RV Journal of Science Technology Engineering Arts and Management

From Editorial Desk.....

The Internet of Things (IoT) is an emerging area of technical, social, and economic significance. Industrial and Consumer products, sensors, and other objects are combined with Internet connectivity and data analytics capabilities that transform the way we work and live. Projections for the impact of IoT on the Internet and economy are impressive, with some anticipating as many as 100 billion connected IoT devices and a global economic impact of more than $11 trillion by 2025. However, the IoT raises significant challenges that could stand in the way of realizing its potential benefits. News headlines about the hacking of Internet-connected devices, surveillance concerns, and privacy fears already have captured attention. Technical challenges remain and new policy, legal and development challenges are emerging. Towards this endeavour, RV College of Engineering is bringing out its First Edition of the Journal ***RV Journal of Science Technology Engineering Arts & Management (RVJSTEAM)***. The Journal provides an opportunity for researchers, faculty and students to publish articles. This edition of the journal covers articles in the field of IoT, Sensors & Systems and its allied areas.

Out of the twenty papers received, eleven papers are accepted for the publication. The manuscripts cover application of edge computing and edge intelligence in the context of IIoT, Internet of Things enabled monitoring of energy meters, vibration of machines and cutting tool temperature, biomedical waste management system, LPG leakage detection, water leakage detection, smart farming, an algorithm for Genomic classification for evaluation of abnormalities and a guide to IoT solution development.

We thank the Editorial Board, Reviewers and Authors for their contribution in bringing out the first issue of the Journal.

We strive to maintain the quality of manuscripts in the journal.

Dr K N Subramanya
Principal, RVCE, Bengaluru, India
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Edge Intelligence Models for Industrial IoT (IIoT)

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Abstract

This paper reports the application of edge computing and edge intelligence in the context of Industrial Internet of Things. The essentials of edge computing, role of edge intelligence and a few models and cases which make use of Industrial Internet of Things environment are presented. The linkages between edge intelligence and its importance in the field of Artificial Intelligence and Machine Learning based solutions infer that the use of edge intelligence not only decreases the time of data processing but also provides data security.

Keywords: *Edge intelligence, Industrial Internet of Things, Edge Computing, Artificial Intelligence, Machine Learning*

1.0 Introduction

Industrial Internet of Things (IIoT) is a domain of machine to machine (M2M) and industrial communication technology. It is an automation application which provides a better picture of manufacturing process and results in efficient and sustainable production [1]. IIoT find opportunities in automation, optimization, intelligent manufacturing, smart controls, on-demand service model and so on. IIoT can be defined as things enabling the operations of an industry in an intelligent way with advanced data analytics for transformational business outcomes. IIoT combines Operational Technology (OT) and Information Technology (IT). IIoT is adopted by industries because of increased productivity and efficacy through smart and remote management.

IIoT is designed for things that are bigger than general IoT devices like smartphones. It connects devices like industrial engines, power-grids, sensor with clouds, etc. over the network [2]. These devices are connected through a software designed for communication which can instantly collect, transfer, and analyze the data. IIoT applications require relatively small throughput per node and connects large number of devices to the Internet at low cost. These devices have limited hardware capabilities and energy resources that results into a greater need for latency, energy efficiency, cost, reliability and security/privacy. IIoT uses fixed infrastructure-based network that are best applicable for communication and coexistence needs [3].

Some of the challenges faced by IIoT include energy efficiency as the devices need to run for a long period of time without battery replacement, real-time

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performance as the applications require an immediate processing of data and interoperability due to a large number of devices that need to coexist.

1.1. Salient features of IIoT

a. Connectivity: connects devices to the Internet with low cost, uses sensors to collect data for faster processes for better efficiency resulting in lesser expenses for a product or service
b. Energy efficiency: adopts Energy harvesting to increase the battery life of the sensors
c. Operational efficiency: uses real-time data from the sensors for the processes such as monitoring to enhance the efficiency and reducing the energy costs as well as human interventions.
d. Improved Productivity: smart factory allows getting real-time task level data which is continuously generated and standardized for performing a detailed analysis of factory performance. The data generated helps supervisors to easily identify the problematic areas to make decisions in order to meet the continuous needs of the production lines.
e. Downtime reduction: all the data obtained can be used to reduce the downtime during maintenance, assets unavailability, and unavailability of human resources within the factory.
f. Maximization of asset utilization: helps in having good control on the equipment and machinery of a business and achieve proficiency through increased efficiency and productivity, reduced costs on operations and increased customer experiences
g. Safety and security: improves safety at the workplace and protects from physical threats with the help of sensors and video cameras used for equipment monitoring.
h. Quality control: the data collected for IIoT helps to automate the process of quality control.

1.2. Edge computing and its implications

Edge computing has gained more attention with its reduced data transmissions, improved service latency, and reduced overhead on cloud computing. It is needed to make real-time decisions independently within milliseconds. Cloud services and IoT devices are relieved from computation with edge computing. It is used in IoT based application because of the following reasons [4]:

a. Latency minimization: Edge computing guarantees timely delivery of services. It can fulfil the QoS requirements of delay-sensitive IoT applications.
b. Network management: Edge computing effectively utilizes network resources. It is the necessary feature for IoT applications.
c. Cost optimization: Deploying optimal number of nodes at proper locations can reduce capital significantly. Deploying edge nodes optimally can minimize the operations costs.

d. Energy management: There is a need to have control over energy management. Applications that use power harvesting guarantees scalability, cost efficiency, and avoid frequent battery replacement.
e. Resource management: Service-level objectives can be met by optimal computational resource management. This is done by resource coordination, resource estimations and efficient workload allocations.
f. Data management: The IoT devices generate a large amount of data which need to be managed efficiently with time. Edge computing requires an efficient data management mechanism.

Applying edge computing in IIoT results in coexistence of several configurations. It consists of edge nodes placed to monitor applications, routers to forward the packets over the network, and interfacing routers between IIoT and the Internet [5]. Edge devices can capture the streaming data to rapidly analyze and process data. It increases the productivity and implementing inferential capabilities for edge devices is difficult [4]. An edge device provides real time data analysis. The latency is reduced when the data is analyzed at the place of data generation. Edge devices minimize the bandwidth requirements and costs as the data is locally analyzed. The local analysis of data also results in an effective decision making.

1.3 Edge Intelligence

Edge intelligence refers to the domain where the edge devices can collect, communicate, generate, and analyze data in near real-time [6]. Some of the edge devices include sensors, navigation systems, autonomous cars and so on. With edge intelligence, data need not be moved. It can be instantly analyzed for decision making without having to transfer it across different locations. It is flexible and efficient in data analyzing. An intelligent edge follows the ease of SQL combined with industry tools to analyze a large volume of data from varying number of devices. The components of edge intelligence are [6]:

i. Connectivity: Intelligent edge device can connect to any network that can generate and exchange data.
ii. Computing: Intelligent edge device needs local computing resources for real time data analysis.
iii. Controllability: Intelligent edge device uses databases to provide intelligent decisions in case of device controls, dynamic changes and action taking in the networks.
iv. Autonomy: Intelligent edge devices have autonomous computing processes capabilities through edge databases and can process independently.

The following features of edge intelligence make it important to implement in IIoT [7]:

i. Supports data exchanges in long distance transmissions. The database management system on edge devices avoids the need for latency, data rate, and bandwidth for data exchanges.

ii. Support unification of security management system which protects from security threats through cyber-security effort.
iii. Organization using edge intelligence must comply with General Data Protection Regulation to support private data. Edge intelligence provides data and identity management at every edge device to process data securely and avoid unauthorized data accesses.
iv. Along with cloud brings together the necessary infrastructure with programming and database management for the data analysis through an application.
v. Provides an effective integration between the connected devices though the database management and also provides services without interruptions.
vi. Reduces the amount of data transferred to the cloud data centers and hence cloud is made available for other tasks. This improves the system's efficiency and reduces the data transfer costs.

1.4. Motivation for Edge Intelligence

With the growth of Internet of Everything, the data generated by the edge increases invariably [8] resulting into high bandwidth requirements. But the current applications require lower latency. Edge computing provided both the requirements through its guaranteed QoS for large volume of data. On the other hand, the Artificial intelligence applications for machine learning are advanced with the latest models, processing capabilities and amounts of data. The applications act as central body for an effective human interaction through the electronic appliances.

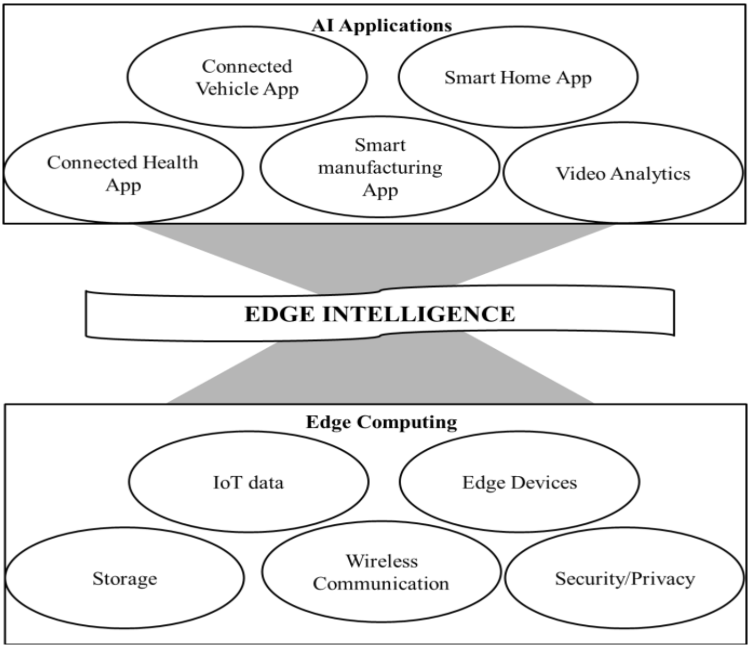

Fig. 1. Motivation to Edge Intelligence

The edge intelligence is hence pushed by the edge computing and is pulled by the artificial intelligence applications as shown in Fig. 1. The edge computing lets artificial intelligence algorithms to run on an edge device. Also the artificial intelligence applications call for run on the edge device. In edge intelligence the artificial intelligence models are optimized for run for optimized machine learning algorithms. In machine intelligence, the data is transferred to the cloud and trained for data analysis. Once the model is trained, the cloud is able to infer based on the edge data and sends response to the edge device. In edge intelligence, the inference is done on the edge device. The data generated by the device acts as input to the model extracted from the cloud. The edge intelligence approach can be upgraded to train the edge and personalize the model at the edge device for a better performance.

1.5. Relevance of Edge Intelligence

Most of the organizations consider the edge intelligence to be a platform to run artificial intelligence algorithms for the data generated on the same device [8]. This requires more resources and better processors at the device. Current edge intelligence approach that deals with the model is trained in cloud data center due to the resource requirements. There is a need to transfer large volumes of data from edge devices to the cloud. It causes a communication overhead and possible threat to privacy. In practical, edge intelligence focuses on optimizing the overall performance in data analysis.

There are five metrics of performance for edge intelligence [7]:

i. *Latency*: it is the total time taken for the inference process. This may be affected due to the resource availability at edge devices or the data transfer techniques.
ii. *Accuracy*: it is the number of correct predictions among the total predictions that represents the overall performance of the model.
iii. *Energy*: the energy efficiency is an important aspect in edge intelligence. This is usually affected by the model used to infer and the resources available at the edge device.
iv. *Privacy*: edge intelligence aims to protect the data privacy at the data source. It depends on the way of analyzing the data.
v. *Communication Overhead*: it depends on the model used to infer the data and the bandwidth requirements.

2.0 Learning Models for Edge Intelligence

Edge intelligence provides a learning process with a heterogeneous environment which combines with a faster computation abilities and achieves a better communication quality with reduced energy consumption. Edge devices avoid the learning process from relying on the cloud and use edge resources for the same. There are models proposed for learning processes based on edge intelligence.

1) *Edge Intelligence in Artificial Intelligence (Complex Edge AI)* [6]: Edge computing is a best model for Artificial Intelligence (AI) applications. Fig. 2 depicts the edge based architecture for AI and facilitates complex edge AI operations scenario. Dispersed Edge and IoT devices generate locality-specific data and share a common knowledge base. The scenario considers AI for decision making. The patterns of data may be similar across the locations where the devices are deployed. To train the base model, on-demand cost efficient public cloud-based machine learning (ML) is used. The data learned are refined by the cloudlets which have access to the local sensors and devices using transfer learning. The cloudlets in turn avoid aggregating the data and produces models the results in low-latency.

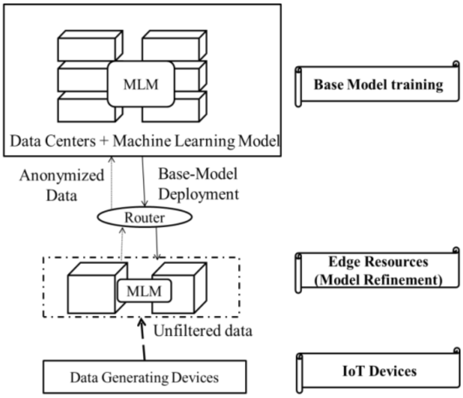

Fig. 2. Edge AI with hierarchical edge architectures

2) *Distributed AI for Intelligence at Edge:* This model is experimented for a home monitoring systems to understand the contribution of edge intelligence. The difference between the cloud-based AI and Edge Inferred AI is as shown in Fig. 3. The edge inferred AI puts less computational load on cloud. It is over 10,000 times lesser than cloud-based AI. The model improves scalability and reduces cost of services. The edge learns the AI model from the local data. The model is then exchanged for faster predictions and information transfer like notifications. The cloud is relieved from the computations of detecting unusual activities. The model trains the cloud for the activity detection. Edge-gateway checks the data quality using the cloud-trained model, and the model is transferred from cloud to the edge gateway. Whereas in cloud-based AI, the cloud-is trained to detect the unusual activities and is also responsible to check the data received from the data transferring devices

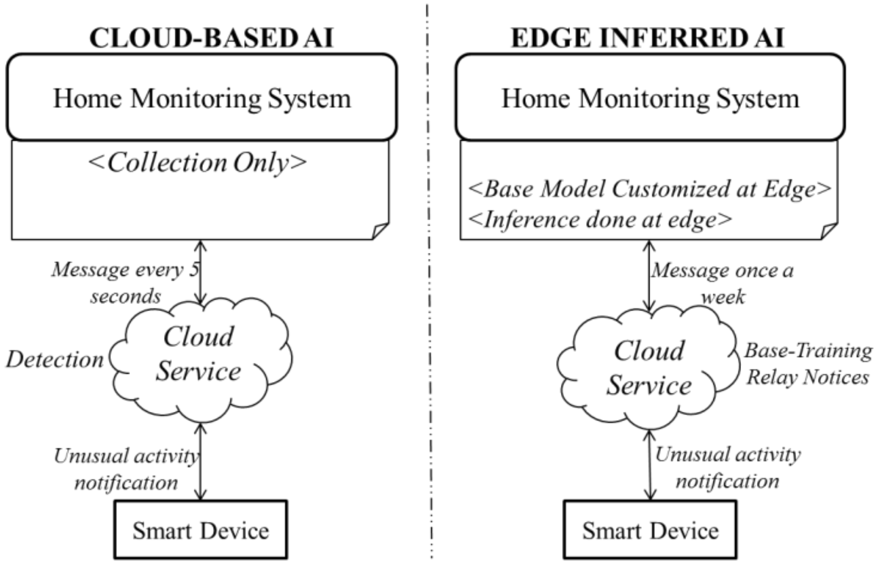

Fig. 3. Comparison of two smart computing models

3) *Edge Intelligence and IoT Sensor Stream System:* Foghorn Model is a method for enabling Edge Intelligence in IoT applications (Fig. 4). The model is triggered by the sensor data which is generated by software in gateway device or an embedded system [9].

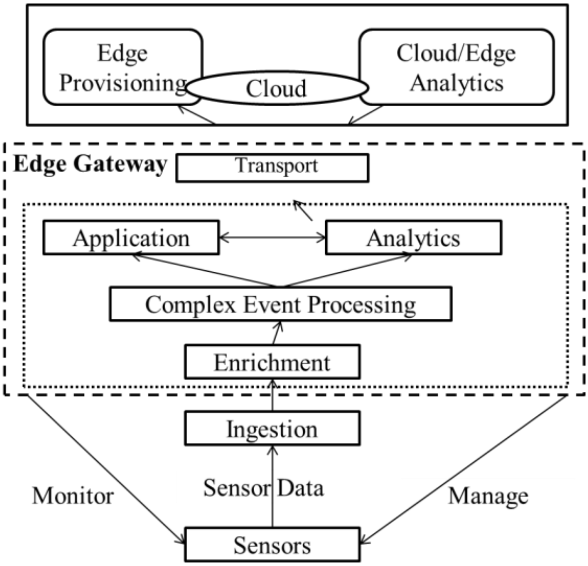

Fig. 4. Edge Intelligence and IoT Sensor Stream System

The layer with the software is connected to a LAN. The layer can access services, applications, and also data processing devices. The layer can match a sensor data with the descriptions of pattern relating a set of patterns of events; automatically identify the events through the continuous execution of expressions; intelligently connecting the services and applications at the edge gateway to link the analytical expressions for the event detection; evaluation and fine tune the model for analytics; and monitoring the status of the software. The gateway also enables to store the raw sensor data and related results in time-based cloud storage.

4) *Hyper-connectivity with Edge Intelligence:*

The model as shown in Fig. 5 represents cloud IoT Edge extending a cloud platform's data processing and machine learning (ML) to the edge devices for processing the data received from the sensors in real-time and make decisions [10]. The model can run on either the smart devices or a desktop with Linux operating systems. There are two components activated during runtime: Edge IoT and Edge ML. The cloud platform is enabled to run ML models on the edge devices. The edge device can store, translate, process, and extract intelligence through the edge devices and interoperates with the cloud platform.

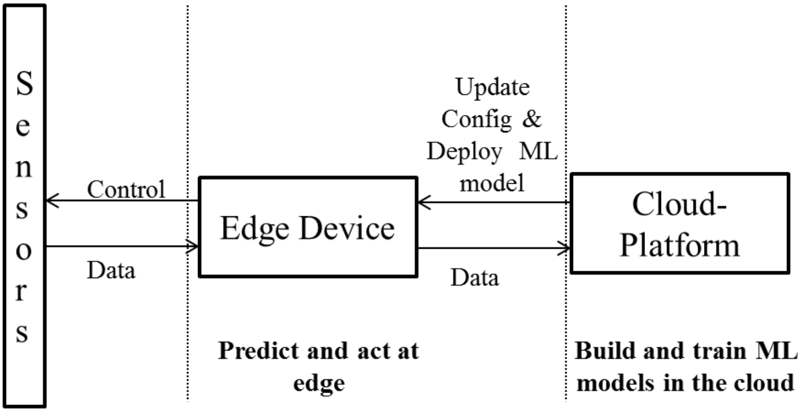

Fig. 5. Edge Intelligence with Cloud-based IoT

5) *Edge Intelligence in IIoT Applications:* IN THIS SECTION, WE PRESENT SOME OF THE EDGE INTELLIGENCE APPROACHES FOR IIOT :

i. *Fog Horn* [2]: It is a leading developer of edge intelligence software for industrial IoT (Fig. 6). The model created for Industrial IoT consists of four major components: machine learning; applications/SDK; local histories and enrichments. A FogHorn manager in this model, manages the data analysis between the four components. The manager implements edge management, edge configurations, edge monitoring, and edge to cloud analytics.

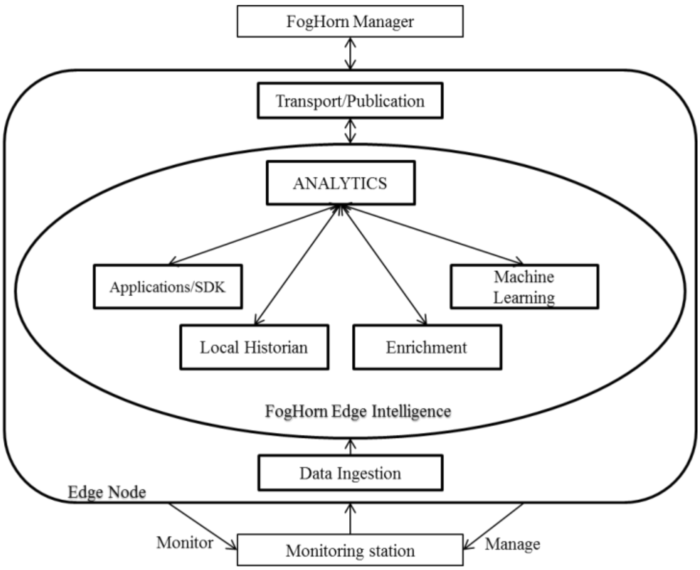

Fig. 6. FogHorn IIoT

Condition monitoring of distribution transformers in an industrial setting [11]: This model demonstrates industrial application of edge intelligence which focuses on condition monitoring of distribution transformers with temperature sensing at surface level (Fig. 7). It contains remote conditioning, monitoring and the maintenance system to accommodate devices that provide a wider functionality than measurement. There are transformers at remote places to transfer the data generated by edge devices. The analytics task is done by the edge device through convergence of information and operation technologies.

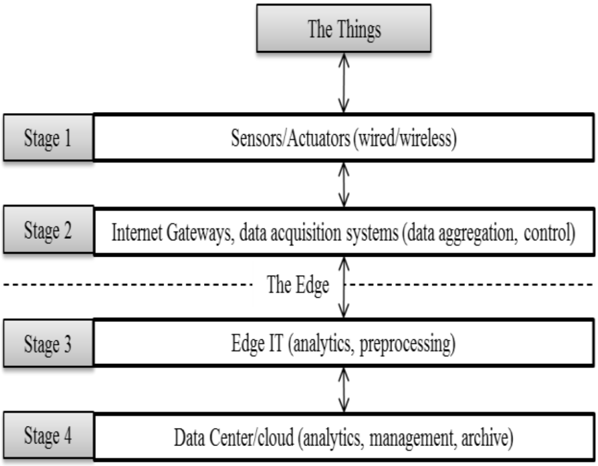

Fig. 7. Conditional Monitoring Model

ii. Blockchain-based Smart Factory [3]: Each entity in the model is a node in IIoT named as either light node or full node (Fig. 8). Light nodes are IoT node that are power constrained and hence do not participate in blockchain sharing. They forward transmissions to the full nodes which are powerful nodes like gateways, servers, etc. the light nodes are implemented based on PyOTA which is a IOTA Python API library.

