storage and networking over the internet. For compute, organizations can choose between bare-metal or virtual servers. With IBM Cloud PaaS, which is based on the open source cloud platform Cloud Foundry, developers can use IBM services to create, manage, run and deploy various types of applications for the public cloud, as well as for local

or on-premises environments. IBM Cloud supports various programming languages, such as Java, Node.js, PHP and Python and extends to support other languages. IBM Cloud platform supports access to other IBM tools and services including IBM Watson and IBM Cloud Functions for server-less computing as well as those from third-party vendors.

The IBM Cloud Catalog lists over 170 services across categories, including:

- **Compute:** Offers various compute resources, including bare-metal servers, virtual servers, server-less computing and containers, on which enterprises can host their workloads.
- **Network:** Provides cloud networking services, such as a load balancer, a content delivery network (CDN), virtual private network (VPN) tunnels and firewalls.
- **Storage:** Offers object, block and file storage for cloud data.
- **Management:** Provides tools to manage and monitor cloud deployments, such as those for log analysis, automation and Infrastructure as Code (IaC).
- **Security:** Includes services for activity tracking, identity and access management and authentication.
- **Data management:** Provides SQL and NoSQL databases, as well as data querying and migration tools.
- **Analytics:** Offers data science tools such as Apache Spark, Apache Hadoop and IBM Watson Machine Learning, as well as analytics services for streaming data.
- **Artificial Intelligence (AI):** Uses IBM Watson to deliver services such as machine learning, natural language processing and visual recognition.
- **Internet of things (IoT):** Includes the IBM IoT Platform, which provides services that connect and manage IoT devices, and analyzes the data they produce.
- **Mobile:** Enables a development team to build and monitor mobile applications and their back-end components.
- **Developer tools:** Includes a command-line interface (CLI), as well as a set of tools for continuous delivery, continuous release and application pipelines.
- **Blockchain:** Provides IBM's Blockchain Platform, a software-as-a-service offering to develop apps, enforce governance and monitor a Blockchain network.
- **Integration:** Offers services to integrate cloud and on-premises systems, or various applications, such as API Connect, App Connect and IBM Secure Gateway.
- **Migration:** Provides tools to migrate apps to the cloud, such as IBM Lift CLI and Cloud Mass Data Migration.
- **VMware:** Enables the migration of VMware workloads into the cloud.

3.2 Node-RED

Fig-5: Node-RED

Node-RED [12] [13] is a programming tool for wiring together hardware devices, APIs and online services in new and interesting ways. Node-RED provides a browser-based flow editor that makes it easy to wire together flows using the wide range of nodes in the palette. Flows can be then deployed to the runtime in a single-click. JavaScript functions can be created within the editor using a rich text editor. A built-in library allows to save useful functions, templates or flows for re-use. The light-weight runtime is built on Node.js, taking full advantage of its event-driven, non-blocking model. This makes it ideal to run at the edge of the network on low-cost hardware such as the Raspberry Pi as well as in the cloud. With over 225,000 modules in Node's package repository, it is easy to extend the range of palette nodes to add new capabilities. The flows created in Node-RED are stored using JSON which can be easily imported and exported for sharing with others. An online flow library allows us to share our best flows with the world.

3.3 Cloudant NoSQL DB

Fig-6: Cloudant NoSQL DB

Cloudant [14] is a highly scalable and performant JSON database service that moves application data closer to all the places it needs to be for uninterrupted data access, offline or online. Cloudant is ISO27001, SOC 2 Type 2 compliant and HIPAA ready. All data is encrypted over the wire and at rest with optional user-defined key management through IBM Key Protect. Cloudant also offers an EU-managed service, that ensures all data and operations are handled solely by EU citizens. Available in all IBM Cloud regions and 55+ data centers across the world, Cloudant can easily be set up for disaster recovery between continents or scaling an app for a global release through a horizontal scaling architecture that can handle millions of users and terabytes of data to grow seamlessly alongside business. All Cloudant instances are deployed on clusters that span availability zones in regions that support them, for added durability at no extra cost. Cloudant is a non-relational, distributed database service of the same name. Leverage a flexible JSON [17] schema and powerful API that is compatible with Apache CouchDB, enabling to access an abundance of language libraries and tools to rapidly build new applications and features. Cloudant's service provides integrated data management, search, and analytics engine designed for web applications.