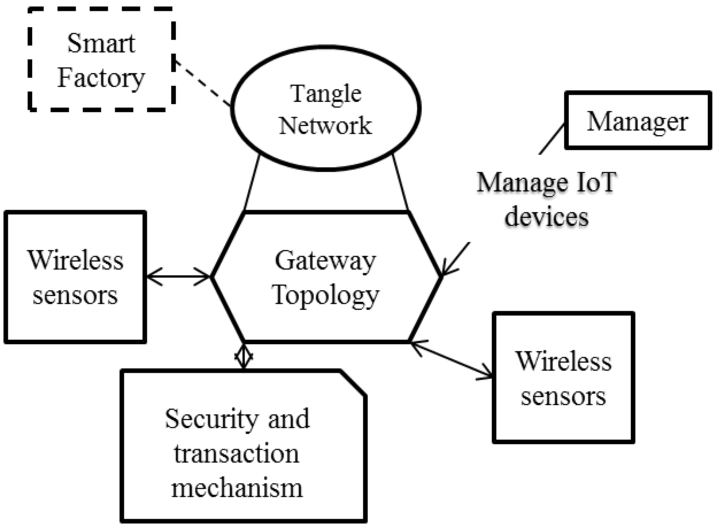

Fig. 8. Blockchain-based IIoT for smart factory

A Full node maintains the blockchain network and broadcast the transactions to the blockchain networks for the completion. They provide a convenient RESTful HTTP interface which receives transactions from light nodes via RPC interface

The model has four components

1) *Wireless sensors*: These are deployed in a smart factory and belong to light nodes. Each sensor generates unique ID for each device and distributes the keys.
2) *Gateways*: These are the full nodes that maintain the network. Gateways receive the request and broadcast them to the blockchain network.
3) *Manager*: It is a full node that manages the IoT devices. The manager has the authorities to publish the list of devices in the network.
4) *Tangle Network*: It is public blockchain network that can be accessed by anyone. It is kept secure and stable by gateways. A PC is used as a gateway/manager to run a full node. Raspberry Pi Model 3B is an IoT device to run light node. A continuous data collection is reported by Raspberry and the status is shown on PC.

iii. HealthIIoT: HealthIIoT (Fig. 9) is a model proposed for healthcare industry to monitor a patient's health [12].

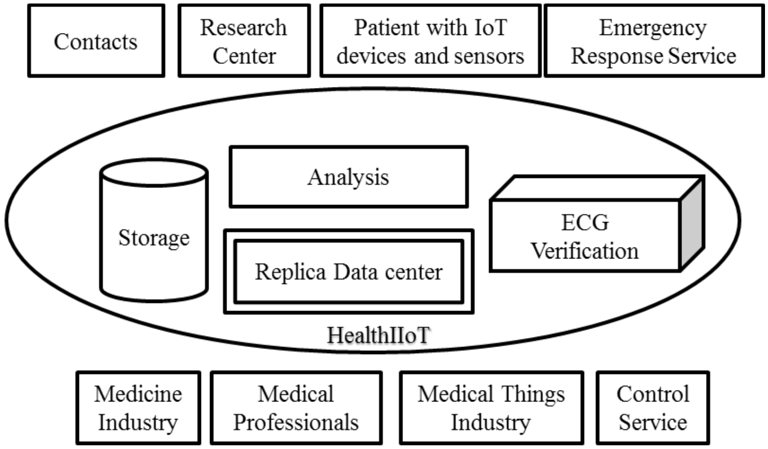

Fig. 9. HealthIIoT Ecosystem

HealthIIoT uses MySQL for as database. The components of HeathIIoT are large number of interconnected machines, IoT devices, sensors, cloud-based computing technologies necessary to collect patient data. The model can transfer the patient information faster to the authorized team of healthcare. Because of cloud-based technology used, the data analysis, storage, data monitoring, and secure transfer to be efficient. The HelthIIoT is a platform for interconnected medical devices which helps to operate on large volumes of data generated from anywhere at any time. The data analysis is done though the e-health records, imaging equipment, sensors, and smart devices. The analysis improves the decisions of the healthcare professionals and enables patients easily manage their personal health. The connected devices and sensors record the patient data and forward it to the cloud-based system through network connections. The cloud validates the data and classifies to redirect to the healthcare professionals for patient care.

iv. Boomerang: It is an automatic inference framework designed for IIoT [13]. Boomrang uses Raspberry Pi as a IIoT device with a desktop PC with 8GB RAM. The bandwidth between IoT device and an edge server is controlled by WonderShaper tool. It works in three phases (Fig. 10):

a) Install: all the devices and edge server gets the Deep Neural Network (DNN) model during installation. The model creates a prediction model and right-sizing model for each layer in the network. The DNN model is trained to obtain accurate predictions.

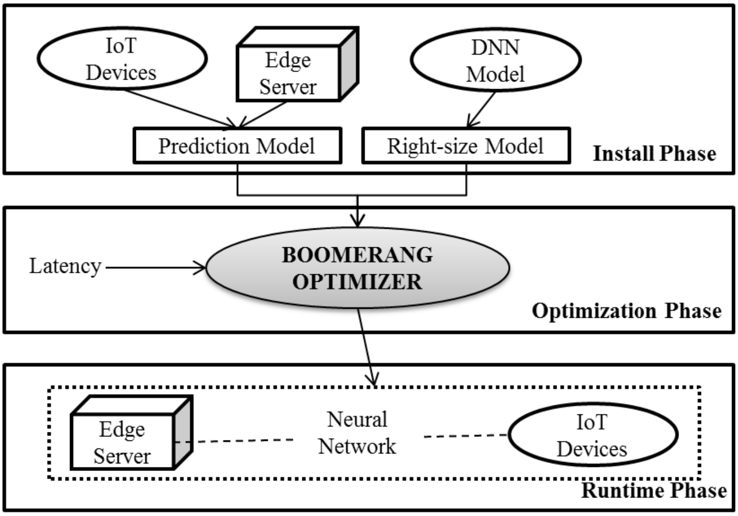

Fig. 10. Workflow of Boomerang

b) Optimization: The model generated in the first step is fed to the Boomerang optimizer along with the latency requirements to optimize the DNN to obtain maximum accuracy.

c) Runtime: the computations are shared between the edge server and other devices. The first half of the computation is done by the edge server and the remaining is processed by other devices. Boomerang sets higher bandwidths and hence improves accuracy through efficiency in large size computations. It also satisfies the latency requirements. In IIoT applications Boomerang can attain higher efficiency due to the lower latencies.

3.0 Conclusions

IIoT driven applications are emerging domain in the data analytics. Applying IIoT to artificial intelligence and edge computing enables efficient processing of data either to make decisions or to transfer to the other devices in the network. With the application of edge devices, that are equipped to locally process data and hence being an intelligent edge device, reduces the time required to process the data. The security approaches applied in the edge computing results into secure transfer of data from one device to another.

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Internet of Things Enabled Monitoring of Energymeters

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Abstract

In India electricity generated from the electric power plants is distributed for domestic as well as industrial usage. Domestic electricity usage is measured by electric energymeter which is installed in every house. Monthly electric bill is generated proportional to the energy consumed and unit cost of electricity fixed by the electricity board. The energy consumption is not monitored periodically and hence a limit is not set on the usage. This work is an attempt to eliminate the human intervention in meter reading in domestic electric meters by introducing an Internet of Things based electric energy monitoring system. This paper proposes a smart electrical energymeter developed using Arduino UNO controller, ACS 712 current sensor to sense the current and ESP 8266 Node MCU module to send the information over the internet. The system can capture amount of energy consumed, computes cost and displays the quantity and cost of electricity by sending information over the internet. The information can be viewed on mobile phone through Adafruit App /dashboard.

Keywords: *Energymeter, Internet of things, ACS 712 current sensor, Node MCU, Arduino Uno*

1.0 Introduction

Internet of things (IoT) is a system connecting mechanical and digital machines, computing devices with the help of the unique identifiers (UIDs) without the interaction of human-human or human-computer. This technology makes easier to track, real time cost of the electricity consumed. This proposed work uses devices such as Arduino board, ACS712 current sensor, Node MCU, 9-volt batteries and the connection jumper wires. According to the energy statistics by Central statistics office ministry of statistics and programme implementation government of India, the estimated electricity consumption increased from 5,01,977 GWh during 2007-08 to 10,66,268 GWh during 2016-17 [1]. So an attempt was made to make it simpler for the common man to get to know the real time cost of the electricity consumed.

Male et al [2] presented a simple low cost wireless GSM energy meter which saves human labour but it has limited access due to the network restrictions. Vijayaraj et al [3] showed automated billing system which used GSM and Ad-Hoc wireless routing protocol for generating the electric bill of all the homes connected. But, this method was not transparent as the end users were not the common men. Koay et al [4] developed bluetooth enabled energy meter which

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transmits the data of the energy consumed over the bluetooth. But, the system used short range bluetooth protocol. Imran et al [5] developed an IoT based electricity meter to display the units consumed and cost over the internet. The system used blinking LED signal interfaced with microcontroller through LDR sensor to give an interrupt when LED blinks. The reading of the energy meter was sent to ethernet shield module being fed through microcontroller, level shifter IC and RS-232 link. The system developed by this project was the device that works for limited distance.

Zahid Iqbal et al [6] proposed an automatic remote meter-reading system based on GSM. It is useful to obtain meter reading when desired so, meter readers don’t need to visit each customer for the consumed energy data collection and to distribute the bill slips. Microcontroller was used to monitor and record the meter readings. In case of a customer defaulter, no need to send a person of utility to cut-off the customer connection. Utility can cut off and reconnect the customer connection by short message service (SMS). Furthermore, the customer can check the status of electricity (load) from anywhere. In this system, energy meter readings are being transferred by making use of GSM.

Ahin Shapir et al [7] presented smart energy meter connected with Electricity Board, household appliances and the user through IoT and mobile application. The system focused on making the smart energy meter to smartly connect with the household appliances through IoT and also to connect with the authorized persons through a mobile application to have a control over it. The idea of home automation was used to think of automation in automatic electricity meter.

The literature review showed that different techniques such as Global System for Mobiles (GSM), Bluetooth, ZigBee, Short Message System (SMS), Automatic Meter Reading (AMR) and the Automatic Polling Mechanism (APM) and Ethernet have been adopted to send the data such as quantity of the power consumed, total power utilized, current from the electric meter to the station or the user. Bluetooth based systems are limited to short range and SMS based systems are not effective because of network error and connectivity issue. Ethernet systems are limited to short distances. ZigBee based systems provide an idea of sending the data over the internet and home automation literatures give the idea of automation. There is a need for the system that can give information such as the amount of electric power consumed and proportional bill generated in real time to the common man. It has been found that sending the data of the electric meter using Internet is the best option to get the real time data. Internet can be used for longer range and there is very little error involved. Hence, the present project utilizes internet to send the data from the system to the end user.

2.0 Experimental Details

2.1 Development of Working Model

The electric energy meter developed consists of Arduino Uno board, ACS 712 current sensor and Node MCU. The Arduino Uno has a microcontroller

ATMEGA 328P to process the data. The detailed method to program the Arduino using Arduino software (IDE) is explained in [8]. The current sensor works on the principle of Hall effect [9]. The node MCU is used for wireless communication with the smartphone or laptop to get real time data over the internet. The pin configuration for the Node MCU can be found in [10]. The processed data (Electric power wattage and cost of the electric power) sent over the internet can be visualised in Adafruit dashboard. The details to configure the dashboard can be found in [11]. The appliance used here is an incandescent electric bulb. The energy consumed by the incandescent bulb and cost of the electric power is to be found. The connections of the IoT based electric energy meter are shown in the Fig. 1 where, the current sensor ACS712 and Node MCU are connected to the Arduino Uno Microcontroller with the help of jumper cables. The current sensor is connected in series with the electric bulb

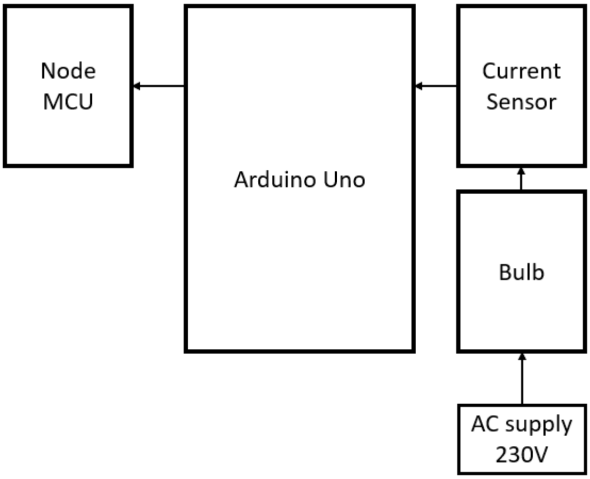

Fig. 1. Block diagram of experimental setup

2.2 Working of the model

The detailed model and working are shown in Fig. 2 respectively. When the power is supplied to the appliance (Incandescent bulb) coupled with the current sensor, the appliance gets switched on and it starts operating by consuming power. The current sensor senses the current supplied to the appliance. The sensed data is sent to the Arduino Uno microcontroller. The microcontroller processes the data and the processed data is fed to the Wi-Fi module (Node MCU). The micro controller is the main part which calculates the power based on the sensed data. The data sent through the Wi-Fi module can be viewed on the mobile screen through Adafruit Dashboard.

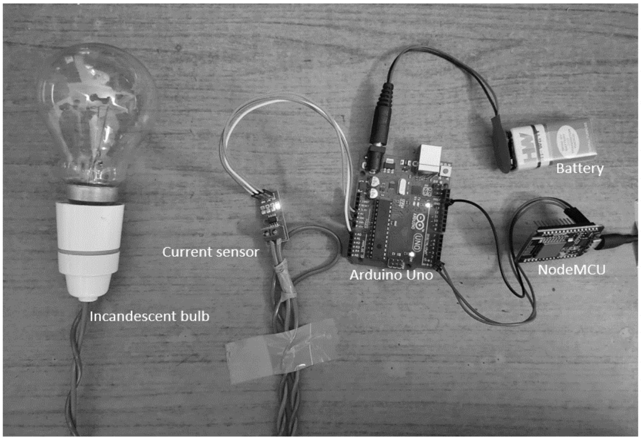

Fig. 2. Working model

3.0 Experimental Results

Experiment was conducted using a 60 W incandescent bulb. Since the electric bulb consumes very less power, a bill equal to ₹ 8 will be generated if the bulb glows for 16.67 hours. In other words a bill of ₹1 will be generated if the bulb runs for 2.08 hours. So, a scaling factor of 2.08 x 60 = 125 is used for simplification. For the data considered, 8 ₹ x 125 = 1000 ₹ is used for calculating the bill and this bill (₹. 1000) will be shown on the Adafruit dashboard if the bulb glows for 16.67 hours. This scaling factor is included in the program burnt on to the Aurdino board. For calculating the actual bill, the bill shown on the Adafruit dashboard should be divided by the 125 to eliminate the scaling factor.

The scaling factor is mainly used to conveniently check for the consistency of the measurement within short time duration rather than conducting the experiment for very long hours. No need of using any scaling factor for the electric power since the dashboard is showing the actual power consumed in Watt hour

The Adafruit dashboard on appears on the computer screen. The same dashboard can be accessible on the phone screen using the Adafruit android app. It displays the cumulative electric power consumed in Watt hour and bill in Rupees. These data were calculated as per the program and sent over the internet to Adafruit dashboard using Node MCU. The electric power can also be monitored in real time and at a particular time interval using the Android app.

As per Adafruit Dashboard the bill amount is ₹.14. This bill was generated by considering the scaling factor. So to get the actual bill, the scaling factor is to be eliminated as follows:

Actual bill $= \frac{14}{125}$ = 0.112 ₹ → 0.112 x 100 Paisa

Hence actual bill rate = 11.2 Paisa, actual cumulative electric power consumed is 14.36 W-h

Cross check

From Figure 4 the power consumed is 14.36 W-h (Actual). Tariff for 1 kW - h = 8 ₹. The bill that should be given from the experiment is $\frac{8 \text{ x } 14.36}{1000}$ = 0.1148 ₹ = 0.1148 x 100 Paisa = 11.48 Paisa

Similar observations were taken from the adafruit dashboard and tabulated as shown in Table 1, which shows the generated bill in ₹. Cumulative time in seconds and the cumulative power consumed in W - h as per Adafruit dashboard

Table 1. Results Showing Bill in ₹ and Power in W – h

Bill in ₹.	Time	Power in W –h
1	1 min 11 sec	1.12
2	2 min 12 sec	2.07
3	3 min 12 sec	3.03
4	4 min 22 sec	4.12
5	5 min 24 sec	5.09

From the Table 1, the bill shown in the Adafruit for 5 min and 22 sec is 5 ₹. Actual bill after 5 min 24 sec by eliminating the scaling factor is,

Actual bill = $\frac{5}{125}$ = 0.04 ₹ = 0.04 x 100 Paisa, Hence Actual bill = 4 paisa

Actual cumulative electric power consumed is 5.09 Watt hour

Cross check

From the Table 1, the power consumed after 5 min 24 sec = 5.09 W – h (Actual).

Tariff for 1 kW - h = 8 ₹, The bill that should be given from the experiment is $\frac{8 \text{ x } 5.09}{1000}$ = 0.0407 ₹ = 0.0407 x 100 Paisa = 4.07 Paisa. Therefore the system arrangement and the experimentation appears to be proper.

4.0 Conclusions

The system was successful in sensing the quantity of electric power consumed, sending the data such as quantity of power consumed and generated bill amount over the internet and displaying them on the phone screen. The data were displayed in real time and hence, continuous monitoring of electric power consumption is possible. Since IoT is used in the system, human intervention in electric meter reading can be completely eliminated. Also, as IoT based systems communicate through internet, power consumption can be monitored continuously anywhere in the world. This is a main advantage compared to the conventional domestic electric energy meters. With some hardware and software modifications, the demonstrated system can be developed into a device to replace the present domestic electric energy meter to monitor the electric energy in real time.

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An Algorithm for Genomic Classification for Evaluation of Abnormalities

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Abstract

SNP (Single Nucleotide Polymorphism) is used to detect complex diseases like pancreatic cancer, age related macular degeneration, prostate cancer and non-Hodgkin lymphoma by extracting the kernel of tag SNP and informative SNP by hierarchical clustering. The detection is also made using random forests for SNP-SNP interaction. Graphic Processing Unit is used for complex data. Energy distribution difference method is used for multiple SNP-SNP interaction and for dealing with different factors of the weighted biological network structure is implemented in turn finding the genome and thereby capturing the complex gene related diseases. The methodology implemented in this research is the hierarchical clustering with the Internet of Things using socket programming for the raw data where the true SNPs are found from the alleles of thymine and cytosine. This is implemented using different forms of raw data analysis where the Protein pattern gets effected by the change in DNA (Deoxyribose Nucleic Acid) with translation and it is used for further analysis of different diseases, specifically rheumatoid arthritis. IoT concept is used to communicate between the physicians, once the result is obtained. The data is stored in the form of cloud and retrieved without any limitations on the data length. Through the internet, an encoding and decoding facility is provided where the data is kept confidential and is open only to the physicians.

Keywords: *Genomic classifications, SNP, Abnormalities, IoT*

1.0 Introduction

SNP stands for Single Nucleotide Polymorphism. It is found in the body for every thousand nucleotides. There are four to five million nucleotides in the body. The nitrogenous bases attached to the sugar forms nucleoside. Each nucleoside attached to the phosphate group forms nucleotide. These nucleotides are attached with the phosphodiester bond. Technically SNP is also called point mutation [1]. There will be cytosine replaced by the thymine for every thousand nucleotides where these changes will be used for the detection of complex diseases like heart disease, diabetics, cancer which includes pancreatic cancer which includes pancreatic cancer and the inherited diseases. There will be more than 1% of SNP found. According to Bostein and Risch there are altogether one million nucleotides in the human genome [2].

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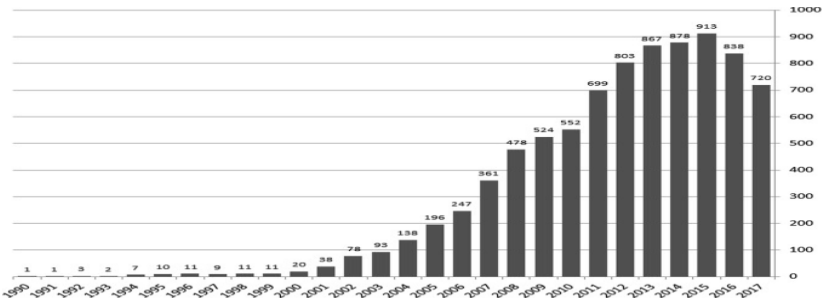
SNPs are located on various parts of the genome with potentially in differing functional implications like within the coding sequences of the genes, non-coding regions of the genes and in an intergenic regional parts. These SNPs do not alter the gene functionalities or protein functions. Consequently, association between the SNP and the developed risk of the tumor or the presence between an SNP and increase in toxicity of an anticancer drug could be due to the dis-equilibrium with another polymorphisms located in the same chromosomal region [3-4]. The existence of an SNP will be indicated only in a proportional of the carriers. In the Oncology, SNP could influence on the susceptibility to specific organ cancer, the clinical result of patients, modify patient's response to the chemotherapy and influence an incidence and the closeness of the side effects produced by the treatment [5]. The existence of the SNPs can be examined from the constitutional DNA which is then drawn from the peripheral blood cells [6]. The distribution of SNP is as shown in the Fig. 1.

Graphical User Interface as shown in Fig. 2 are the data used to get the patterns and are saved in a database. The changes in the DNA by SNP is reflected in the Protein Pattern by translation [7].