4. OVERALL ARCHITECTURE

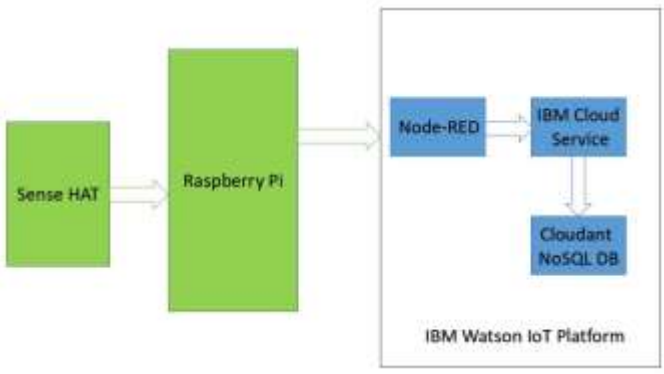

Fig-7: Overall System Architecture

Figure 7 describes the overall system architecture of the Environmental Monitoring by using Sense HAT based on IBM Watson IoT platform. Sense HAT is an add on board to Raspberry Pi which contains several sensors including Temperature, Pressure, Humidity, Accelerometer, Gyroscope, Magnetometer, etc. Sense HAT collects the real time data and sends it to Raspberry Pi via GPIO pins. Then the data is processed through Node-RED application and the real time data passes through the gateway in the IBM Cloud. The Cloud data then gets stored into Cloudant NoSQL DB for further data analysis.

4.1 Raspberry Pi

Fig-8: Raspberry Pi

The Raspberry Pi [16] is a low cost, credit-card sized computer that plugs into a computer monitor or TV, and uses a standard keyboard and mouse. It is a capable little device that enables people of all ages to explore computing, and to learn how to program in languages like Scratch and Python. It's capable of doing everything like a desktop computer does, from browsing the internet and playing high-definition video, to making spreadsheets, word-processing, and playing games.

The Raspberry Pi 3 Model B+ is the latest product in the Raspberry Pi 3 range.

Specifications:

- Broadcom BCM2837B0, Cortex-A53 (ARMv8) 64-bit SoC @ 1.4GHz
- 1GB LPDDR2 SDRAM
- 2.4GHz and 5GHz IEEE 802.11.b/g/n/ac wireless LAN, Bluetooth 4.2, BLE
- Gigabit Ethernet over USB 2.0 (maximum throughput 300 Mbps)
- Extended 40-pin GPIO header
- Full-size HDMI
- 4 USB 2.0 ports
- CSI camera port for connecting a Raspberry Pi camera

- DSI display port for connecting a Raspberry Pi touchscreen display
- 4-pole stereo output and composite video port
- Micro SD port for loading operating system and storing data
- 5V/2.5A DC power input
- Power-over-Ethernet (PoE) support (requires separate PoE HAT)

4.2 Sense HAT

Fig-9: Sense HAT

The Raspberry Pi Sense HAT [10] is an add-on to Raspberry Pi which is attached on top of the Raspberry Pi via the 40 GPIO pins (which provide the data and power interface) to create an 'Astro Pi'. The Sense HAT has several integrated circuit based sensors that can be used for many different types of experiments, applications, and even games.

Technical Specifications:

- Gyroscope – angular rate sensor: ±245/500/2000dps
- Accelerometer - Linear acceleration sensor: ±2/4/8/16 g
- Magnetometer - Magnetic Sensor: ±4/8/12/16 gauss
- Barometer: 260 – 1260 hPa absolute range (accuracy depends on the temperature and pressure, ±0.1 hPa under normal conditions)
- Temperature sensor (Temperature accurate to ± 2 °C in the 0-65 °C range)
- Relative Humidity sensor (accurate to ±4.5% in the 20-80%rH range, accurate to ± 0.5 °C in 15-40 °C range)
- 8x8 LED matrix display
- Small 5 button joystick

5. INTERFACING BETWEEN RASPBERRY PI AND SENSE-HAT

Raspbian is a Linux based operating system for Raspberry Pi. After installing Raspbian in Raspberry Pi, the Sense HAT module needs to be attached with the GPIO pins of Raspberry Pi.