X-axis=years, Y-axis=SNP number

Fig. 1. Distribution of SNP disease year-wise

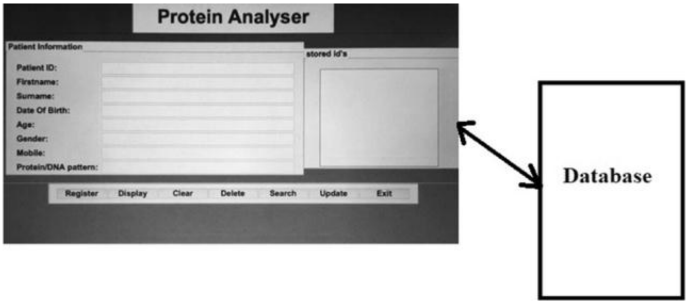


Fig. 2. GUI of Protein analyser

2.0 Design and Implementation

A code is implemented as per the designed flowchart using different modules and in-built functions required for calculating the DNA bases, gathering the standard and obtained result and displaying them in the form of graph.

```
import pandas as _pd
import numpy as _np
import matplotlib.pyplot as _plt
import time

data =
pd.read_csv("http://genome.crg.es/datasets/genomics96/seqs/DNASequences.fa
sta")
data.to_csv("/Users/arunkumaria/Desktop/filename", sep=' ')
print(data)

data1=pd.read_csv("http://genome.crg.es/datasets/sgp2002/testsets/scimit.fa")
data1.to_csv("/Users/arunkumaria/Desktop/filename1", sep=' ')
print(data1)

data2=pd.read_csv("http://genome.crg.es/datasets/gpeval2000/data/SGS/embl50
.h178.masked.fa")
data2.to_csv("/Users/arunkumaria/Desktop/filename2", sep=' ')
print(data2)

print("######Welcome to the World of Bio-Informatics######")

print("\n")
f_obj=open("/Users/arunkumaria/Desktop/filename",'r')
f_obj1=open("/Users/arunkumaria/Desktop/filename1",'r')
f_obj2=open("/Users/arunkumaria/Desktop/filename2",'r')

data=f_obj.read()
str=data.upper()
slen=len(str)

data1=f_obj1.read()
str1=data1.upper()
slen1=len(str1)

data2=f_obj2.read()
str2=data2.upper()
slen2=len(str2)

print("fetching the data containing the DNA....")
time.sleep(3)
print("\n")
print("displaying the data....")
time.sleep(1)
print("\n")
```

```
print(str)#Data Displaying
ac=0
tc=0
gc=0
cc=0
n_count=0
a_count=0

ac1=0
tc1=0
gc1=0
cc1=0

ac2=0
tc2=0
gc2=0
cc2=0
for i in str:
 if(i == 'A'):
  ac=ac+1
 if(i == 'T'):
  tc=tc+1
 if(i == 'G'):
  gc=gc+1
 if(i == 'C'):
  cc=cc+1

for i in str1:
 if(i == 'A'):
  ac1=ac1+1
 if(i == 'T'):
  tc1=tc1+1
 if(i == 'G'):
  gc1=gc1+1
 if(i == 'C'):
  cc1=cc1+1

for i in str2:
 if(i == 'A'):
  ac2=ac2+1
 if(i == 'T'):
  tc2=tc2+1
 if(i == 'G'):
  gc2=gc2+1
 if(i == 'C'):
```

```
  cc2=cc2+1

from pandas import DataFrame

Data = {'x': [ac,tc,gc,cc],
        'y': [ac2,tc2,gc2,cc2]
       }
df = DataFrame(Data,columns=['x','y'])
print (df)

from sklearn.cluster import KMeans

_kmeans = KMeans(n_clusters=2).fit(df)
centroids =_ kmeans.cluster_centers_
print(centroids)

_plt.scatter(df['x'], df['y'], c= _kmeans.labels_.astype(float), s=50, alpha=0.5)
_plt.scatter(centroids[:, 0], centroids[:, 1], c='red', s=50)

char n[10];
structlogin_d
{
        char uname[10];
        char upass[7];
} s;
Int signin(int rd);
Int signup(int rd);
Int signin(int rd)
{
        Charname[10],pass[7];
        Lseek(rd,0,SEEK_SET);
        Printf("\n \t username");
        Fgets(name,10,stdin);
        Printf("\n \t password");
        Fgets(pass,7,stdin);
        Printf("\n \t password");
        Print("\n\n");
        Lseek(rd,0,SEEKSET);
        While(read(rd,&s,sizeof(s)))
        {
                If(strcmp(s.uname.name)==0)
                {

                        If(strcmp(s.upass.pass)==0)
                        {
```

```
                                        Strcpy(n,name);
                                        Return 1;
                              }
                    }
          }
          Return 0;
}

Int signup(int rd)
{
          Char name[10],Pass[7],name[20];
          Printf("\nenter required username");
          //fpurge(stdin);
          Fgets(name,10,stdin);
          Printf("enter the password for your profile");
          //fpurge(stdin);
          Fgets(pass,7,stdin);
          Strcpy(s.uname,name);
          Strcpy(s.upass,pass);
          Write(rd,&s,sizeof(s));
          Name[0]='\0';
          Strcpy(nam,name);
          Strcat(nam,"serverfile");
          Open(nam,O_CREAT|O_RDWR|O_APPEND,0777);
Nam[0]='\0';
          }
}
##server##
int main()
{
          char ch2;
          int sd=open("server_data",O_RDWR |O_APPEND,0666);
          int sid=socket(PF_INET,SOCK_STREAM,0);

          int rd = open("security",O_WRONLY | O_CREAT, 0666);
          printf("\n\n\n========================WELCOME TO THE
DATA SERVER==================================\n\n\n");
          printf("\n==>Assign an account for a CLIENT to transfer a FILE to the
SERVER.....\n");
          signup(rd);
          if(sid == -1)
          {
                    perror("Socket");
                    exit(0);
          }
```

```
            else
            {
                        struct sockaddr_in ser_sock;
                        ser_sock.sin_family = AF_INET;
                        ser_sock.sin_port = htons(5051);
                        ser_sock.sin_addr.s_addr = inet_addr("127.0.0.1");
int b = bind(sid,(struct sockaddr *)(&ser_sock),sizeof(ser_sock));
                        if(b == -1)
                        {
                                    perror("Bind");
                                    exit(0);
                        }
                        else
                        {
                                    while(1)
                                    {
                                                int l = listen(sid,2);
            if(l==-1)
                                                {
                                                            perror("Listen");
                                                            exit(0);
                                                }
                                                else
                                                {
                                                            struct
sockaddr_in cl_sock;
int size = sizeof(cl_sock);
                                                            int cid = accept(sid,(struct sockaddr
*)(&cl_sock),&size);                                                if(cid  == -1)
                                                            {
                                                perror("accept");
                                                exit(0);
                                                            }
                                                            else
                                                            {
printf("Acknowledgement Successful...!!!\n");
printf(">>>>>>>Accepting the FILE from the CLIENT.......\n\n\n");
sleep(10);
            while(read(cid,&ch2,1))

                                                            {
                                                                        write(sd,&ch2,1);
                                                            }
                                                                        printf("*****FILE received
Successfully....!!!\n");
```

```
printf("==>Assign an account for a CLIENT to transfer another FILE to the
SERVER......\n");
                                                            signup(rd);
                                                    }

                                            }
                                    }
                            }
                    }
}
##client##
int main(int argc,char *argv[])
{
        int _eq;
        char _ch[60];
        //int nd=open("client_file1",O_RDWR);
        int nd=open("client_data1",O_RDONLY|O_CREAT,0666);
        char ch1;
        int rd = open("security",O_RDONLY);
        printf("\n==>Verify your account to transfer a FILE to the
SERVER....\n");
        eq = signin(rd);
        if(eq == 1)
        {
                int cid = socket(PF_INET,SOCK_STREAM,0);
                if(cid == -1)
                {
                        perror("Socket");
                        exit(0);
                }
                else
                {
                        struct sockaddr_in ser_sock;
                        ser_sock.sin_family = AF_INET;
                        ser_sock.sin_port = htons(5051);
                        ser_sock.sin_addr.s_addr = inet_addr("127.0.0.1");
int c = connect(cid,(struct sockaddr *)(&ser_sock),sizeof(ser_sock));
                        if(c==-1)
                        {
                                perror("connect");
                                exit(0);
                        }
                        else
                        {
                                while(read(nd,&ch1,1))
```

```
                                        {
                                            write(cid,&ch1,1);
                                        }
                                }
                        }
                }
                else
                {
                        printf("\n you are not the user \n");
                }
}
/*end of the server client coding lines*/
```

3.0 Methodology

The program code works like a database. Once the data is extracted it is categorized and a graph is plot with respect to the present reference data. From the obtained graph one can identify the cytosine variations [8] and use it to debug the disease in the body. The obtained graph uses the K-means clustering. The libraries like pandas, numpy, matplotlib are used for the data extraction, representing the array and to get the result in the form of graphs. Data set of readily available and to be extracted into the csv format works successfully. Socket Programming [9] is used to send the live results to the remote physicians for analyzing the data using encryption and decryption methodologies.

4.0 Functional Block diagram and Flowchart

Fig. 3 consists of the raw form of data which is stored in a temporary file and then retrieved. It is then gathered as adenine (A), guanine(G), thymine(T), cytosine(C). The graph is plotted by clustering method [10] by taking the standardized AGTC count and the obtained AGTC count.

In Fig. 4, the obtained and analysed result is sent through socket programming to the remote physician by encoding and decoding through internet where IoT concept [11] is being involved to store the data and retrieve it efficiently. The data hence sent is preserved and retrieved without any limits [12].

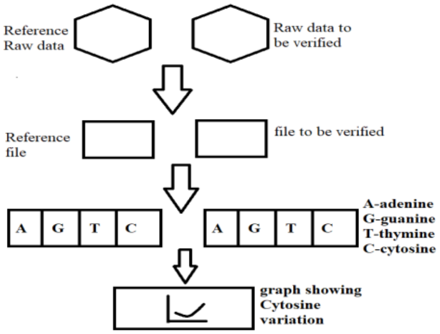


Fig. 3. Flowchart of a functional block

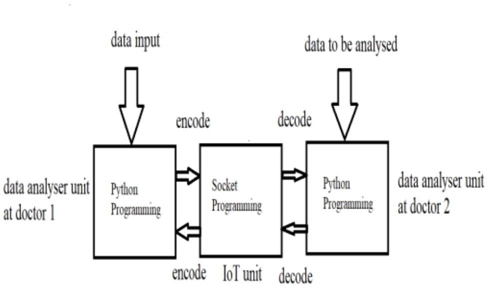


Fig. 4. Flowchart of an IoT based connection

5.0 Results

The standard data is compared with the obtained calculated data to get the graph of following pattern. The importance of SNP in the disease identification is mainly highlighted. For identifying the disease here from coding using Python we have the different sorts of data where the presence of cytosine is seen in which we are able to get the result of cytosine replaced by thymine instantly represented by the diagram using the K-means clustering where in case the missed alleles are found. Plenty of diseases like cancer, sickle-cell anaemia, beta-thalassaemia and cystic fibrosis are identified.

	X(standard in counts)	Y(calculated in counts)
adnine	736902	245056
guanine	763077	252562
thymine	702601	253079
cytosine	689613	248551

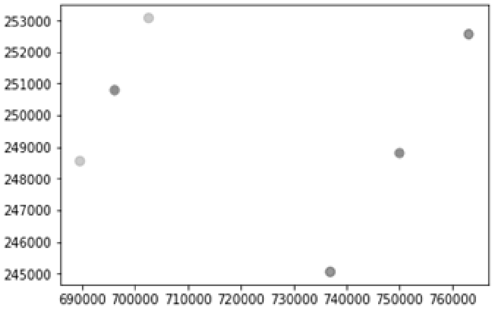


Fig. 5. Distribution of adenine, guanine, thymine and cytosine

Fig. 5 shows the distribution of adenine, guanine, thymine, cytosine for a given set of data. Yellow colored data shows the replacement of the alleles, i.e.., thymine and cytosine. Red colored data is the centroid point. Blue colored data is the distribution of adenine & guanine.

Conclusions

Importance of SNP in the disease identification is mainly highlighted. For identifying the disease based Python coding, different sorts of data are obtained in which the presence of cytosine is observed. Cytosine replaced with thymine instantly as represented in the diagram using the K-means clustering in which missed alleles are found. Diseases like cancer, sickle-cell anemia, beta-thalassaemia and cystic fibrosis can be identified using the algorithm developed. Future enhancements can be made to directly analyze the graph with different diseases by assigning the threshold which help to segregate the diseases more clearly.

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Internet of Things (IoT) Enabled Vibration Monitoring

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Abstract

Nearly 70 % of machines are driven by induction motors. Their failure incidence is 40% which is mainly due to mechanical faults connected with bearing and rotor. These failures increase vibration levels beyond safety limits. Several research works have focused on vibration monitoring of induction motors. But, a few have worked on remote monitoring of induction motors. The objective of the paper was to develop Internet of Things enabled vibration monitoring system for induction motors. The monitoring system was developed using Arduino microcontroller and ADXL 335 accelerometer sensor. ESP 8266 Wi-Fi module was used to communicate the sensor readings to Blynk IoT platform. The obtained readings were plotted for peak acceleration and the same was compared with the standard vibration severity chart. The experiments were carried out on three different induction motors and in each case real time acceleration data was recorded on the IoT platform.

Keywords: *ADXL 335 accelerometer, IRD Mechanalysis, Blynk, Internet of things (IoT)*

1.0 Introduction

About 70% of industries utilize Induction motors as major tools to drive machines [1]. Faults in induction motors have led to increased downtime affecting productivity of machines [2]. Bonaldi et al. [3] suggested preventive maintenance techniques as simpler and economical means of preventing catastrophic breakdown of induction motors in industrial machines. Nandi et al. [4] have performed condition monitoring of induction motors in real time to detect occurrence of faults. Types of faults in induction motors commonly identified were mechanical faults such as air gap, eccentricity, stator faults and bearing faults. Kande et al. [5] suggested and compared different condition monitoring techniques such as vibration monitoring, acoustic emission monitoring, Multiple Signature Current Analysis (MSCA), and thermal monitoring. Vibration monitoring as a preventive maintenance technique offers advantages of easier mechanical fault detection and economical measuring instruments [6].

Internet of Things (IoT) was used as a tool for remote sensing and monitoring in real time on industrial machines. Sensor data was acquired in real time and pushed to cloud in order to access the data through a smartphone application

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[7-9]. Internet of Things (IoT) based vibration monitoring system was developed to obtain vibration readings in real time to perform fault diagnostics [10]. However, the literature does not mention development of an IoT based system which sends an alert when the vibration levels are exceed a certain limit. Only a platform for monitoring real time data without a control alert has been created. The present work focused on development of an IoT based vibration monitoring system for acquiring vibration data in real time and checking it against vibration severity chart by IRD Mechanalysis Ltd. [11] to detect whether the vibration levels are in safe limits. The system sends an alert notification in the form of an email and short text message to the user if the vibration levels exceed safe limits.

2.0 Experimental Details

The block diagram (Fig.1(a)) shows the major components and sequence of signal flow in the IoT enabled vibration monitoring system. Power supply of 5V is provided to the Arduino microcontroller, which in turn supplies power to the accelerometer and Wi-Fi module. The accelerometer acquires vibration data in the form of acceleration and sends it to Arduino microcontroller. Arduino microcontroller is responsible for calculating absolute acceleration from the three axis acceleration readings and pushing the values in real time to the Blynk IoT platform via ESP 8266 Wi-Fi module.

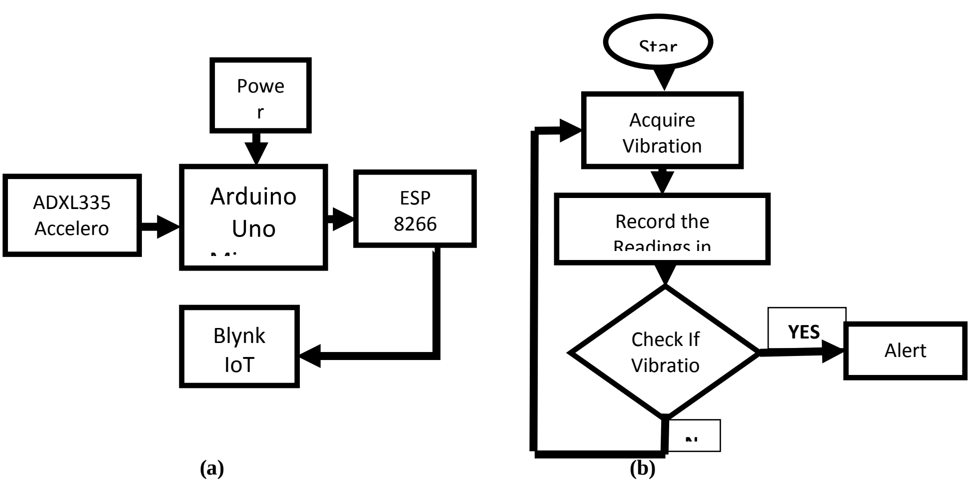


Fig. 1. (a) Block Diagram of system and **(b)** Process flow chart

Fig. 1(b) depicts the functioning of the IoT enabled vibration monitoring system. The vibration data acquired is compared against threshold values. If the acquired value exceeds the threshold, an alert notification is sent to the receiver, else the system keeps on continuously acquiring and storing data.

The absolute acceleration is determined from the triaxial accelerometer readings using equation (1).

$$A = \sqrt{X^2 + Y^2 + Z^2} \tag{1}$$

where,

X = Acceleration along X-axis in g

Y = Acceleration along Y-axis in g

Z = Acceleration along Z-axis in g

A= Absolute acceleration in g

g = Acceleration due to gravity =9.81 ms^{-2}

In order to determine if the absolute vibration (in g) is safe or not, vibration severity charts are used. IRD vibration severity chart developed by IRD Mechanalysis Limited (Fig. 2) was used.

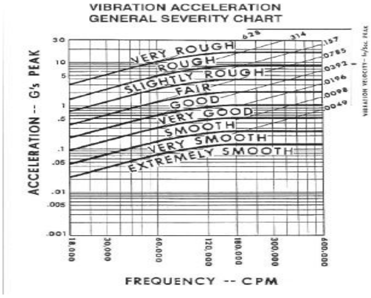


Fig. 2. IRD Vibration severity chart

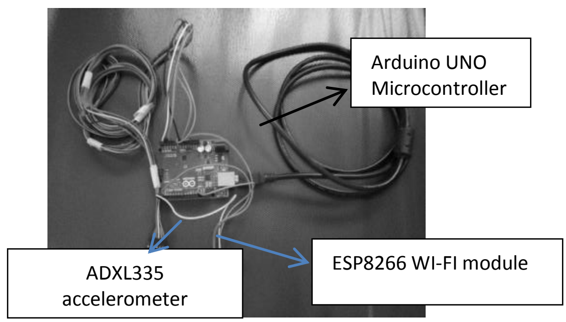


Fig. 3. Circuit setup

IRD vibration severity chart characterizes vibrations based on acceleration in g peak. In general, vibration levels around 1 g is taken to be safe limit. For induction motors, the angular speed in rotations per minute (rpm) is equal to frequency in cycles per minute (cpm).

The developed setup is as shown in Figure 3.The system was tested on three different Induction motors of different machines as follows:

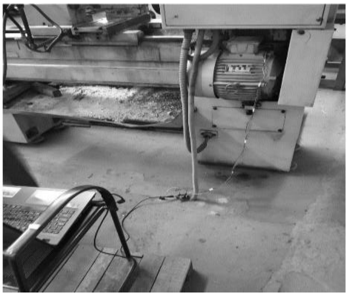
Case 1: Vibration monitoring on Induction motor of a centre lathe machine. The specification of the induction motor of a Centre lathe machine is as shown in Table 1.

Table 1. Specifications of induction motor of a center lathe

Power Supply :	415 V, 11 A
H.P	7.5
kW	5.5
RPM	1450

An accelerometer was mounted at the shaft end (Fig. 4a and 4b). As the mounting should have less damping effect and firm grip, masking tapes were used to mount the accelerometer, which was placed such that the accelerometer's Z direction is collinear with gravitational force. The machine was operated under no load condition at a particular speed.

The vibration data obtained from the machine was captured using accelerometer and pushed to the Blynk platform where the data was presented pictorially.



(a)

(b)

Fig. 4. (a) Experimental setup of Centre lathe and (b) Mounting of the accelerometer

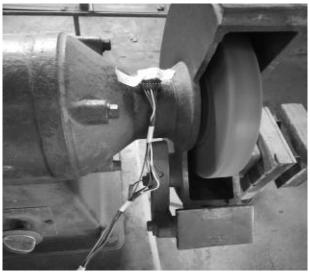
Case 2 Vibration monitoring on Induction motor of a Bench Grinding machine. The specification of the induction motor of the Bench Grinding machine is shown in Table 2.

Table 2. Specifications of induction motor of bench grinding machine

Power Supply :	415 V, 0.9 A
H.P	1
kW	0.75
RPM	2800
SIZE	250 mm

The accelerometer was mounted on the casing of the grinding wheel as shown in Fig. 5a and 5b.

(a)



(b)

Fig. 5. (a) Experimental setup - grinding wheel and **(b)** mounting of the accelerometer

Case 3 Vibration monitoring on a stand-alone induction motor**.** The specification of the stand-alone induction motor is shown in Table 3.

Table 3. Specifications of stand - alone induction motor

Power Supply :	220 V, 1A
H.P	1
kW	0.75
RPM	4800

The accelerometer was mounted at the shaft end of the induction motor as shown in Fig. 6.

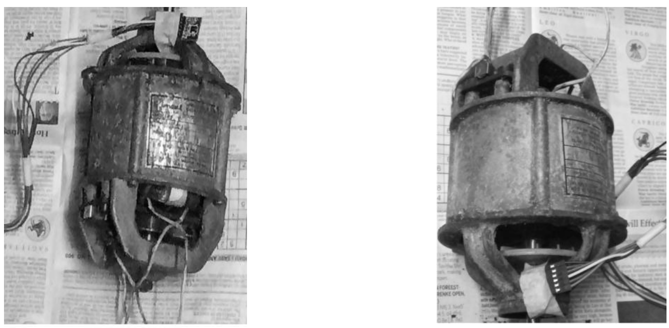


Fig. 6. Experimental setup of a stand-alone motor

3.0 Results and Discussion

The accelerometer readings obtained on performing different experiments (cases 1 to 3) were plotted on the Blynk app platform as shown in Figure 7 to 12. The Blynk platform also allows the accelerometer readings to be exported as a Comma-Separated Values (CSV) document that can be viewed by a spreadsheet reading platform. However, it becomes difficult to convert the data to real time units, as the time is a cumulative value in seconds. Hence, the readings were displayed on the home screen of the Blynk app itself along with the plots. The plots obtained for the experimental cases are follows:

Case 1 Vibration monitoring on induction motor attached to a center lathe

Fig. 7. Absolute acceleration value with graph (case 1)

Fig. 8. Landscape view of real time Absolute acceleration plot (case 1)

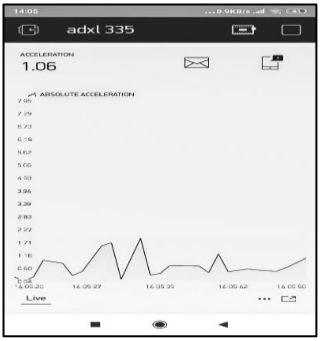
Fig. 7 shows accelerometer readings as absolute acceleration, in units of ‘g’, obtained on performing vibration monitoring on the induction motor of a center lathe machine rotating at an angular speed of 1450 rpm. Landscape view of the plot is shown in Fig. 8.

As observed from the values, the peak value was below 1g. On comparing with the IRD vibration severity chart, it was inferred that the vibration levels were under permissible limit for a frequency of 1450 cpm. As a result, no alert notification was displayed on the screen. Hence, the monitoring goes on continuously.

Case 2 Vibration monitoring of induction motor of a bench grinder

Fig. 9 shows accelerometer readings as absolute acceleration in units of ‘g’, obtained on performing vibration monitoring on the induction motor of a bench grinder machine rotating at an angular speed of 2800 rpm. Landscape view of the plot is shown in Fig. 10.

As observed from the values, the peak value is just about 1g. On comparing with the IRD vibration severity chart, it was noticed that the vibration levels were under permissible limit for a frequency of 2800 cpm. As a result, no alert notification was displayed on the screen. On comparing case 2 with case 1, it was observed that the vibration levels were slightly greater on the induction motor of bench grinder machine (case 2) as against that of the center lathe machine (case 1). This was to be expected as the angular speed of operation in case 2 was roughly twice that of case 1.



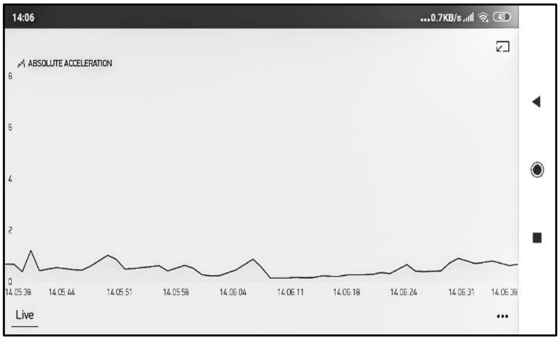


Fig. 9. Real time Absolute acceleration value with graph (case 2)

Fig. 10. Real time Absolute acceleration graph (case 2)

Case 3 Vibration monitoring of a stand-alone induction motor

Fig. 11 shows accelerometer readings as absolute acceleration in units of ‘g’, obtained on performing vibration monitoring on the stand-alone induction motor rotating at an angular speed of 4800 rpm.

As observed from the values, the peak value exceeds 2 g. On comparing with the IRD vibration severity chart, it was noticed that the vibration levels were beyond permissible limit of 1.5 g for a frequency of 4800 cpm. As a result, alert notification was displayed on the screen as shown in Fig. 11 and an email was sent to the receiver as shown in Fig.12.

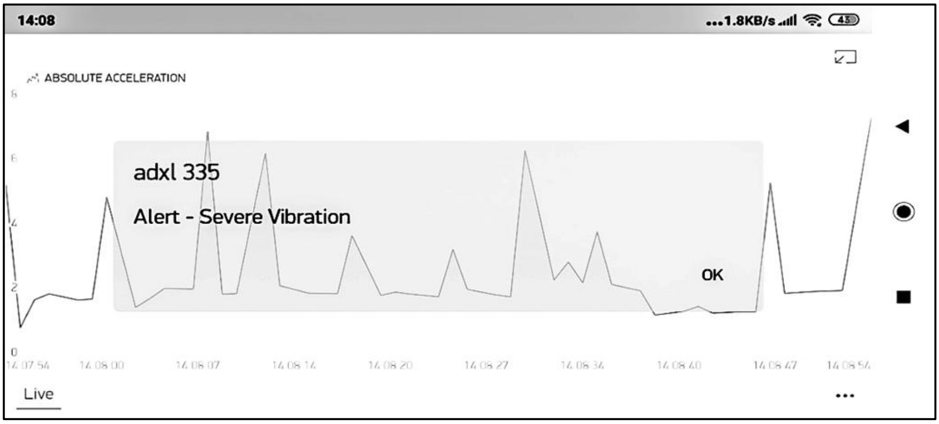


Fig. 11. Real time Absolute acceleration graph with alert notification (case 3)

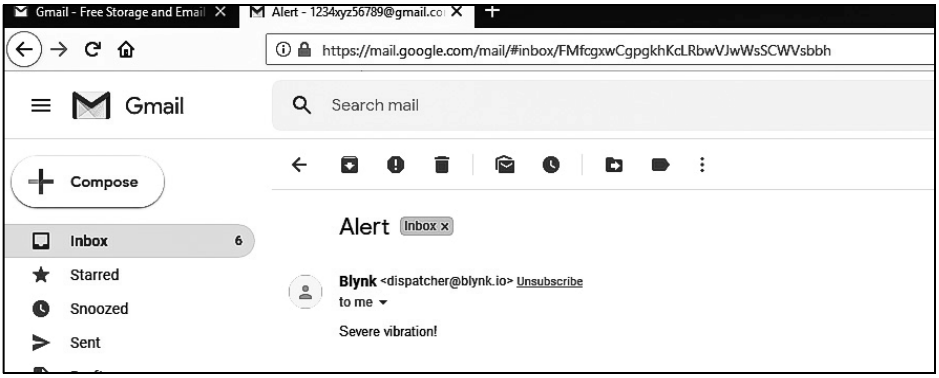


Fig. 12. Email alert notification (case 3)

The acceleration readings in case 3 were greater than that of cases 1 and 2 because the stand-alone motor had degraded owing to aging and wear. Therefore, clearances and eccentricities had developed which gives rise to severe vibration.

The conducted experiments bring out the application of a vibration monitoring system in industries for several machines running continuously and connected to internet. Whenever a fault occurs, the receiver receives a notification. The receiver on receiving the alert notification is supposed to take necessary steps in controlling vibration levels. The monitoring will still happen continuously and alert notifications are repeatedly displayed and sent to the receiver until the receiver himself resets the monitoring system and takes necessary steps towards fault diagnosis and vibration control.

4.0 Conclusions

The IoT enabled vibration monitoring system was found effective for preventive maintenance of machines. The system sends alert notification whenever the vibration exceeds the permissible value for the operating speed of induction motor.

In case of induction motor of centre lathe and bench grinder, the peak acceleration levels were below ‘1.5 g’ which is in the permissible limit of vibration severity corresponding to rotational frequency below 18000 cpm. Hence, no alert notification is sent in these cases.

In case of stand-alone induction motor, the peak acceleration level exceeded ‘1.5 g’ permissible limit corresponding to rotational frequency below 18000 cpm. The system successfully sent an alert notification by means of text message and email indicating vibration severity.

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Smart LPG Leakage Detection and Control System

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Abstract

LPG leakage can lead to disastrous and fatal consequences. This paper presents Internet of things enabled LPG leakage detection and monitoring system. A cost effective kit was developed for the purpose. The kit can detect gas leakage, controls the stove knobs and regulator valves automatically. The leakage is notified with an SMS to the user and subsequently for maintenance measures. A gas sensor which is sensitive to gases such as butane and propane is used to detect the leakage. Stepper motors were used to control the stove knobs and regulator valve.

Keywords: *LPG leakage, Gas Sensors, Stepper motors, Internet of Things*

1.0 Introduction

In India, about 3525 accidents have been reported due to bursting of LPG cylinders in 2014. The number of accidents reported in Karnataka alone due to cooking gas barrel/stove burst in 2014 is about 627 incidents. Detection of gas leakage using sensors controlled by microcontrollers is reported. The microcontroller is connected to an audio-video alarm. Buzzer and LEDs are used for indication and alerting mechanism. The system uses microcontroller which detects the gas leakage and activates the alarm when permissible limit is crossed [1]. A framework that screens the gas spill continuously with the sensors is suggested. The information is accessible progressively through internet and IOT is used to provide ongoing sensor information. Preferred position of the proposed framework alongside gas spillage identification, constant information is accessible through ongoing feed over internet [2]. A machine which includes sensor, GSM module, microcontroller is proposed. The GSM module is connected to the microcontroller to stop the main supply. The system was found to be fairly reliable, tamper-evidence and user - friendly. On a longer run, the protection value is efficient [3]. A device with LPG sensors is developed to sense the leakage of gas through the variation in temperature and alerts the micro controller. GSM module was linked to the microcontroller to provide a command to stop the supply [4]. An automated email is sent to the owner. The signal is sent to the DC motor to shut off the regulator valve [5]. Works related to use of automatic control of stove knobs with stepper motor are scarcely reported.

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2.0 System Details

2.1 Specifications

ARDUINO is an open source laptop hardware, software, software program, employer undertaking, person community that designs and manufactures single-board microcontrollers and microcontroller kit. Arduino includes Hardware component inclusive of Arduino circuit and software component with instructions. It consists of programming to manipulate the assignment and hardware. It is a tool used for controlling the venture along with commands to the circuit. In addition, Arduino can be procured easily. C -programming is used for application in Arduino.

Gas sensor module is beneficial for LPG leakage detection whether inside the domestic or in industrial regions. It is noticeably touchy to LPG, Propane and Hydrogen. Due to its high sensitivity and speedy reaction time, measurements can be taken as soon as feasible. The sensitivity of the sensor can be adjusted by means of using the potentiometer. The price of these sensors is low and is appropriate for exceptional packages.

GSM Module aides in sending voice, SMS and information facts with low strength consumption. The module is compact and can be made to suit the needs of the. Featuring Bluetooth and Embedded AT, it allows total cost financial savings and is a quick method for customer programs.

Relay is an electromagnetic switch operated with a small electric current to activate or cut off a far large electric modern-day. The heart of a relay is an electromagnet.

Stepper Motor is a brushless DC motor that rotates in steps. This is useful to get precisely positioned without any feedback sensor and represents an open-loop controller. The stepper motor consists of a rotor that is usually made of permanent magnet and its miles surrounded through the windings of the stator. After activating windings little by little in a particular order and letting a present day to waft thru them they will magnetize the stator and make electromagnetic poles respectively in order to motive propulsion to the motor.

2.2 Working details

LPG is highly inflammable and can burn everything very easily. These gases are mostly used in large scale industries, Automobiles, home appliances as fuel. The paper concentrates on Smart DCM kit that assists in gas leakage detection, automatic controlling, monitoring etc. The Smart DCM kit consists of Arduino was programmed using Arduino IDE software. MQ2 gas sensor is heart of the kit, it is used to sense the leakage of gas if the concentration in beyond 400ppm, then a signal is sent to Stepper motors which in turn are connected to the stove knobs and regulator valve. In case of a gas leakage, Arduino firstly checks for the OFF/ON position of the knobs. Secondly, if any of the knobs are in ON position, they are shut off immediately and simultaneously regulators valves are shut OFF. Relay works as a switch between Arduino and stepper motor, if leakage is sensed relay completes the circuit and charges the stepper motor to control stove knobs and regulator valve and is as shown in Fig. 1.

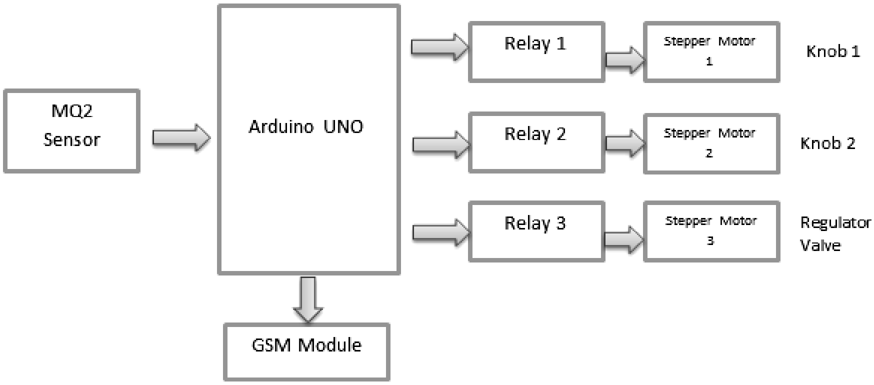

Fig. 1. Smart DCM Kit

2.3 Cause and Effect Diagram

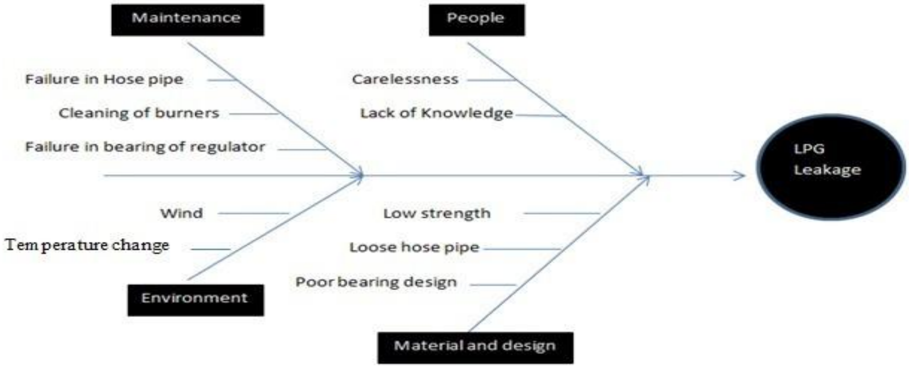

Fig. 2. Cause and effect of LPG gas Leakage

Cause and effect diagram for LPG leakage is presented in Fig. 2. Due to carelessness of users, accidents may occur. Carelessness includes improper tightening of hose pipe and regulator. If Water is boiling and overflowing on the gas stove putting the flame out might cause gas leakage. Maintenance is the main cause for any of the accidents. In the case of LPG Leakage there may be over usage of hose pipe and regulator even after their expiry date. Due to the deposition of oil and dust over the burner may lead to blocks in the burner holes which results in improper functioning of the burners. Environmental conditions like wind and temperature also leads to leakage. Every component cannot be manufactured exactly without any defects, leakage may be caused due to the manufacturing defects like quality of the hose pipe, malfunctioning of bearings and etc.

3.0 Conclusions

The proposed Smart DCM kit provides better safety measures to user in a very affordable cost. It is programmed in such a way that automatically stove knobs and regulator valve are controlled when there is a leakage. The advantage of this kit is that there is no intervention of human in leakage detection, controlling of valves and monitoring of the unit. The modalities of DCM kit is shown in Table 1.

Table 1 Cost of DCM kit

Component	No. of units	Unit cost (Rs)	Total cost (Rs)
Arduino	1	350	350
MQ2 Gas sensor	1	90	90
Stepper motor	3	100	300
GSM Module	1	400	400
Relays	1	50	50
Stepper motor driver board	1	50	50

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IoT Enabled Biomedical Waste Management System

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Abstract

Sustainable management of Biomedical waste has become an increasing concern to governments and healthcare facilities around the world. As per World Health Organization (WHO) report about 75–90% of Biomedical waste are nonhazardous, and the remaining 10–25% are hazardous. The amount of Biomedical waste produced and its characteristics depend on many factors such as type of Health Care Facilities and the specific area within the health care facilities that generates the waste, and patient flow. This research work involves conduction of an exploratory survey to identify the problems and pain points in biomedical waste management system and digitization of the biomedical waste management system using an IoT architecture. A prototype of digitized bag was developed that sends the unique ID and weight of each bag to the application database. This data can be used for multiple applications including route optimization and pilferage reduction.

Keywords: *Biomedical waste management, Internet of Things, Bio-medical Waste Management*

1.0 Introduction

Poor management of Biomedical Waste (BMW) exposes health-care workers, waste handlers and the public to infections, toxic effects and injuries. Sound management of BMW is an important part of environmental protection. A number of countries across the globe have national policies, guidelines and action plans, as well as best practices on Biomedical Waste Management (BMWM). However, the process of BMWM may vary from country to country, as some are at a more advanced level of development than others. There is a need to take account of the status of BMWM in countries in order that gaps may be identified and future support programs may be informed.

The number of Health Care Facilities (HCFs) in India is on the rise, making healthcare accessible to more people and also generating more waste in their treatment. As per Central Pollution Control Board (CPCB) Annual Report Information 2017, there are 2,38,254 HCFs in India, out of which 87,282 are bedded facilities with 20,94,858 beds. BMW is being generated at each of these facilities, collecting, moving, and disposing of biomedical waste from each of these locations is an enormous challenge. Ministry of Environment and Forests, Government of India issued guidelines governing BMW in July 1998. These

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guidelines deal with issues such as definition, categories of segregation of waste, protection and handling the waste, treatment of waste [1]. An amendment to Biomedical Waste Management (BMWM) rules was passed in 2016. The new rules simplified the classification of BMW and authorization, thus improved handling of BMW [2].

Mathur, et al. [3] discussed the need for a BMWM system, the sources of biomedical waste, its categorization and disposal. Ira F Salkin et al. [4] listed the health impact due to spread of microbial hazards and BMW. Greesham Tony et al. [5] carried out a system analysis of BMW process in clinics in Udupi Taluk in 2018. The study revealed that majority of the clinics had inadequate BMWM equipment, training and failed to meet the BMWM guidelines.

Seetharam [6] discussed the case of study of Hepatitis-B outbreak in Gujarat in 2009. Over 240 people were infected and 70 succumbed to the disease during the outbreak. The cause of outbreak was identified as use of unsterilized syringes and needles, which were pilfered from used medical equipment. A study was carried out by INCLEN Program Evaluation Network (IPEN) Study Group [7] to evaluate the state of BMWM system all over the country. Data was collected from across 20 states of India and was found that 82% of primary health centers, and more than 50% of secondary and tertiary care health facilities had inadequate BMWM system. Dr. Sushma Rudraswami et al. [8] looked into the global statistics of BMW generation. Kumar et al. [9] examined the transportation of BMW within a healthcare institution. It was found that waste bags from various locations were not being cleared on time, uncovered trolleys were in use and sharp containers were improperly closed, and only 0.66-1.12% of staff used protective equipment while handling waste.

K Usha Krishnan et al. [10] tested the efficacy of the training for BMWM. The results showed that participants felt an improvement in practices post training. Matthew et al. [11] studied the BMWM practices among healthcare workers and found that they are ignorant of sound BMWM practices and yet injury reporting was low for all groups of healthcare personnel.

Shyam et al. [12] and Soni et al. [13] implemented IoT Technology in waste management by integrating sensors which collects' information from the garbage bin for live monitoring of the state of the waste. Hong et al. [14] developed and implemented an IoT based garbage system for food waste management and the pilot project showed reduction in food waste Raundale et al. [15] discussed various technologies available to automate management and handling of BMW. IoT based sensors are proposed to collect and store data on BMW which can be used to improve the process.

There is a need for proper collection and disposal system for BMW waste. Guidelines that regulate management of biomedical waste were notified by government and regulatory bodies. But gaps exist between statutory requirements and the BMWM systems in practice. The objective of this research work is to conduct an exploratory survey to identify the problems and pain points in BMWM system and digitization of the bio medical waste management system using an Internet of Things (IoT) architecture.

2.0 Biomedical Waste Management - Process

The BMWM process, illustrated in Fig. 1, begins with waste being generated as a by-product of healthcare functions like treatment, diagnosis etc. At the place of generation, the waste is identified, segregated and disposed of into the right colored bin according to the color code shown in Fig. 2.

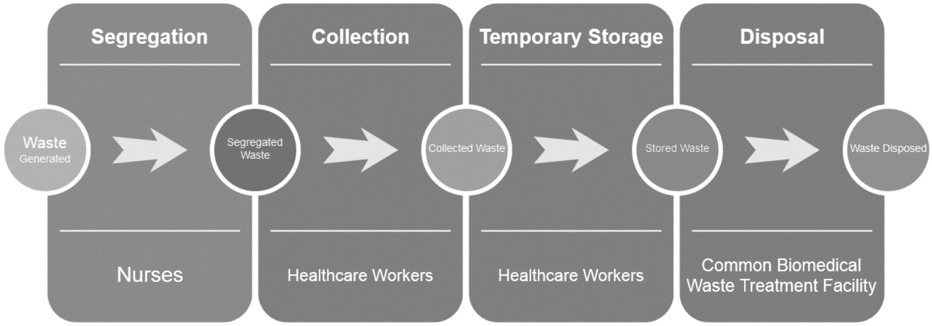

Fig. 1. Biomedical Waste Management Process

Waste from all the bins are collected and moved to a temporary storage, usually outside the hospital premises or in the basement. The waste is stored in temporary storage until time for disposal. Regulatory requirements state that waste shall not be stored for more than 48 hours [3].

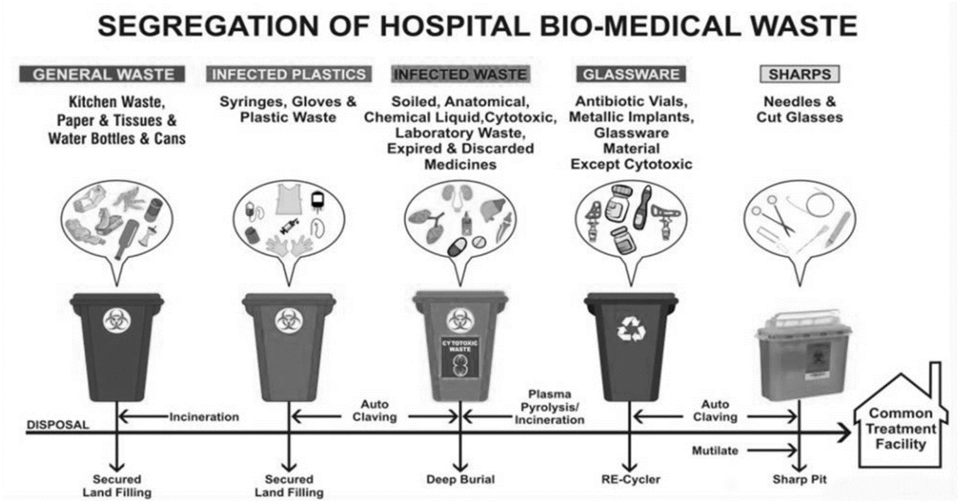

Fig. 2. Categorization of biomedical waste and its disposal methods

The disposal process may be done either at on-site or off-site facilities owned by hospitals, if Common Bio-medical Waste Treatment Facilities (CBWTFs) are not available in a radius of 75km. A bar coding system which is aimed at ensuring waste is accounted for, from generation to disposal, so that waste is not disposed of illegally or using wrong methods has been introduced by law. It also brings accountability for the waste as any bag of waste can be traced back to the hospital. Any discrepancies in the bag of waste have to be reported to the respective state pollution control board.

3.0 Exploratory Study - Summary

Initially a pilot study was carried out, that gave insights into the current BMWM system and inputs for designing and conduction of study. Final survey was conducted for a sample size of 110 HCFs and the results were analyzed for relative importance of the factors causing pain points in the BMWM process. The BMWM practices were reviewed to identify the gaps in the system, opportunity for digitization using IoT architecture and exploring possibility of integrating the current KSPCB bar/QR coding guidelines.

The HCFs were asked to rate the awareness of risks among the person(s) who directly handle BMW. The average rating was 70.68 with a standard deviation of 21.48. It was observed that large HCFs have a higher average rating than small HCFs.

The regulatory requirements state that BMW must be stored in the HCFs for a maximum of only 2 days. However it was observed that most of small HCFs are storing BMW for up to 3 days with only 1.4% with everyday collection. The HCFs do face some problems with the segregation of waste. Training of health care workers on BMWM is mandatory by law. The larger HCFs have planned their internal waste collection periodically instead of collecting only when the bins are full. The temporary storage of BMW is the final process carried out within the HCF. This stage involves keeping the BMW in a specially designated area, usually outside the premises of the HCF.