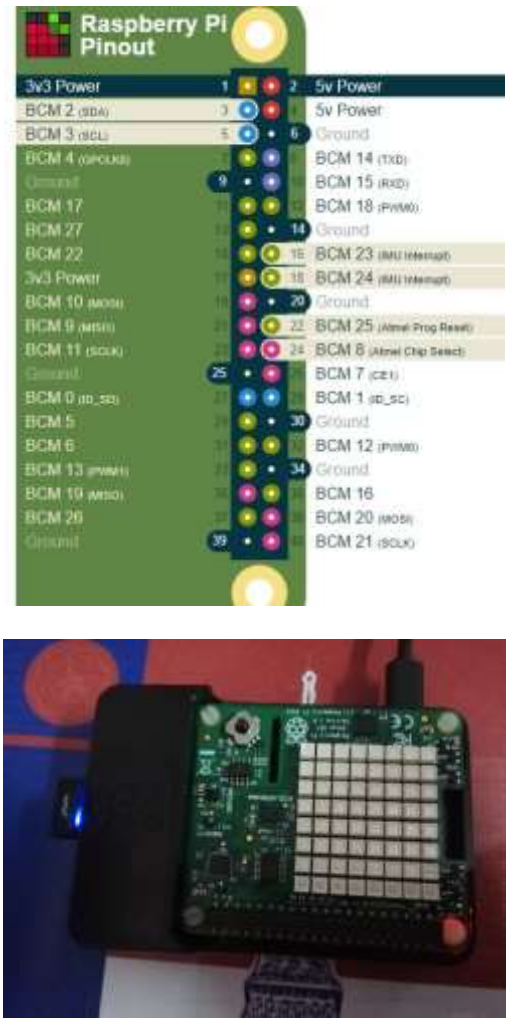

Fig-10: Interfacing between Raspberry Pi and Sense HAT

The Sense HAT is an add-on board for Raspberry Pi comprising of a 8×8 RGB LED matrix, a five-button joystick and the following sensors: Gyroscope, Accelerometer, Magnetometer, Temperature, Barometric pressure and Humidity. The shift register driving the LED Matrix is a LED2472G connected via an Atmel ATTINY88 communicating via i2c at address 0x46 with the Pi. The Multi-Directional SKRHABE010 Switch/Joystick is similarly controlled. The sensors themselves also operate over the i2c bus. The IMU (Accelerometer and Magnetometer) through a LSM9DS1 found at i2c address 0x1c(0x1e) and 0x6a(0x6b), with Interrupts on the ATTINY88. Environmental sensors

are represented by a LPS25H Pressure/Temperature sensor at address 0x5c and by a HTS221 Humidity/Temperature sensor at 0x5f on the i2c bus. In addition, the Atmel chip can be reprogrammed via the SPI interface. In order to work correctly, the Sense HAT requires an up-to-date kernel, I2C to be enabled, and a few libraries to get started. Installing the sense-hat package will allow the python module to control the Raspberry Pi Sense HAT. "sense-hat" is the officially supported library for Sense HAT, it provides access to all of the on-board sensors and the LED matrix.

6. RESULTS

Figure 11 describes the overall system design which depicts the flow of sensor data from Sense HAT to IBM Cloud via Raspberry Pi and finally gets stored in the Cloud DB.

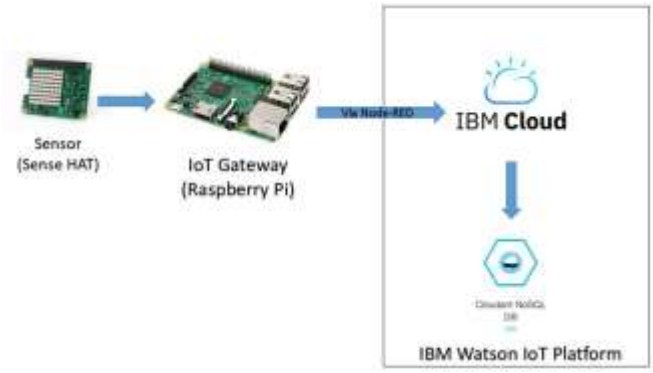

Fig-11: Overall System Design

Step 1: Sense HAT sense the data and sends to Raspberry Pi via GPIO pins.

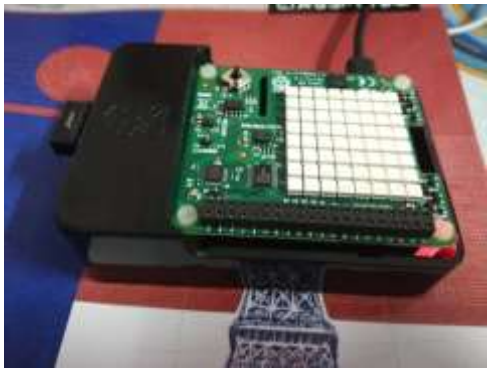

Fig-12: Sense HAT with Raspberry Pi

Step 2: Raspberry processes the data through Node-RED application via JSON Format.