Stratifying the results into small HCFs and large HCFs, it is observed that small HCFs have more of a problem with lack of space and long storage times (due to infrequent collection by CBWTFs). Mann Whitney U test was performed on the data to test if there is actually a difference between small and large HCFs. The results at a confidence level of 90%, show that there is a difference in the median response for small HCFs being higher than the median response for large HCFs. Therefore they face more of a problem with CBWTFs collection frequency.

4.0 Development of IoT Enabled BMWM System

Findings from the exploratory study reveal that the improved collection, transport and disposal are the fundamental requirement for resolving BMWM problems. The overall IoT architecture developed is shown in Fig. 3.

4.1 Design Input Examination:

The exploratory study provided some useful information about the system such as how often the CBWTFs visits the hospital, number of segregation points in the hospital and common difficulties and problems faced by the hospital. It was found that very few hospitals had systems in place that adhered to the guidelines set by the government. Two Hospitals were identified and the existing process of BMW process was studied in detail to understand the process and requirements for IoT based BMWM system.

4.2 Functional and hardware design

IoT based BMWM system functional design was carried out. The components, modules and subsystems of the IoT architecture were listed.

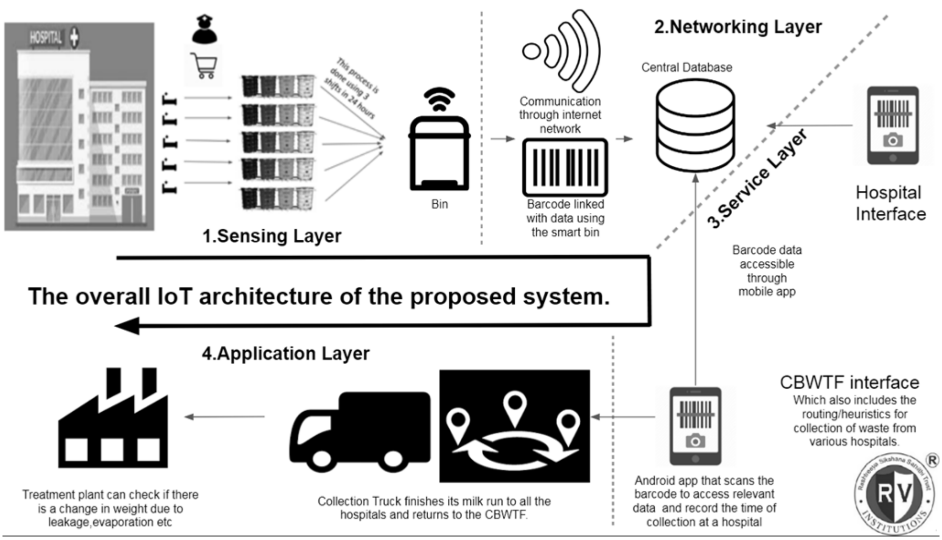

Fig. 3. Four layered IoT Architecture

4.3 Software design

The software was designed such that it has separate logins for HCFs and CBWTFs. Once logged in the user can scan the barcode using the camera to save the weight of that bag and link it to the bag ID. The data is transferred over the Wi-Fi network and stored at the central database. Separate mobile app interfaces was developed for HCFs and CBWTFs to ensure smooth operation of the system and shown in Fig. 4 and 5.

App flow design for CBWTF interface: The app that is developed is called BioCollect and works with two different interfaces, one for the hospital employees and another for the CBWTF employees. The app interface is designed in such a manner that it is easy for any personnel to understand and navigate through the app. The user has the option to register himself / herself if it is a new user or just enter the login credentials (email ID and password) and click on login to enter the app. Once the user has logged in, the dashboard is displayed. The dashboard contains four options to choose from for the user. The user can click the first option to view the BMW records already available and receive a report of the records which can be downloaded or printed date wise.

The second option on the dashboard is the option to view the CBWTF upcoming scheduled visits, last visit details etc. This will aid the CBWTF to keep track of all their waste pickups and drops. The third option on the dashboard is the QR/barcode scanner. This will open the camera scanner and wait for the user to scan the QR/barcode. Once it is scanned the first time before pickup, it will save the weight of the bag. Afterwards, when the bag is scanned just before it is sent for disposal it will check the value of the weight stored and display the pilferage percentage. The last option is the routing heuristics, which help the CBWTF driver take the optimal route while going from hospital to hospital to pick up the biomedical waste. The above app interface is illustrated in Fig. 4 and 5.

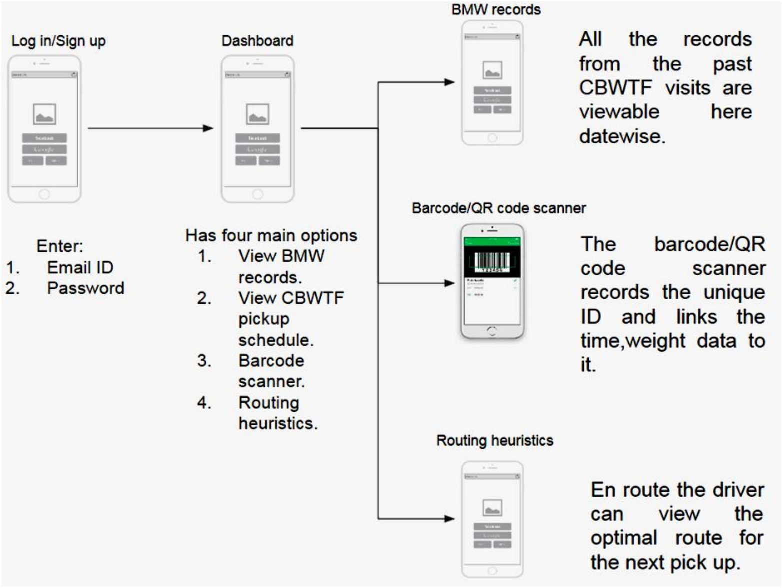

Fig. 4. Mobile app flow for CBWTF interface

App flow design for Hospital interface: The app flow for the hospital interface is very similar to the CBWTF interface in the sense that the login credentials and the login page as well as the register new user page remain the same. Once the hospital user has logged in, the user can view the three main options available. The first option is the option to view all the BMW that has been moved from the hospital to the CBWTF in the past and the option to view it in a report format date wise. The second option is to open the QR/barcode scanner and record the weight of the bags in case the initial weight check is done the hospital. This functionality is added to the hospital interface to make sure that either the hospital or the CBWTF can do the scanning and recording of weight as per whatever the understanding is between the two parties. The third and final option available to the hospital personnel on the dashboard is the option to view the CBWTF scheduled upcoming visits in a date wise format so that appropriate actions are taken from the hospitals side to prepare for the upcoming CBWTF visits.

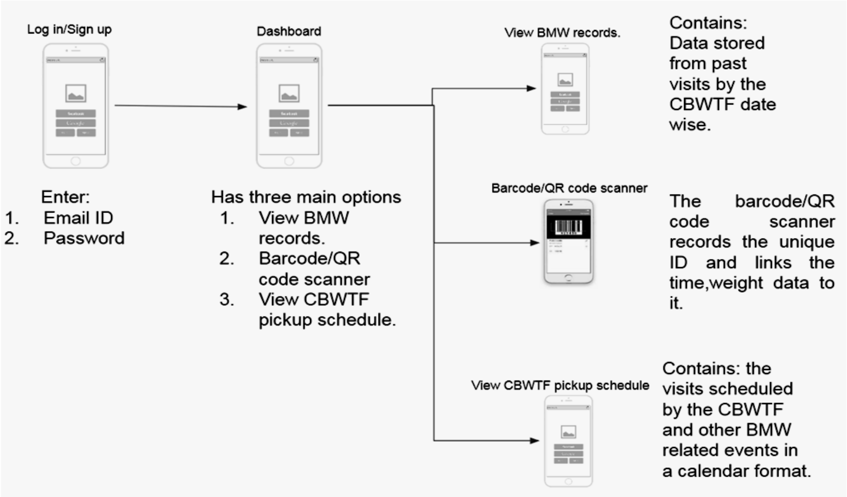

Fig. 5. Mobile app flow for hospital interface

4.4 Prototype Development

The prototype (shown in Fig. 6) houses the 4 load cells, HX711 amplifier, ESP32 Wi-Fi module, load cell combinator, Arduino UNO and the wiring. The ARDUINO board was coded on the IDE platform to enable the data sensing, data relay and data calibration.

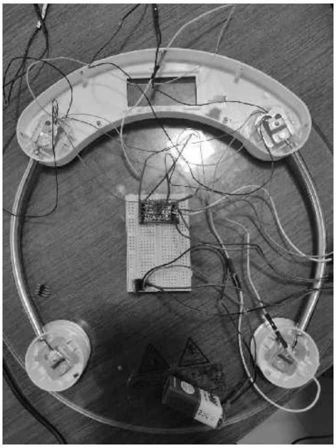

Fig. 6. Prototype circuitry

A specific casing design was developed to house the prototype and make the whole circuit compact, allowing it to be highly portable. Bio Collect app that facilitates the digitization of the weight collection routine, also complying with the required biomedical waste management guidelines was developed. The guidelines by the government require HCFs to have a digital record of the weight generated at the facility and the disposal agency to adopt a QR code or barcode scanner app to log the weight collected and later be able to check any possible pilferage. The integration of hardware and software leads to the total digitization of the BMWM system. The hardware components function to sense the weight data, calibrate and relay to the app the sensed data over a Wi-Fi network. The app allows for the scanning and logging of the relayed data. A digital dashboard for the specific stakeholders is provided in the app to display a recent history of waste collections for a better understanding to further improve biomedical waste management.

5.0 Results

5.1 Conformity to government guidelines.

The digitization of the bio-medical waste management system has been beneficial for both HCFs and CBWTFs to adhere to the government guidelines.

1. The barcoding system has been accommodated through the use of a bar/QR code scanner in the app which identifies the unique ID of the bag, reads all the static data stored and links the weight of the bag to the ID.
2. The policy which states that if bags undergo more than a 10% change in weight due to pilferage the amount of pilferage and time of occurrence has to be reported has been incorporated by the proposed system through time stamp recording and alert messages after the final scanning in the project above if the pilferage exceeds 10%.
3. It is mandated that all the data regarding bio-medical waste collected by the CBWTF be stored by the CBWTF for a stipulated period of time on a web based platform which is being done as the data regarding the waste collected by the CBWTF is stored on the apps server until it is requested to be cleared by the CBWTF.

5.2 Ease of use

The data generated by weight modules and stored on the web platform has facilitates the following:

1. There is a very high amount of data visibility as the exploratory study revealed what kind of data is relevant and important for both the HCF and CBWTF.
2. The data transparency factor is also vastly improved due to the fact that it can be easily accessed by any personnel who has the app and has registered on the app with his email ID and password.
3. Automation of the recording process has reduced the number of personnel required for this process to one. A single person can place the waste bag on the weighing module and then scan using the mobile app to record the waste in that bag onto the online platform.

6.0 Conclusions

The main pain points in BMWM activities segregation, collection and storage of wastes and noncompliance of government guidelines were addressed by the IoT enabled BMWM system. Implementing IoT based BMWM system has led in increasing operational efficiency and decreasing BMWM costs in HCFs. Web based platform facilitate tracking the bio-medical waste by multiple parties such as the government bodies, the hospital and the CBWTF.

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Appendix-Exploratory Study

The exploratory study of BMWM system was conducted and the Fig. 4 illustrates the steps in the study.

Survey objectives

- To identify the pain points in existing Biomedical waste management system.
- Digitization of the bio medical waste management system using an IoT architecture that integrates the current KSPCB bar/QR coding guidelines.

Design and Development of Survey Queationnaire

- Questionnaire - 6 sections :
  - General information
  - Information on risk awareness and disposal methods
  - Factors affecting segregation, collection, movement and storage
  - Market perception
- Likert 5 point scale used to measure factors.

Content Validity and Pilot Study

- Experts examining the survey items for ambiguity and redundancy
- Survey answered by hospital administrators in charge of biomedical waste management

Administering Questionnaire

- Questionnaire administered online on smartphones by hospital administrators
- Total Hospitals Approached - 170
  - Response received - 110
  - Rejected questionnaires - 60

Data Analysis

- Relative importance of each factor in the three categories
- Data stratified into Small HCFs and large HCFs. Differences in median of factors for the two subsets tested using Mann - Whitney U test.

Digitization model

- Selection of 2 hospitals
- Brainstorming Session
- Decision to develop IoT model for BMWM

IoT product development

- load cells that read the weight signal,
- an amplifier to convert the signals to a digital format,
- a WiFi sensor
- module to transmit the data via a WiFi network to a central database
- CAD model
- Prototype development
- Android development

Fig. A1. Steps in conduction of the study

Development of Survey and Conduction of study

The survey questionnaire was structured on a framework for rapid assessment of BMWMs, developed by World Health Organization (WHO). The survey questionnaire contained items that categorized the HCFs, as private or public and also based on the number of beds in the HCFs. Questions with Likert scale were used to test participants' agreement to certain factors causing problems in various steps of BMWM process in the HCFs. Further, the HCFs were asked about their perception of IoT enabled BMWM system, their interest in implementing such systems. These questions were designed to evaluate the HCFs readiness for digitization or automation of BMWM. A convenience sampling approach was used for HCFs in geographical regios covering Bangalore North, Bangalore South and Bangalore East. Anonymity was ensured in the surveys. 110 responses were collected. The respondents were approached personally and the responses were recorded online on smart-phones.

Study Findings

The complete set of responses was first analyzed and descriptive statistics for various types of questions were computed. The responses were stratified based on capacity of HCFs. Complete statistical analysis was then carried out on the two subsets. For the Likert scale type data Kruskal Wallis and Mann Whitney U test (non-parametric tests) was carried out on samples from both subsets to test if the results were statistically different from each other. Among the respondent HCFs, 101 were from private HCFs and 9 were from the public sector. For analysis, the HCFs were subdivided into small HCFs (Clinics and hospitals under 30 beds – 68% of respondents) and Large HCFs (Hospitals with more than 30 beds – 32% of respondents).

The HCFs were asked to rate the awareness of risks among the person(s) who directly handle BMW. The average rating was 70.68 with a standard deviation of 21.48. Table 1 shows the summary of the responses recorded. These figures are however the perceptions administrators with respect to the awareness of their employees. These numbers need to be higher as the risk posed by BMW is really high, including contracting fatal diseases and infections. One can observe that large HCFs have a higher average rating than small HCFs.

Waste Collection Frequency

The regulatory requirements state that BMW must be stored in the HCFs for a maximum of only 2 days. However it was observed that most of small HCFs are storing BMW for up to 3 days as the waste is being collected by the CBWTFs once in three days, as shown in Table 1. Most of the Small HCFs have collection frequency of every three days, with only 1.4% with everyday collection. However in large HCFs collection was every 2 days for over 75% of them. The waste collection frequency can be increased using IoT technology to track fill level of bins and optimizing collection routing.

Segregation of BMW

The respondents were asked to record on a scale of 1 to 100, to what extent they agree with the statement "There is trouble in identifying the right bin to dispose the waste in" and the results are shown in Table 1. One can observe from the frequency distribution that some kind of clustering of responses are on the scale. It can be inferred that HCFs do face some problems with the segregation of waste. The perception is that human error and lack of experience are the major causes of this problem, and cost is not a significant factor. This should mean that segregation issues should naturally reduce as employees get experienced on dealing with the various types of waste. Training is mandatory by law. Visual aids at the point of segregation like charts showing the right segregation can be used to aid decision making for segregation.

Table A1. Summary of the findings

	All HCFs	Small HCFs	Large HCFs
Awareness rating			
No. of participants	108	74	34
Average	70.68	68.16	76.24
Mean Absolute Deviation	17.16	18.80	12.99
Standard Deviation	21.48	21.10	16.34
Waste collection frequency in %			
Everyday	26.5	1.4	51.6
Every 2 days	26.0	26.2	25.8
Every 3 days	39.2	59	19.4
Weekly	8.3	13.4	3.2
Segregation of BMW (0 - Disagree, 100 - Agree)			
Average	38.44	54.2	22.68
Mean Absolute Deviation	23.47	25.62	19.63
Standard Deviation	25.67	22.87	20.69
Collection of waste, opinion (0 - Disagree, 100 - Agree)			
Average	31.18	52.12	18.62
Mean Absolute Deviation	19.07	17.12	22.02
Standard Deviation	23.32	18.02	23.56

Collection and Storage of Waste

The collection of waste in color coded plastic bags from various bins across the facility and then moving to a central location for temporary storage. It is observed that majority of the respondents are in 0-30 % band of the scale. Small HCFs usually have little to no trouble with collection of waste as the bins are less in number. So it is easy to track waste and collect regularly from all locations. However, it becomes significantly harder as the size of HCF increases. Tracking of waste from hundreds of bins in large facilities becomes an operational challenge. And number of healthcare workers increase leading to increased cost of operations.

The primary factor is considered to be human error, an oversight in collection from bins which is the reason for irregular collection. Lack of information on the amount of waste collected in bins and may seem like a major issue in collecting of waste in large HCFs. But the survey results say otherwise as larger HCFs have already planned their internal waste collection periodically instead of collecting only when the bins are full. Therefore, information is not considered necessary for collection of waste from bins.

The temporary storage of BMW is the final process carried out within the HCF. This stage involves keeping the BMW in a specially designated area, usually outside the premises of the HCF. Yet, simple storage of waste can have a lot of problems. Some factors and their perception are illustrated in Fig. A2. Stratifying the results into small HCFs and large HCFs, it is observed that small HCFs have more of a problem with lack of space and long storage times (due to infrequent collection by CBWTFs). To test if there is actually a difference between small and large HCFs, Mann Whitney U test was carried out on the data and are shown in Fig. A3. Based on the results of the Mann Whitney U test, it can be said that at a confidence level of 90%, that there is a difference in the median response for small HCFs being higher than the median response for large HCFs. Therefore they face more of a problem with CBWTFs collecting waste from small HCFs every three days and once a day for large HCFs, as mentioned before.

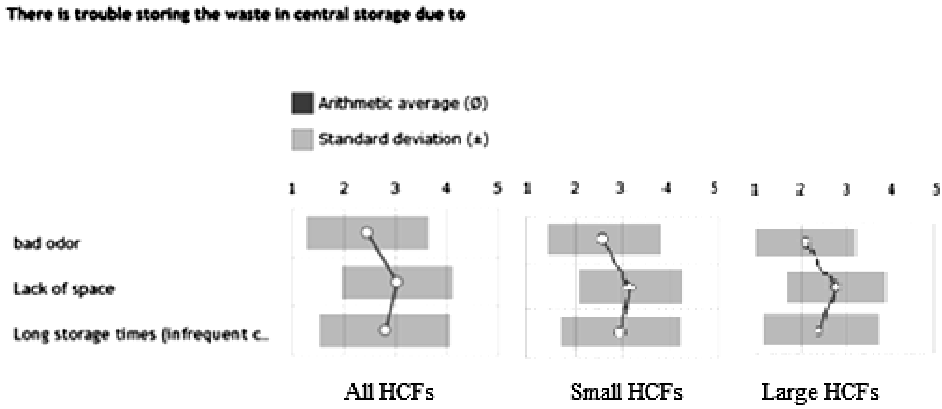

Fig. A2. Issues in storage of waste

Results for: Hospital Higher.MTW

Mann-Whitney Test and CI: Lack of space_Higher, Lack of space_Lower

```
                      N  Median
Lack of space_Higher  34  2.5000
Lack of space_Lower   73  3.0000


Point estimate for η1 - η2 is -0.0000
95.0 Percent CI for η1 - η2 is (-0.9996,0.0001)
W = 1610.5
Test of η1 = η2 vs η1 ≠ η2 is significant at 0.1322
The test is significant at 0.1143 (adjusted for ties)
```

Mann-Whitney Test and CI: Long storage tim, Long storage tim

```
                                    N  Median
Long storage times (infrequent     34   2.000
Long storage times (infrequen_L    73   3.000


Point estimate for η1 - η2 is 0.000
95.0 Percent CI for η1 - η2 is (-1.000,-0.000)
W = 1580.0
Test of η1 = η2 vs η1 ≠ η2 is significant at 0.0874
The test is significant at 0.0783 (adjusted for ties)
```

Fig. A3. Mann Whitney tests

Opportunities for IoT in Building Smarter e-governance Systems

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Abstract

Technological advancements have provided a great opportunity in making transparent decisions in various fields of civilization, especially in e-governance. E-governance systems are expanding their range of applications for the citizens and businesses by adopting the Internet of Things (IoT). The coordination among various IoT devices and systems are the key to build smarter E-governance. Smarter e-governance systems have variety of use cases which includes public health sectors, banking sectors, and life sciences mainly in agriculture, farming, and forestry. It has also increased the intelligence of security, transport, and utility services. Despite various developments in IoT technology, there are still a number of research challenges in this domain of smarter e-governance with IoT. This paper identifies impacts of IoT to form a smarter e-governance application, followed by a review on IoT initiatives taken by e-governance across the globe. It is understandable that IoT will have a dominant impact on e-government services in the future, and the smarter e-governance can leverage IoT devices to offer service which will be efficient, shareable, on-time and transparent to the citizens.

Keywords: *Internet of Things, Internet of Things, Smarter e-governance*

1.0 Introduction

Governance is understood as a “manner of governing a state” which means the ability of the government to ensure effective and transparent administration and when it comes to e-governance, it emphasis more on Information and Communication Technologies (ICT) and it creates a new avenues for communications for the expansion of the appropriate e-government structures [1].

E-governance has become a solution, providing better communication between the government and the citizens. Today, technologies such as Big Data, Internet of Things (IoT), Artificial Intelligence (AI) and Cloud Computing (CC) are leading us to develop smart e-governance applications for core governmental sectors like Agriculture, Forestry, the Environment and Food Technologies, Health Care, etc. For a country like India with a vivid culture, diversified languages and large population, deploying a trustworthy, secure, efficient and

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smart e-government systems is challenging, yet always been encouraged by national governmental agencies.

National Informatics Centre (NIC) was established in the year 1976 with the financial support of the United Nations Development Program (UNDP) and this act was a major step in the execution of e-governance in India [2]. After this event many e-governance initiatives were set in motion at national and state levels. The government flagship initiatives such as Digital India, Make in India and Smart Cities, are playing a role of key enablers for these public services.

1.1 Internet of Things (IoT) and its expansion

The Internet of Things (IoT) is the advancement of the internet services over a network of interconnected computers and all other nodes which can access internet. IoT increases the presence of Internet by providing coordination among every device for the exchange of information and making devices to respond to the desired situation via embedded systems. The interconnected objects in IoT are assigned with IP address which collects and transfer the data without manual assistance. These objects contain embedded electronic system collaborated with some technologies like the radio frequency identification (RFID), wireless sensors with existing LAN / WAN networks [3]. The embedded technology in the objects helps them to interact with the external environment and to take effective decisions to become smart.

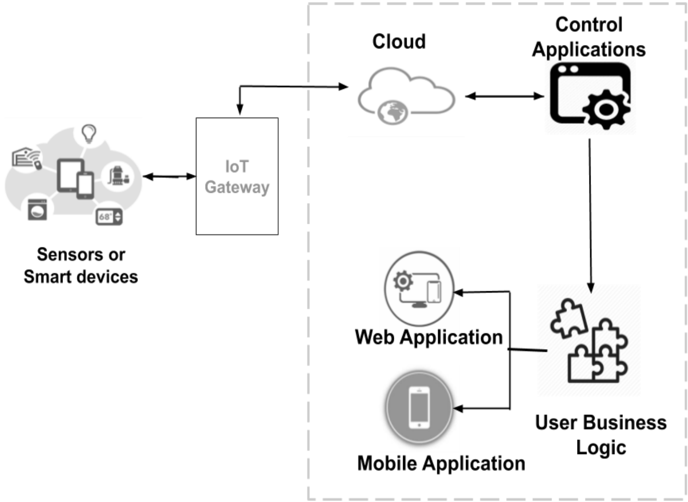

Fig. 1. Overview of IoT Architecture

The ‘thing’ in IoT could be an automobile with built-in-sensors or a person with a heart monitor. Data collected from the things are passed to the cloud services and vice versa where data is stored through the gateways. IoT gateways provide filtering and data pre-processing to reduce the amount of data and also impart control commands going from the cloud to the things (Fig. 1).

Cloud facilitates secure data transmission and also assures compatibility with all the protocols supported by IoT gateway. Control applications send commands and alerts the sensors or devices, like, if the result from sensor show that soil is dry then the watering devices or system will get commands to water the plants. These control applications can be designed on a rule-based or machine learning-based, which depends on the business requirement of the IoT application [4]. A user application connects users with IoT devices and also gives the benefits to the users to regulate or monitor their smart devices.

1.2 Need for IoT and its implications

Today, industries require a great revenue management system to reduce waste, loss, and cost. If there exists a device that can communicate and gather data without any human involvement then many things can be tracked and controlled. This is precisely what the IoT platform does. It enables the devices to identify, observe and understand the situations or surroundings. IoT connects its users with the application having on and off switch functions via internet and serves a much better way to the people to control their environment. This makes the communication and remote manual control as the two ultimate goals of the IoT devices.

There are hundreds of IoT applications which are being recognized by different industries, they can be logically divided into two categories [5].

Category 1: This category is about averaging the data that gets collected by different sensors and smart devices. Data mining for patterns and trends is done on this data for useful marketing information. For example, store/website tracking which includes the path from where you visited the store, at which division of the store you spent the most time and even what type of materials you searched at the store and picked.

Category 2: In this, IoT plays the role of remote tracking, routing, and commanding device. This means IoT applications of this category are not about data mining of user practices but relatively they extend the automation and communications between IoT devices as well as between devices and nature. For example, IoT enabled weather updating device can inform about the forthcoming weather conditions and can change users room temperature accordingly.

Dynamic interactions between internet enabled nodes created through IoT devices leads to a better resource utilization and optimization. Energy utilization and responding to the information to minimize the resource allocation can be achieved effectively by making use of IoT. Item tracking, which is done with barcode and manual steps can be replaced in the future by IoT enabled smart tags, near-field communication (NFC) and RFID to globally track all kinds of items.

IoT system strengthens the device to device communication resulting in a long-term efficiency for both the IoT companies and the users. More information flow will lead to the analysis of large trends in the data to improve the features of the device which further reduces the cost of implementation and time. When devices can represent themselves digitally, they can be controlled from anywhere and this greatly reduces human efforts.

2.0 Smarter e-governance

Presently, governments around the world have realized the potential benefits of providing integrated services to their citizens using internet as their tool. Furthermore, they are also fully aware of the need for transforming themselves to smarter government as the emergence of newer technologies are allowing the citizens to connect with their government at very ease and decision-making procedures can be effectively improved by processing the data generated by these newer technologies.

2.1 e-governance versus smarter e-governance

Nevertheless, the concept of e-governance is fizzing from last few decades, there are many works going on to forecast the benefits of smarter e-governance in modern service delivery to the citizens and for the public administration by the government. This section provides the major difference between e-governance and smarter e-governance.

E-governance is an automation and technology-driven relationship between citizens and their government with respect to interaction and deployment of various policies using internet [6]. On contrast to e-governance, “smarter e-governance” refers to the deployment of different business processes with corresponding technologies so that information can seamlessly flow across various sectors of government to provide best services to the citizens [7]. To understand it more clearly it can be stated that smarter e-governance is an expansion of e-governance which involves applying information and smart technologies across multiple governmental domains to generate meaningful value to the governmental services. As people are relying mostly on technologies these days, smarter e-governance involves expansion and collaboration of various technologies to gain maximum advantages out of it.

The aim of e-governance is to enhance the use of information technologies to provide efficient interface with the citizens and businesses. In turn, to achieve transparency, accessibility and finally growth of revenue [8]. E-governance model focuses on eCitizens, eServices and eSociety. eCitizens and eServices involves usage of innovative technologies by the government to interact with their citizens and eSociety is to build external relationships with governmental agencies, public agents and so on. Contrary to e-governance model, smarter e-governance model focuses on citizen participation, information transparency and collaboration of newer technologies. This involves formal circulation of information and ensuring that citizens participate in governmental decisions and feel free to give feedbacks. Smarter e-governance is citizen directed which aims at providing personalized information [9]. Fig. 2, manifests that the smarter e-governance extends the concepts of e-governance for better resource utilization to provide greater services to the citizens.

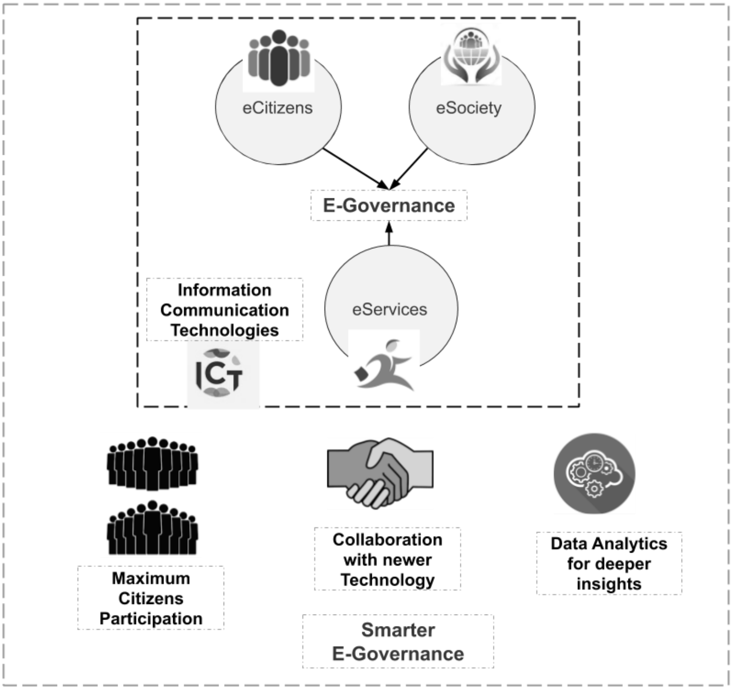

Fig. 2. *e-governance and Smarter E-governance*

It is understood that e-governance and smarter e-governance are related yet comparatively different terms of government. On its role, e-governance implies using digital tools and technologies for effective, transparent and efficient services for the citizens and private or public business and smarter e-governance involves leveraging innovative technologies and business models for making smarter decisions for the well-being of the citizens.

2.2 IoT in e-governance

E-governance initiatives towards different usage scenarios of IoT enabled solutions will make smarter e-governance for citizens. IoT enabled industry-agnostic can be deployed in the manufacturing, automobile, educational, healthcare, agriculture, banking & insurance, logistics sectors, etc. It will lead to identified citizen services, in turn, improving the efficiency and effectiveness in the communication between government and its citizens and other stakeholders involved.

There are several ways in which IoT enabled smart devices can impact the working of e-governance. Like in India, where agricultural land patterns are very different and global solutions do not typically work, IoT enabled automated systems can play a crucial role. It can be used in all aspects of agriculture from soil testing, tilling, seeding to post-processing. Coming to Safe

Water Networks which aims to provide safe drinking water, IoT solutions can be used to get real-time data to anticipate water shortages in rural areas. Further, IoT solutions can be used to track the cash levels in ATMs and also to track the banking agent's activities thus improving the banking infrastructure.

In the energy utility sector, millions of meters could be connected to form smart meters which can extend to utilities like water and gas, thereby reducing distribution and transmission losses. IoT can be used for monitoring the petrol/diesel generators for fuel usage, power output, and other parameters. IoT enabled mobile POS (Point-of-Sale) cards can be used in multiple cases like fair price shop payments or Aadhaar linked payments. IoT enabled wearable devices and sensors can give insights on medical effectiveness by monitoring pulse, heart, walking, and other health data. Remote monitoring of various medical equipment is also possible which will reduce the possible downtime. IoT could be used for fire detection in forests and rural areas. For instance, a set of sensors could be adopted to monitor a forest for identifying fire events. Mobile IoT devices, particularly unmanned vehicles, could also be extremely valuable tools for fire protection.

Mobile IoT devices are capable of generating fire alerts in case of fire detection in residential areas or in forests. These could assist emergency management authorities for taking proactive decisions. IoT based meteorological systems can give precise and frequent weather updates and in case of intense weather phenomena it can generate alerts. E-government services under environmental sector could also involve IoT devices for the auditing and follow up of waste management and also for the pollution converging from residential or industrial activities.

The advancing connectivity via IoT enables changes in every sector of the country and IoT enabled e-governance services will lead to better access to public services. Reduction of congestion and queues due to traffic, improved and affordable healthcare, lesser environmental impact, improved safety and security for citizens, etc can be acquired with IoT adoption in e-governance.

2.3 Impact of IoT on smarter e-governance

IoT systems can bring varieties of benefits including real-time measurements and analyses of historical data over time collected from different sensors. IoT devices and the interaction between them can benefit e-governance by providing on-time, required data to the citizens and at the same time required information could help government to take right decisions at the regular time intervals [10].

There are at least four ways in which IoT will impact government bodies. First, it will enable government employees to be more productive since the technology can be used to automate many tasks. IoT devices can take significantly more complex tasks and interact with people, machines and the physical environment to discover new insights that will improve the quality of internal local government operations. Second, the IoT will make a more responsive and agile government. IoT solutions can answer citizen's questions on a timely basis and also improve the delivery of services to the citizens. IoT will allow people to interact more naturally with digital government services, increasing citizen participation.

Third, IoT solutions will provide a new vision for managing the public and private infrastructure which will lead to the reduction of labour cost. In case of infrastructure maintenance, embedded wireless sensors can provide data required for the event and load managements [11]. It will lead to better access to the public services for the citizens. Fourth, it will promote government transparency. Sharing and collaboration of sensor generated data between various divisions of government will make the working of e-governance more transparent to the citizens. From the government point of view, IoT will lead to a quality of life, economic growth, health and safety, sustainability of energy and mobility for its citizens. The smarter e-governance means best engagement of all the shareholders across the country; therefore, government must focus on adapting IoT solutions at the greater extent in both private and public sectors.

3.0 Proposed IoT-Based Models for E-governance

IoT enabled government always extends the quality of services to their citizens by providing inventive smart provisions in various domains such as health, transportation, energy, energy, defence, smart cities and so on. This section reviews some of the IoT initiatives taken by e-governance across the globe.

3.1 Road and Water management in Netherlands

"Rijkswaterstaat" (RWS) is a member of the Netherlands Ministry of Infrastructure, responsible for the design, construction, and maintenance of infrastructure facilities. Over the years, RWS has placed several sensors on the road for many purposes. Embedded loops of sensors in the road surface detect the movement of vehicles which is used for optimizing traffic signal timings accordingly [12]. "Weigh in Motion" facility of RWS acts as a monitoring point on the roads to weigh the heavy vehicles. It helps the government to take proper actions against overloaded vehicles.

National Water Management Network of Netherlands comprises of more than 400 sensors to collect data for measuring a wide variety of hydrological data for water levels, water flow levels, water temperature, water velocity, etc. These sensors give more detailed weather forecasts and helps for long term analysis for rising sea levels detections, etc. The Netherlands has deployed smart levees [13] for detection and warning system to prevent the overflow of a river. Benefits of IoT in smarter e-governance in the Netherlands can be summarised with improved effectiveness of services, health and safety measures, and tactical improvements of services to the citizens.

3.2 Transport and Traffic Management in Spain

In the city of Madrid, Spain [14], a control centre called Emesa has been built to monitor the underground traffic of a busy highway with extended tunnel, M30. According to M30, an average of 1.5 million motor vehicles passes the highway on a daily basis. To manage this significant number of vehicles, incidents and maintenance works, the Control Centre features the most advanced IT systems, which guarantee a safe and smooth traffic flow. The control is conducted from different posts in the Primary Control Centre, as well as from the Backup Control Centre.

Some systems that stand out among others in this project are the Automatic Incident Detection system, the energy remote control, CCTV and several Supervisory Control and Data Acquisition (SCADA) systems. The SCADA systems allow the control centre to supervise and run all the facilities, including signals coming from security systems, electromechanical installations and traffic. Multi-lane speed cameras are also installed at various spots of the highway which can observe 6 lanes of both directions at the same time. Exit tunnel of M30 highway have emergency exist at every 200 metres and Emesa keeps on checking the status of these exits at regular time interval.

3.3 Crime prevention in United State

In United State, Police Department of Chicago has combined its forces with the University of Chicago Crime Lab to bring out the data analysis at real-time [15]. This project aims to increase the effectiveness of police work across the city and to reduce the crime rates at the same time. Under this project, areas with ShotSpotter are monitored with license plate recognition systems. These systems are very carefully built to locate the exact location and time when gunshots were fired. The police squads are using a web-based patrol management system called Hunchlab that can predict where and when crimes could happen and also can suggest the best way to respond to such crimes.

Canadian Border Service Agency (CBSA) tested An Automated Virtual Agent for Truth Assessments in Real Time (AVATAR) to help border security police. This will help the police to verify if the travellers are legally entering the country's border or not. Motion and sensor technology along with eye detection software are being used by the police department to detect psychological and physical behaviour of the suspects to explain if suspects are telling the lie or not. Use of analytic tools helps to identify, classify and match stored surveillance data. This project has built a trustworthy environment between the citizens and the government.

3.4 Agriculture in China

In the Internet-based agriculture park of Shishan Town, Haikou City of China, IoT based company named Sun's has deployed IoT based devices and sensors which runs on specialized algorithms to detect the moisture level in the soil and environment. These sensors work by considering the cool and humid environment of the local areas. Smart irrigation systems are also installed in this park to water the soil and plants according to their requirements. This project has led to a dramatic reduction in irrigation problem in this area. Furthermore, it has been stated by the company that earlier at least 10 workers were required to irrigate an area of 100 mu (1 mu = 0.0667 hectares) of vineyard but after the implementation of this project the same work can be done by one person [16].

It has been recorded that by using the drip irrigation system citizens can save up-to 70 percent of the water required for watering the crops or plants. Furthermore, 60 percentage of fertilizers can be saved by just placing the fertilizers to the root areas of the crops. The company, Sun has expanded its business over to 10 more provinces in China, providing IoT based technologies for saving water and fertilizers. This project has given a new way to test, alert and make adjustments for the best of plant development environment.

3.5 Health management in Singapore

KK Women's and Children's Hospital (KKH), in Singapore collaborated with UnaBiz, which is a company aimed to provide end-to-end Internet of Things (IoT) solutions. The main project of this company is to deploy low-powered IoT sensors for temperature monitoring and checking humidity of the environment [17]. Under this project more than 100 temperature and humidity sensors were placed in KKH at different locations within the hospital premises, especially in intensive care units and patient wards. After the deployment of this projects, hospital staff no longer have to maintain daily temperature logs manually and they can use that time for the well-being of their patients.

4.0 Smart e-governance in India

In India, industrialisation and urbanisation is expanding very rapidly and it is estimated that in the upcoming 15 years, around 200 million people of the country will shift to the urban areas [18]. Over the years many governmental plans have been proposed and many projects have been implemented to achieve smarter e-governance in India. According to the United Nation's E-government Survey 2018 [19], India was ranked 96 whereas in 2014, India ranked 118. This hop of 22 place shows that digital technologies have already started impacting the governmental sector of the country.

4.1 Recently deployed e-governance initiatives

During the 5th Digital India Summit on 28th June 2019, many technologies were discussed which are influencing the government at bigger extent. Very first, Cochin police claimed about usage of facial recognition cameras for predicting suspicious activities based on the previous facial records of criminals in their database. These cameras are placed at many public places in the city. Furthermore, Cochin traffic police is using AI devices called ITMS (Intelligent Traffic Management Systems) for keeping the track of the traffic, and also to manage the traffic lights according to the traffic congestion [20]. Applications of technologies has also started its rooting in the department of fertilizers with the use of bio metric verification to track the fertilizer's sale rate. This facility will track that which fertilizers, and how much of that fertilizers are purchased by individual farmer. In the healthcare sector, smarter technologies like Artificial Intelligence is used to detect the early stage of diseases like

Tuberculosis. Adaptation to this technology has filled the gap with radiology and image-based detection systems.

To empower farmers and to increase the agricultural productivity, GIS (Geographic Information Systems) are being deployed to understand and operate crop yield estimates. These systems use remote sensing and geospatial technologies to make the estimations. In 2017, GIS platform was awarded as one of the best projects by the government of Gujarat [21]. The government of Andhra Pradesh, working in partnership with Hitachi, claims its real time governance initiative that has benefitted over 50 million citizens by mainly resolving citizen grievances. This project aims at providing data about climate changing events in real time across the state and monitoring of infrastructural projects undertaken by the private and government agencies. This has created more efficient way of carrying out the governmental operations and has led to sustainable society in the state.

4.2 Scope for IoT based smarter e-governance

IoT for smarter e-governance encourages enhancements in almost every infrastructure like agriculture, transportation, healthcare, education, power, environment and so on. Smarter IoT based cities will lead to real-time interactions between each entities of cities including sensors, citizens, business processes and governmental agencies. Apart from providing automation of different processes, IoT will gather and analyse information for making efficient town planning and control. Traffic is one of the growing problems in India and IoT based vehicles or smart highways can extend the e-governance services to assist the users to provide facilities associated with traffic management. Along with saving time and cost, it will also take care of emergency management as better flow of traffic will reduce the accidental cases.

Environment monitoring is another key challenge in India and IoT based smarter governance can involve applications for air pollution level detection, monitoring soil quality for agriculture, observing water quality for drinking and waste management. Energy based provisions like electricity or gas fields, where there are always life risks, IoT based e-government systems will lead greater managemental support. It will respond quickly in case of emergency situations. Security and safety are another important concern for the Indian society. IoT based sensors like environmental sensors can be used for efficient surveillance and also can report early signs of any crime to the police in case of dangerous situations. IoT devices can be used by government to monitor boarder security and also to for public security at highly populated places like, airports, metro stations, popular road junctions, malls etc. Smarter e-governance can surpass human limitations and can offer increased safety to the citizens.

The lack of real-time medical data has always limited the work towards healthcare applications and IoT based devices can produce far superior data for performing much advanced research on medical field. In a country like India where the most of the population have diagnosed with some or other health problems, IoT solutions can lead to accurate and large location specific data generation, in turn providing better healthcare services to the citizen. Patient centric information can be analysed from far distance, bringing better secure environment to the country people. Another area which needs to embrace IoT solutions is agriculture sector. IoT based e-governance services can effectively guild framers about extreme weather conditions and enhance productivity by measuring the quality of soil or fertilizers. IoT based agricultural drones can be further used for soil analysis, irrigation and also for crop health assessment. The IoT based sensor systems can also be used in greenhouse for measuring temperature, pressure and light levels which will help the farmers for better yield production.

The power of Internet of Things has let many initiatives by many IoT based Indian companies. One such company is IoTrek which aims at developing low powered tracking devices. These devices are embedded with sensors which connects assets and people in real time and works over wireless infrastructure. This project has saved millions of dollars under infrastructural operational costs [22]. DeTect Technologies is another such IoT based company which has built a pipeline condition monitoring ultrasonic sensor for temperature about 350 degree Celsius. The company provides many IoT based sensors for boilers, chimneys, vessels etc. Deployment of these devices have given a deeper insight of automation and control.

The government of India has already in the path towards productive implementation of innovative technologies for smarter e-governance. Despite of the larger population and lesser literacy rate at rural areas, many governmental services have reached remote areas of villages in most user-friendly and reliable manners. More accurate and precise citizen centric information will increase the citizens faith towards government. Scope of mining the data generated by IoT sensors and using the data science in every sectors of e-governance is very vast and yet to be researched at deeper level.

5.0 Conclusions

Internet of Things is growing as a connected device and the future of IoT in making users life much easier is very promising with underlying support from the government. Collaboration and sharing of data collected with sensors and various IoT enabled devices from various governmental domain, enables effective knowledge management. Use of IoT enabled devices has already brought many benefits in various sectors of e-governance in many countries. The objective of this paper was to highlight the possible benefits of IoT for smarter e-governance. IoT enabled devices can collect remote sensor data so that physical world or devices can be monitored and controlled from a distance without human involvement. In addition, combining different senor data and analysing these collected data can bring out the insights of many solutions which in turn can help the government to develop, deploy and improve services to its citizens. Despite the fact that there has been a very precise work done so far on the ground level of IoT based smarter e-governance, there are many potential benefits of IoT ranging from operational to a political level. The benefits of smarter e-governance can be attributed to effective and flexible services, governmental transparency, improved efficiency in policies, forecasting of events and improved health and safety measures to the citizens.

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Water Leakage Detection and Location Identification using IoT and Cloud Interface

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Abstract

Water loss due to leakage in water supply pipelines needs to be addressed. This paper presents a system for water leakage detection by using sensors in pipelines and transfer of the data to the cloud. Two sensors attached to the pipelines are used to capture leakage detection through variation in pressure. They record water pressure when water flows through the sensors. A laboratory set-up was developed and tested for water leakage detection.

Keywords: *Distribution Network, Leakage Detection, Sensors, Water Distribution*

1.0 Introduction

Internet of Things (IoT) and wireless communication are useful to provide solutions different complex problems. Water leakage long distance pipelines can be detected using IoT solutions. IoT enabled systems can be implemented for water leakage detection, monitoring and controlling. Such a system is shown in Fig. 1.