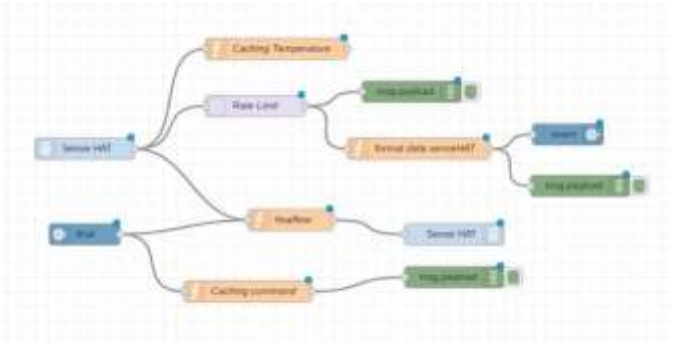

Fig-13: Node-RED Schema

Step 3: The data then passes through IBM Cloud service.

Fig-14: IBM Cloud Service

Fig-15: IBM Cloud Overview

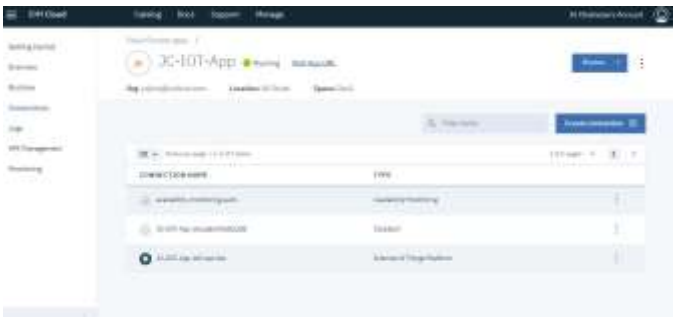

Fig-16: IBM Cloud Connections

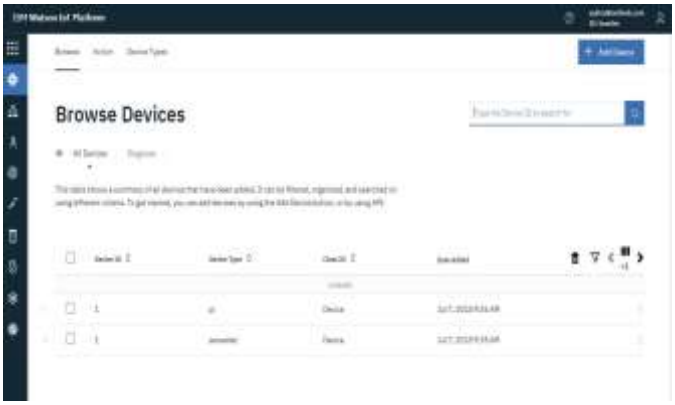

Fig-17: Devices registered in IBM Watson IoT Platform

Step 4: From IBM Cloud the data (temperature, humidity) then gets stored into the Cloudant NoSQL DB (in JSON format) for monitoring.

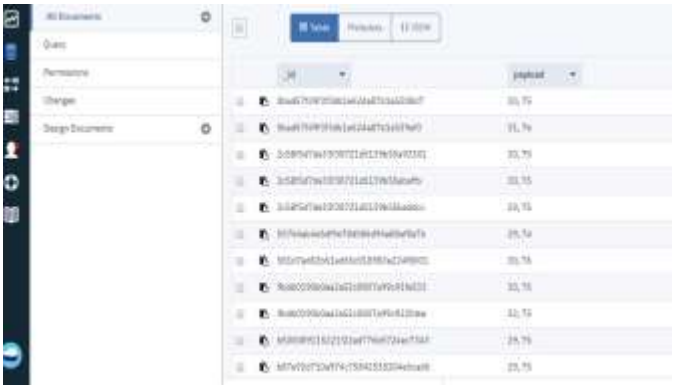

Fig-18: Received Output store in Cloudant NoSQL DB

Step 5: Figure 18 shows the real time data like temperature and humidity which are stored into the Cloud DB.

7. CONCLUSION AND FUTURE WORK

7.1 Conclusion

Environmental Monitoring using IoT [6] has been experimentally established to work satisfactorily by connecting the different modules of IoT into a single platform (IBM Watson). The designed system not only monitors the real time data but also stores it into the Cloud DB for further analysis. This will eventually help to determine the different environmental conditions.

7.2 Future Work

The data stored into the Cloud DB can be used in data analytics which will eventually lead to predictive analysis of Environmental factors.

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