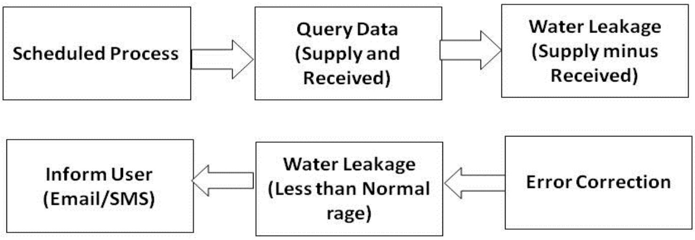

Fig. 1. IoT based system architecture for leakage detection

Major challenge for water distribution authority is managing damages in water supply lines due to aging of pipelines [1]. Maintenance of water distribution networks has to be undertaken in a cost effective manner. There are several methods for monitoring water distribution networks and measuring variations in water pressure in pipelines using sensors for detecting leakage and through IoT solutions [1-3] and it opens-up several domains of research in reducing the overheads in infrastructure maintenance. These monitoring systems [4-5] adopt a damage identification strategy to monitor the performance of water supply

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pipes. It involves leakage detection [5-7], extraction of damage-sensitive features.

Newer technologies, wireless sensor networks and the Internet based solutions can decrease the cost of maintenance [8] by installing improved flow sensors in water distribution networks. A hydraulic model embedded with the necessary application software records the change in pressure sensor data within the supply pipe [9]. This creates a file of pressure sensor data which may be observed to detect the leakage in the near future. Leakage detection based on prediction [10] uses classifiers that function based on learning algorithms. The output of these classifiers is a human-readable code, which helps to locate the leakage and magnitude of leakage occurred in pipeline. The main objective of this work is to develop an IoT based solution for leakage detection and location identification in water supply pipelines.

2.0 System Details

Most of the domestic or office establishments have single water supply and multiple receiving inlets with traditional watermeters. Single supply end and multiple receiving inlets are common even in multistoried apartments. Traditional watermeters collect data only at the supply end which is generally read once a month for billing and cross checking of the data is not in place. Incidence of water leakage due to broken pipes is not detected. The proposed methods uses two sensors for each pipeline, one to monitor the supply and another to monitor the data which is updated periodically to the smart water meter application on cloud. A process runs on the cloud to monitor the data and raise alerts whenever any discrepancies are found. The system monitors water supply data in real-time and raises email alerts in case of discrepancy (Fig. 2).

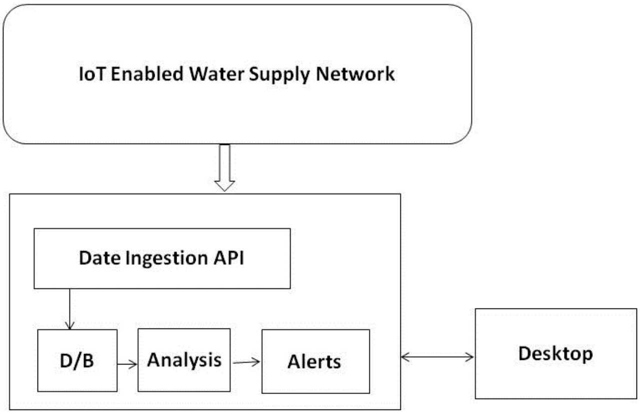

Fig. 2. System Architecture: IoT enabled water leakage detection system

Two processes are developed to monitor water flow data using YF S201 flow sensor (Fig. 3), one for measuring water flow at supply end and another to measure water at the receiving end. Both the processes upload data periodically to smart water meter application hosted on the cloud. Flow in the pipeline is measured using flow sensors which are equipped with pin-wheel sensors to monitor the flow. The sensors are connected in-line to the water flow, to monitor the pressure with every revolution that occurs in pin-wheel. The sensors provide a digital output with varying pressures.

Fig. 3. Flow sensor (YSF 201)

3.0 Results and Discussion

Performance of water leakage detection system is tested in the lab. The performance is evaluated using two sensors. The output of these sensors is used to detect and recognize the exact location of water leakage in the supply pipe. In the lab set-up, performance of the proposed system was tested for detecting water leakage and to identify the location of the leak within the supply pipe. The set-up consists of a section connected with a 40 mm plastic pipe and with a hole of 5 mm, to simulate the leakage at a section. Water is circulated through the pipe with the known pressure. Initially, the hole is closed with the rubber strip, which will pop-out when the water pressure increases, resulting in water leakage from the pipe. In order to detect the leak and to pin-point the location of water leakage, two sensors attached to the end of the pipe sections, one at the start (Sensor -I - at the water inlet) and another at the end (Sensor-II - at the water outlet). Each sensor was housed over the pipe firmly using an SS clip which records the water pressure. Burst of water, from the hole created in the supply pipe, results in pressure drop sharply (Fig. 4). Pressure profiles of sensor –II indicate the leak as downstream in the graph. Output of these sensors showed gradually increased at the incidence of leakage due to pipe burst. Difference in sensor profile or output is used to determine the location of the water leakage.

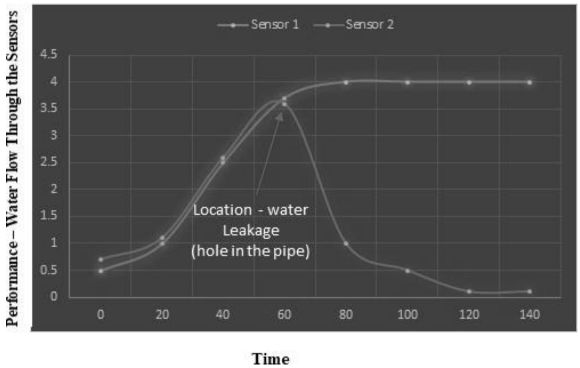

Fig. 4. Results of water leakage detection system

4.0 Conclusions

Internet of Things enabled water leakage detection system was successfully implemented. The sensor data indicated leakage and its location in the water supply line. Two sensors were attached to the end of the pipe sections, one at the start - at the inlet and other at the end at the outlet. The sensors record water pressure when water flows through the sensors.

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A Smart Temperature Monitoring System for Cutting Tools

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Abstract

In cutting tools nearly 70% of the heat is carried away by the chips which are formed during machining. Most of the remaining heat is transferred to the tool due to which the tool life suffers. It also affects the surface finish of the workpiece. Many research works have focused on analytical and numerical approaches to estimate the tool temperature. This paper presents Internet of Things enabled temperature monitoring of cutting tools. The system is built using Arduino microcontroller and MAX6675 Type K sensor. USB module is used to communicate the sensor readings to an android application named Blynk. The data obtained are monitored to observe any peak in temperature beyond a certain limit which intern turns on buzzer and light. Experiments were carried out on a center lathe and real time temperature data of tool was monitored on the Blynk android application.

Keywords: *Cutting tool temperature, Internet of Things, MAX6675 Type K, Tool Temperature, Blynk, Arduino*

1.0 Introduction

Wide ranges of cutting tools are used in lathes. Material of the cutting tool is selected based on the material to be machined and the machining process [1]. In metal cutting, heat generated on the cutting tool tip is important for the performance of the tool and quality of the finished workpiece. Effect of the cutting temperature, particularly when it is high, is detrimental to both the tool and the work piece [2-4]. The cutting tool temperature data can be analyzed and used in improving the machining quality and tool life. IoT is the state-of-the art technology for remote sensing and monitoring real time the industrial machines. Sensor data is acquired in real time and transferred to the cloud in order to access it through a smartphone application, which can be processed and presented in the required form [5, 6]. This paper focuses on development of an IoT enabled temperature monitoring for acquiring temperature data of cutting tool in a lathe in real time and compare the same with the preset threshold value to assess safe limits [7-10]. In case of temperature crosses the set limits, the user is alerted through an alarming system.

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2.0 System Development

2.1 Methodology Adopted

Existing tool temperature monitoring systems were studied for identifying improvements [11-13]. Functions related to sensing, sensitivity of the sensors, temperature measurement, fixing of threshold were studied. Suitable sensors were selected for the application and the circuitry was developed. A program developed using C++ was flashed into the microcontroller and the data obtained was forwarded to the cloud. The same data is monitored through smartphone Android application. The system gives alert in the form of a buzzing alarm if the temperature exceeds the preset safety limit and continuous monitoring of the tool temperature can be done in the mobile application.

2.2 Experimental Details

The block diagram, shown in the Fig. 1, depicts the major components and sequence of signal flow in IoT based temperature monitoring system.

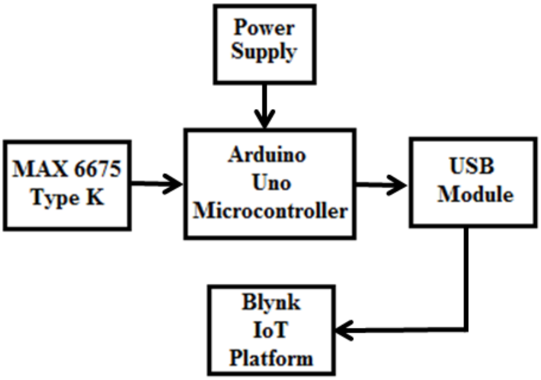

Fig. 1. Block Diagram of Arduino system

MAX6675 Type K sensor is connected to the Arduino as shown in Fig. 2. MAX6675 runs on 3.3V power supply. VCC and CH_PD are connected to 3.3V pin of Arduino and the network is completed as per fritzing diagram (Fig. 3). A controlling program is written and transferred it to Arduino Uno. The Arduino is connected to the Internet and the results are monitored on Blynk IoT platform. USB Serial communication module gives access to Internet. It is a very cost effective device and makes the system portable.

MAX6675 sensor senses the temperature of the tool through contact type. The Arduino connected to the sensor reads the temperature data, and provides the same data in degree Celsius or Fahrenheit. The temperature data in degrees is displayed on the serial monitor.

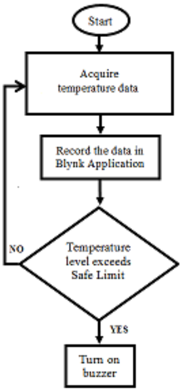

Fig. 2. Process Flowchart of temperature measurement

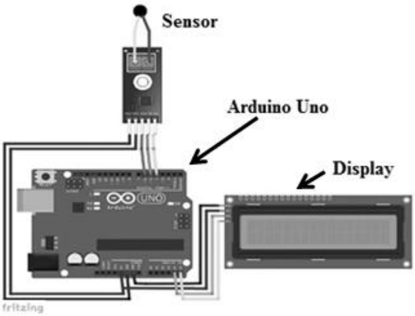

Fig. 3. Fritzing Diagram

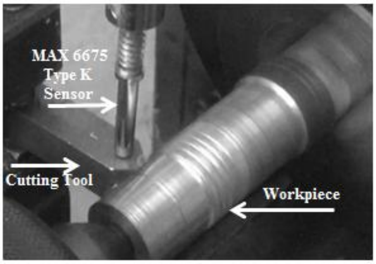

Fig. 4. Max 6675 sensor in contact with tool

Sensor provides the temperature value of 27°C (or room temperature) when it is not in contact with the cutting tool and provides the instantaneous temperature data as the sensor makes contact with the workpiece (Fig. 4).

3.0 Results and Discussion

The C++ code is compiled and flashed to the Arduino Uno. The temperature data are acquired on the serial monitor and the same is reflected on Blynk Android application.

1. The temperature of the tool is observed in the Serial Monitor and change in the temperature is monitored in the mobile application (Fig. 5).
2. The buzzer and LED are ON if the temperature is above is 50°C and below the range of 50°C the buzzer and LED are OFF (Fig. 6).

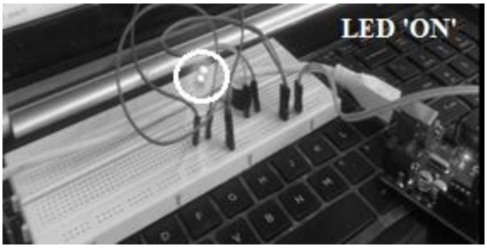

Fig. 5. Buzzer and LED light ON during temperature exceeding limit

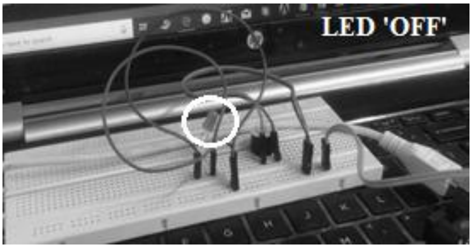

Fig. 6. Buzzer and LED light OFF during temperature within limit

The modelled Arduino system for tool temperature measurement finds its application in tool industries where machining is performed for long hours due to which the temperature of the tool increases which affects tool life and surface finish of the workpiece. The real time monitored data is shown in Fig. 7. It is wireless device and hence the data can be accessed from anywhere with the help of Blynk android application (Fig. 8).

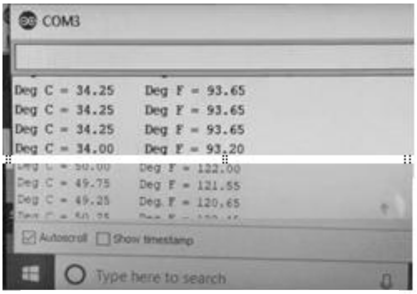

Fig. 7. Temperature output on serial monitor of Arduino IDE

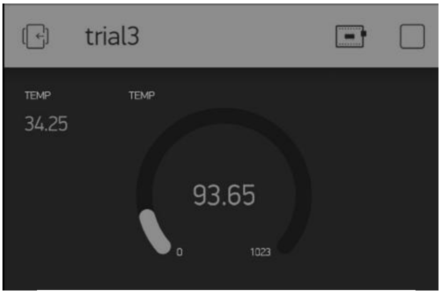

Fig. 8. Temperature output on Blynk application

4.0 Conclusions

The tool temperature monitoring using IoT is successfully developed. The smart temperature monitoring in the model shows the complete architecture with configuration of contact type temperature sensors and the Android application for showing the change in temperature. The proposed IoT based methodology can easily provide the information and the proposed hardware can serve the purpose for all tool types. The technology is robust, cost effective and easy to use. The following conclusions are arrived at based on the experimental results:

Temperature monitoring system is developed using Arduino Uno microcontroller and MAX6675 Type K contact sensor. Real-time temperature data of cutting tool tip is obtained by connecting the set up to internet using USB module and recording on Blynk android application. The system signals through buzzer and light whenever the temperature exceeds the permissible value for the machining speed of cutting tool. In case of centre lathe, initial temperature is below 50℃ which is the user specified limit of temperature. Hence, no signal mechanism is activated. As the temperature increases beyond 50℃, the developed IoT based system successfully activates the buzzer with a light as an alert notification indicating temperature exceeding limit.

Although an alert is given to the user through internet, the temperature is monitored by contact type. But, temperature measurement can be optimized using non-contact type sensor. Also, if a fixture is used to hold the sensor in place, a more sophisticated temperature monitoring system can be achieved. If Artificial Intelligence is used with the developed set-up, corrective actions such as change of tool and turning on coolant may be incorporated.

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IoT Solutions for Smart Farming - A smart weather and wind speed monitoring system

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Abstract

This paper presents the-state-of-the-art on Internet of Things enabled plant growth monitoring, application of pesticides, prevention of insects, birds and animals into the agricultural fields, food storage, apiculture, animal husbandry, natural disaster alerts and energy harvesting using bio-waste. A smart weather monitoring system incorporating hall sensor, DHT11, UV sensor, CO sensor and IR sensors. The hall sensor detects magnetic field and provides frequency of magnetic field detected per second. IR sensor detects direction by sensing obstacles of the wind vane. Other sensors provide analog output according to weather parameters. The output data is processed by Arduino and the data is visualized on dashboard. Farmers can visualize the weather parameters of the field remotely on thingsboard dashboard. The data is also stored for graphical representations.

Keywords: *framing, smart weather, Data, Raspberry Pi, Arduino*

1.0 Introduction

Rapid growth of population and limited supply of resources drive toward smart technologies for optimum utilization of the resources, especially in farming. Smart farming encompasses advanced technologies for plant growth monitoring, application of pesticides, prevention of insects, birds and animals entering into agricultural fields, food storage, apiculture, animal husbandry, natural disaster alerts, energy harvesting using bio-waste, etc. Advanced technologies enable to assess the health state of farming, optimum production and utilization through automated decisions of interventions on the feeding of the soils, protection from insects, etc. With advances in Internet of Things (IoT), a number of sensors can be used to capture, process and analyses data in real-time employing different IoT platforms.

Agriculture has fostered advances in human civilizations over the ages. In developing countries like India where agriculture is mainly dependent on rainfall is still a gamble for farmers. Automatic sensing of the conditions on a farm enables to implement best possible practices in farms which can result in maximising the yield. Authors [1] used Temperature and humidity sensors and height measuring apparatus comprising of magnetic switches and a Neodymium magnet. Data pertaining to height of the plant, moisture content in the soil,

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ambient temperature and relative humidity collected from the sensors were compiled and transmitted to the farmer for suitable action which is also recorded. The ground data and the actions taken together help to improve the productivity. Zhang Xiao-dong et al. [2] developed a digital monitoring solution for grain warehouse based on microcontroller and Linux embedded OS. The experimental results showed that the IoT solution was capable of real time monitoring the warehouse environmental parameters namely the grain temperature, humidity, video image and other important sensor data's.

Priya et al. [3] developed a prototype model for continuous monitoring of potato crop in cold storage unit. The prototype evaluated the appropriate threshold range and updated the condition to the vender using GSM in the form of SMS. The developed model was tested for accuracy with respect to monitoring conditions of light intensity, humidity, temperature and detection of potatoes rotting in the initial stage. Ahmed et al. [4] proposed integrated management of production by an automatic monitoring system for biogas plants using Arduino. Automatic monitoring involves the supervision and planning functions that ensure continuous and efficient operation of the plant. The measure of gas production and consumption were tested by deploying an Arduino micro-controller. The program automatically warns the instructor on the amount of methane production by setting an alarm in case of an increase or deficit in produced quantity.

Suruchi Dedgaonkar et al. [5] studied the process monitoring parameters in two different groups for measuring the volume of biogas using microcontroller and GSM. The first group of parameters includes the early indicators of process imbalance and this indicator allows the biogas plant operator to react in time, before a process imbalance occurs. The second group of parameters are the one which characterize the process. Dasig Jr. and Mendez [6] presented the introductory apiculture space, challenges and evolving methods of the apiarists in beekeeping at lesser cost IoT. Authors deployed remote sensing technologies for gathering information and vigor monitoring to improve the beehive colonies productivity.

Anatolijs Zabasta et al. [7] developed IoT based modern autonomous beekeeping system. The IoT system aids to analyses correlation data with video, mass changes in-time with the interpretation of humidity, temperature, networking to local biological and geographic situations. IoT system permits a beekeeper to collect key information indicators and in agreement with this display beekeeper reacts in-time and provide the best preservation of the bee colony. By employing the autonomous beekeeping, the situations of the hives can be tracked remotely. Abhinav and Deshpande [8] described the method to protect farms from animals through ubiquitous intelligent security system wired network devices to farm along with traditional method. Operational amplifier circuits are utilized mainly for the detection of animal intrusion into the farm. S.R.Kurkute et. al. [9] designed the agriculture wonder drone system using GPS which automatically control areal drone consisting of a quad copter and spraying mechanism. Initially quad copter is assembled using necessary components such as flight-controlled board, GPS, BLDC motor, ESC controller and battery.

Review of literature [1-9] indicated that IoT is effectively used for smart farming with different automation technologies. Their efficiency of these systems depend on the robustness of the sensors and accuracy of the output signals. The main objective of this paper was to develop a smart weather and wind speed monitoring system. Using Internet of things, the weather parameters are monitored in real time, the data is stored in a remote cloud server. The stored data can be visualised in graphical forms.

2.0 Development of Smart weather and wind speed monitoring system

2.1 Methodology of developing monitoring system

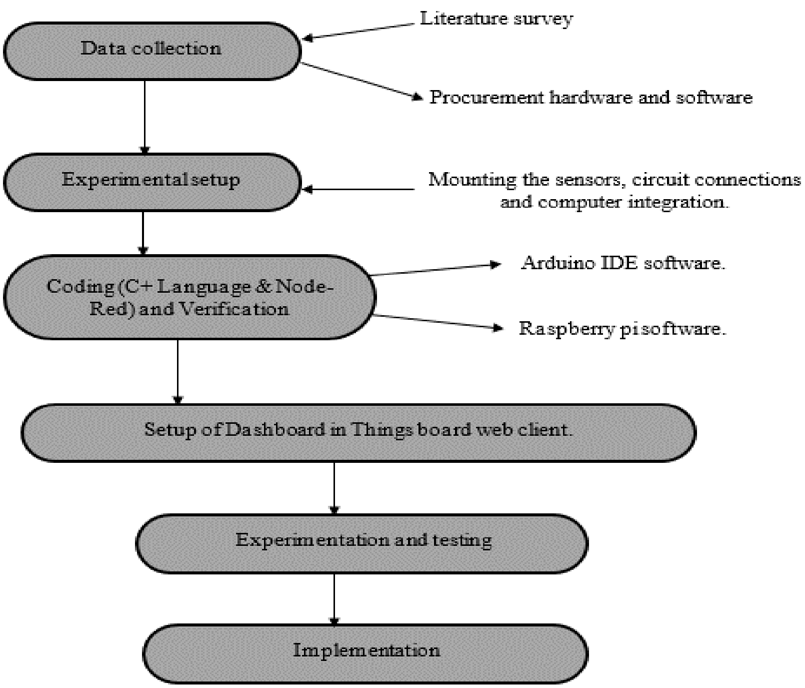
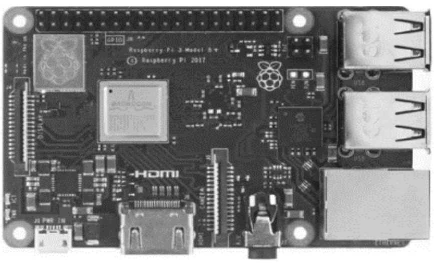


Fig. 1. Stages of developing smart weather and wind speed monitoring system

Different stages of developing smart weather and wind speed monitoring system are presented in Fig. 1. The stages include: data collection on existing weather monitoring systems by literature survey and simultaneous procurement of required hardware and software installation, building the experimental setup i.e., mounting the sensors, circuit connections and computer integration, coding in C+ in Arduino IDE software, verification of the program code by compilation and uploaded onto the Arduino Board, coding in Node-Red environment in Raspberry pi and set-up of Dashboard in Thingsboard web client. Experiments and testing were conducted to examine the required outputs and implementation.

2.2 Specifications of Smart weather and wind speed monitoring system

2.2.1 Hardware Specifications



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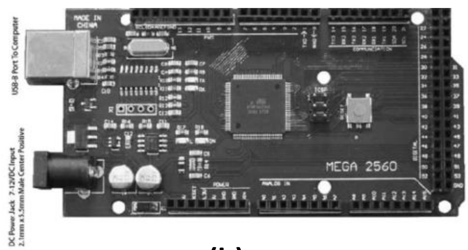

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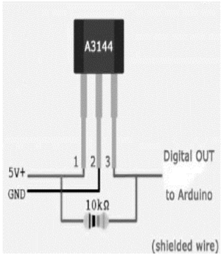

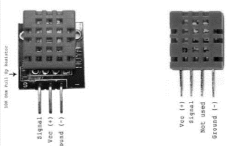

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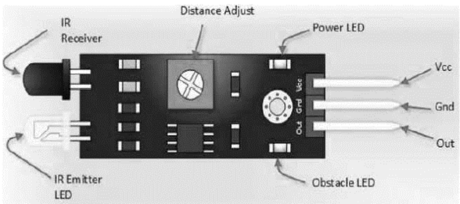

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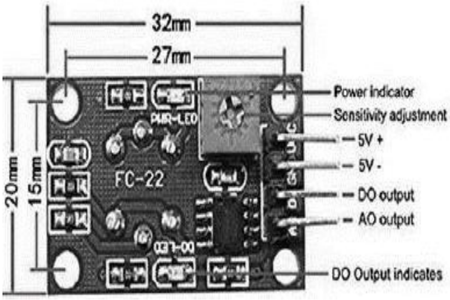

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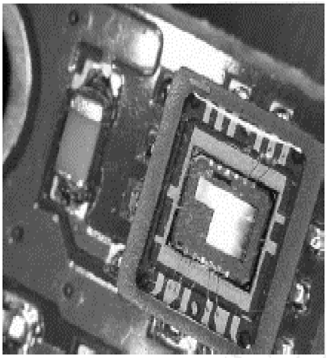

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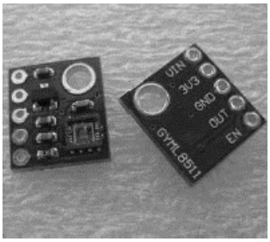


Fig. 2 (a) Raspberry Pi B+ Model with 64-bit quad core processor, (b) Arduino Mega 2560 pin-out configuration microcontroller board, (c) Hall Effect sensor, (d) DHT11 Temperature and Humidity sensor, (e) IR sensor Module with pin-out configuration, (f) CO sensor pin-out configuration and (g) UV sensor and sensor pin-out

Fig. 2(a) presents Raspberry Pi B+ model with 64-bit quad core processor at 1.4 GHz, dual-band 2.4 GHz. This model consists of dual-band wireless LAN with modular compliance certification, allowing designed board into end products of reduced wireless LAN compliance testing by improving both cost and time to market. Fig. 2(b) presents Arduino Mega 2560 microcontroller board built on the ATmega2560 with 54 digital in/output pins, 16 analog inputs, 4 UARTs hardware serial ports, a 16 MHz oscillator crystal, a power jack, an ICSP header, and a button to reset.

Fig. 2(c) shows an integrated Hall Effect non latching sensor A3144. This sensor is monolithic integrated circuits with tighter magnetic specifications, designed to operate continuously overextended temperatures to +150°C, and are more stable with both temperature and supply voltage changes. Fig. 2 (d) show DHT11 temperature and humidity sensor which a calibrated digital signal output. The sensor includes a resistive-type humidity measurement component and thermistor temperature measurement component, and connects to a high-performance 8-bit microcontroller, offering excellent quality, fast response, anti-interference ability and cost-effectiveness.

Fig. 2(e) shows IR Sensor Module with pin-out configurations. The IR sensor module consists mainly of the IR Transmitter and Receiver, Op-Amp, Variable Resistor (Trimmer pot), output LED. Fig. 2(f) shows MQ-7 CO sensor pin-out configuration. The sensor detects CO gas at high and low temperature. Fig. 2(g) shows UV sensor pin-out configuration of ML8511. The ML8511 UV sensor is suitable for indoors or outdoors for acquiring UV intensity. Depending on the UV intensity photo-current is converted to voltage through ML8511 consists an internal amplifier. This distinctive feature offers an easy interface to external circuits such as analog-to-digital converter.

NSK 696ZZ Ball Bearings of miniature size with Dynamic load rating of 1,750 N, Static load rating of 670 N is used to provide rotational motion to the wind speed and wind direction vanes. Single start threaded bar and hexagonal nut of 6 mm diameter is used to support the bearings and mount the sensors. to create interrupts in Hall Effect sensor for measuring wind speed a neodymium permanent magnet is used, which is the most widely used type of rare-earth magnet.

2.2.2 Software Configuration

Arduino with integrated development environment (IDE) is a cross platform application for operating systems such as Windows, Linus, mac, written in the C programming language. The Arduino IDE services the program avrdude for converting the executable code to a text file in a hexadecimal encoding loaded into the Arduino board by a program loader in the board firmware as shown in Fig. 3(a). Code written in Arduino IDE though the interface called sketch.

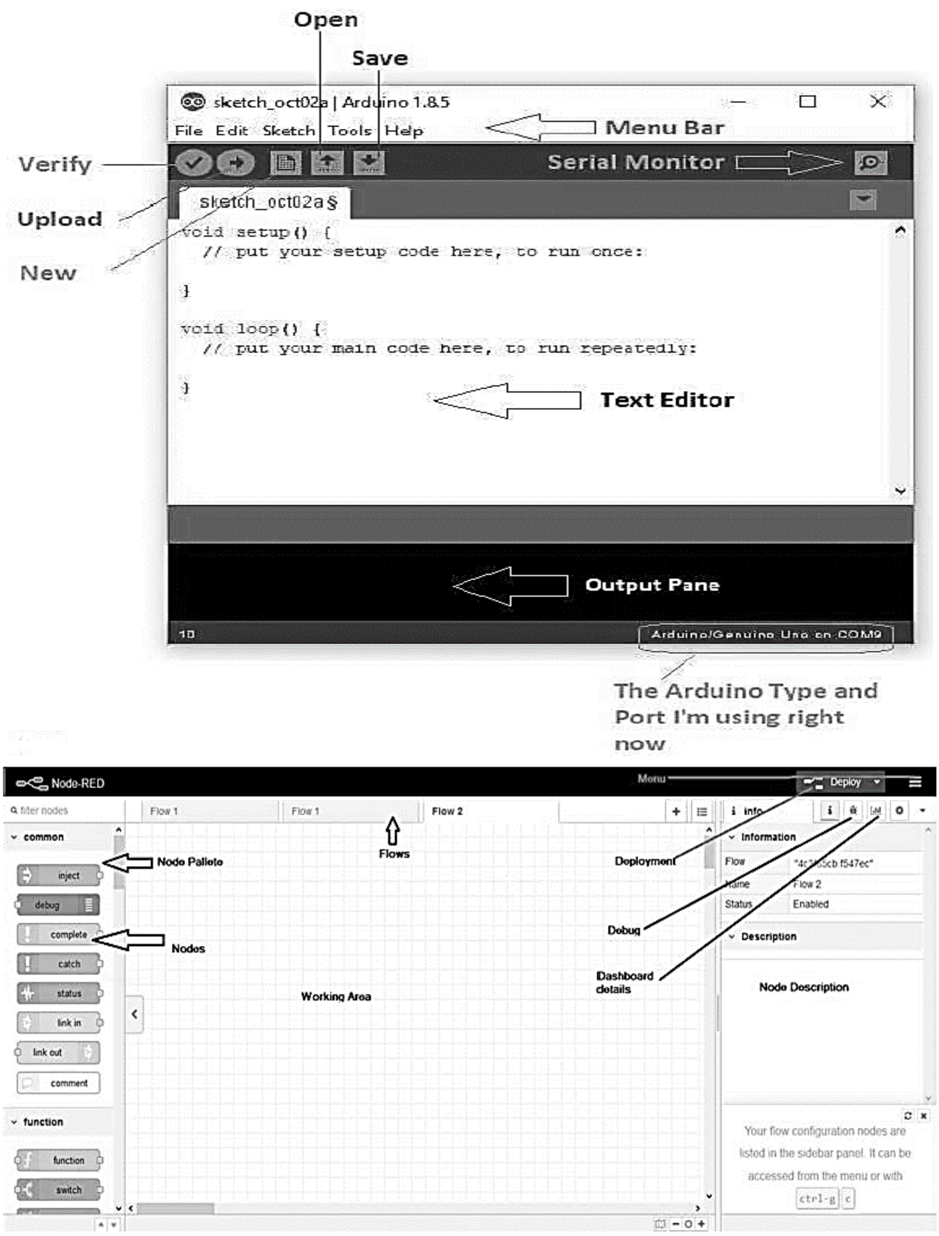


Fig. 3(a) Arduino IDE interface and (b) Node-RED interface

IoT applications is build using a powerful tool called node-RED with application on streamlining the wiring together of block of codes to carry-out complex tasks. Node-RED uses a visual-programming approach allowing the developers to link block codes, called as nodes. The connected nodes so called combination of processing nodes, input and output nodes are wired-together to make up a flows. Fig. 3(b) shows Node-RED interface.

ThingsBoard platform is an open source IoT aimed at data collection, processing, visualization, and device management. The board enables device connectivity via industry standard IoT protocols - MQTT, CoAP and HTTP and supports cloud as well as on premises deployments.

2.3 Development of working model and working procedure

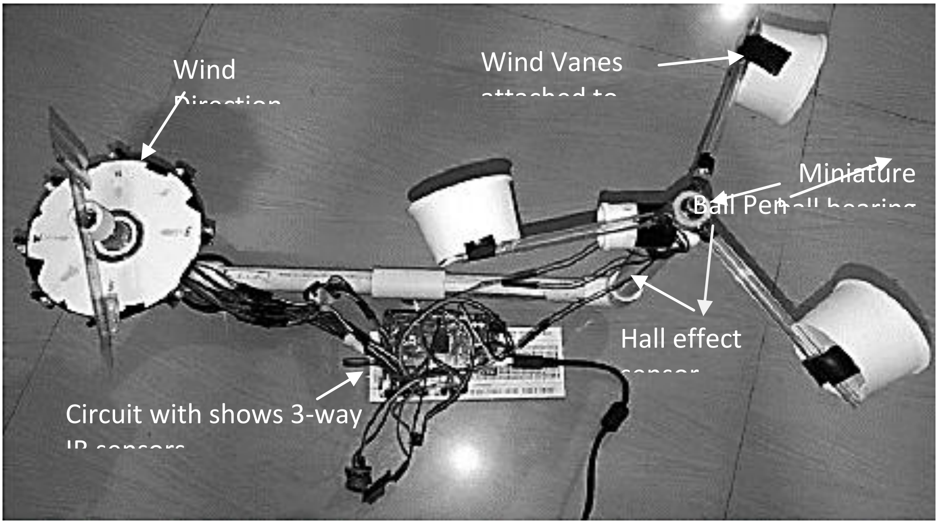


Fig. 4. Top view of prototype model of smart weather and wind speed monitoring system using IOT

Fig. 4 represents the top view of prototype model of smart weather and wind speed monitoring system using IOT. The model consists of miniature ball bearing fixed inside pipe of 15mm ID and 10 mm height, 3 ball pen ends are attached at angle 0-120-240º. Either ends of the pens are attached to the bearing and tea cups. A magnet is attached to one pen at a distance of 33 mm. Hall Effect Sensor mounted for measuring the magnetic interrupts.

IR Sensor Module are attached to a disc with 45 º between them. The disc is mounted on the threaded bar using washer and hexagonal nuts. At the top end of the threaded bar miniature ball bearing is supported. A scale is used as wind vane. An obstacle is attached to vane at a distance equal to the distance of IR Led from the centre. A 3-way circuit diagram of IR sensors connected to 0k ohm resistor between +5V and Data of Hall Sensor A3144 with USB type A/B cable to Arduino and Raspberry Pi.

Wind rotates the anemometer vanes, magnet attached to the vane comes near above the hall sensor. When the sensor detects magnetic field the output toggles to HIGH. The sampling time is 1 second i.e, the system counts number of time the sensor output state is HIGH in 1 second. The system stores number of counts per second. The wind vane moves in the direction of the wind, the obstacle attached to the vane reflects the light from IR LED to photo diode and the output state of that IR Sensor Module toggles to LOW. This output is detected by the Arduino and it gives the wind direction.

The windspeed is calculated by $windspeed = \frac{\pi DN * 3600}{1000}$ kmph. where, D = diameter at which magnet is fixed (m), N = counts/second.

Fig. 5 shows the node-red flow for visualizing the data on node-red dashboard as well as thingsboard dashboard.

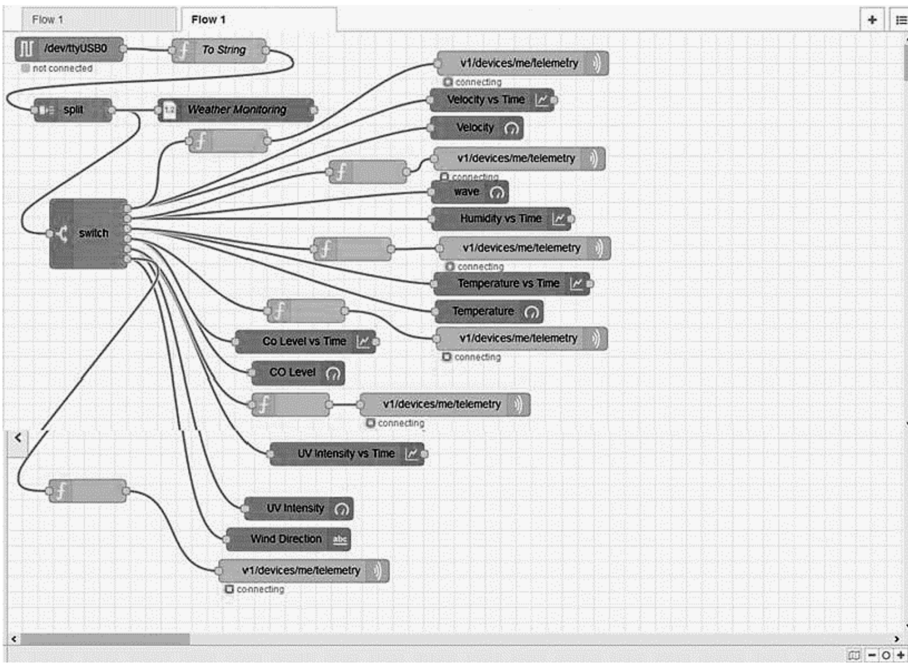
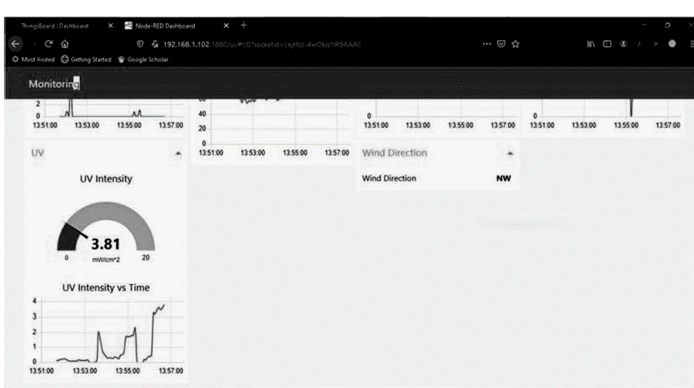


Fig. 5. Node-RED flow for data visualizing

3.0 Results and Discussion

The weather parameters were visualized on the local server without internet connection using node-RED dashboard. Fig. 6 presents visualization of weather parameters in real time on node-RED dashboard.



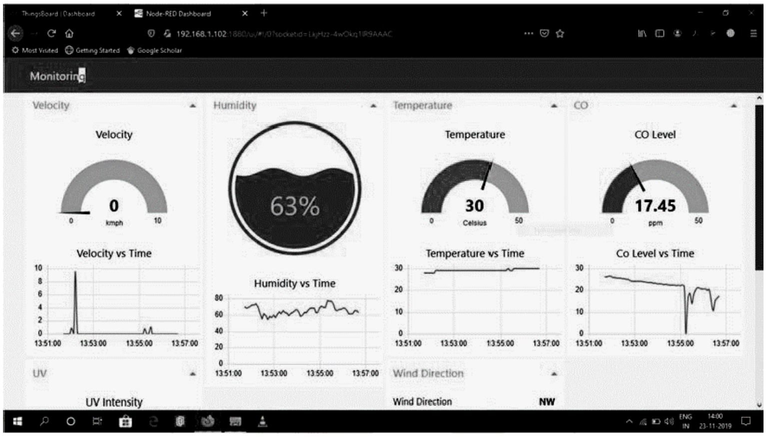
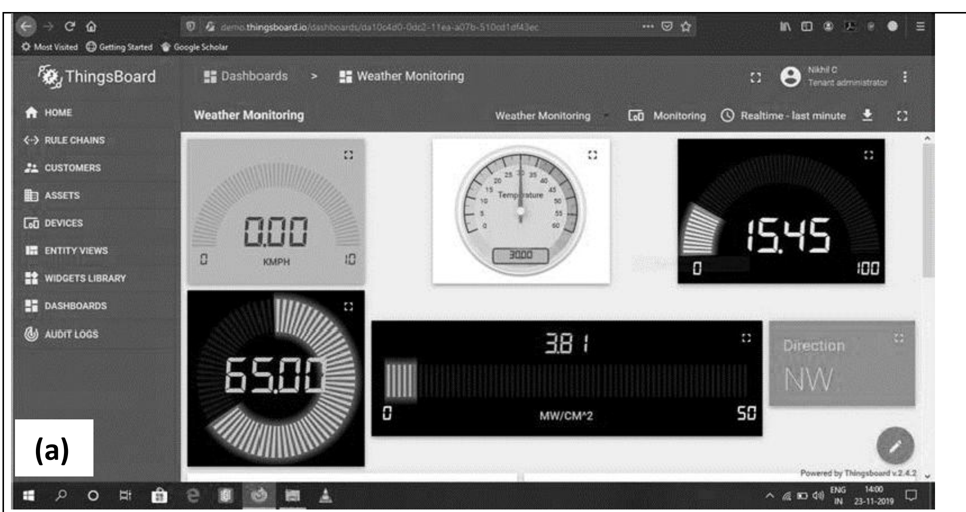


Fig. 6. Node-RED dashboard (a) showing velocity, humidity, temperature and CO level and (b) showing UV intensity and wind direction

When the raspberry Pi is connected to the internet the weather parameters are logged to the remote cloud server. The data is stored on the web server and can accessed anytime and anywhere using ThingsBoard. Fig. 7 (a) shows visualization of weather parameters and Fig 7(b) shows graphical representation of parameters in real time on ThingsBoard dashboard.



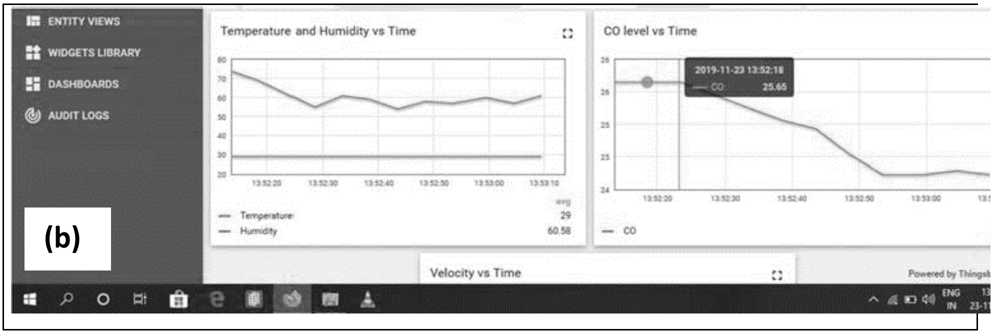


Fig.7. Thingsboard dashboard (a) weather parameters, (b) graphical representation

4.0 Conclusions

As Internet of Things application in farming continue to develop, farms will become more streamlined, connected, efficient and productive. The IoT brings a broad efficiency to the farming space by creating a worthy cycle which makes food crops more readily available to consumers, saves farmers' time and money, and reduces the environmental effect on farming by driving sustainability into the process. IoT based smart weather and wind speed monitoring system using Raspberry Pi and Arduino Mega 2560 was developed. The model demonstrates that cost effective sensors can be used to monitor weather parameters in agriculture field and in greenhouses. The use of node-RED on device connected to local server enables to visualize parameters without internet. The model also reveals how the data can be stored and visualized in real time at remote location using IoT. In future, the range of transmission can be increased by using transmitter and receiver module to visualise data at multiple locations using one station by configuring more number of receivers.

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Guide to Internet of Things Solution Development

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Abstract

Internet of Things is fast emerging as a technology solution for a variety of complex problems. Implementation of IoT demands upskilling on the existing technologies and research on the futuristic technologies. In this paper, details of various stages of development of an introductory laboratory based on IoT are presented. The technology domains in IoT and their implementation at different levels of complexity are presented. Project based learning approach is adopted for imparting IoT skills for applications in areas such as agriculture, healthcare and manufacturing.

1.0 Introduction

Internet of Things (IoT) is a rapidly evolving technological driving force of the IT industry. The demand of Industry level skills in IoT as well as IoT enabled solutions is rapidly increasing. Consequently, demand for IoT connectivity sensors, wireless devices and hands-free connectivity is witnessing new heights. Industry 5.0 covers IoT sensor enabled devices, vehicles, equipment and machinery connected to one another. The basic requirement of Industry 5.0 is IoT contributing to the development of the infrastructure [1-3].

IoT was initially used in business and manufacturing and was known as machine–machine communication. Presently, the technology is expanding to homes and workplaces with smart devices, transforming the places to smart places. Earlier IoT was known as internet connected devices to perform ubiquitous, invisible and pervasive computing. Today the technology is known as Internet of Things to connecting things than people in the World. Internet of Things is a way of programming the physical world. Programming physical world involves monitoring or controlling things, essentially sensors or actuators. It is done to monitor or control a physical phenomena like temperature, humidity, force, position, flow light radiation, velocity, occupancy and others [4-5]. The main objective of this paper was to identify the major domains of IoT, components of IT solutions, up skilling requirements and typical IoT solutions for applications such as weather monitoring, acquaponics, Blue tooth communications and Home automation which are developed and demonstrated as part of the up skilling modules.

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2.0 Multidisciplinary domains of IoT

IoT is multidisciplinary in nature and it encompasses domains such as embedded systems, communication protocols, cloud computing, wireless sensor networks, application development and data analytics. It draws expertise from different engineering disciplines for sensor development, driver development for different architectures, network laboratory to handle secured computing and communication, application development to integrate sensors / actuators and development boards with online hosted services or local services on a local cloud infrastructure and IoT Data Visualization and Analytics laboratory for monitoring the data and generating analytics to for decision making.

2.1 Components of a typical IoT solution

Processing, storing and computing the sensor data are the key tasks associated with IoT Solutions.

The components of a typical IoT solution (Fig. 1) are [6]:

- Things (Devices - sensors / actuators)
- Development Boards based on microcontroller or microprocessors
- Networking Infrastructure
- Computing server cluster for Alert, Storage and processing services at local or remote location
- Development, testing and deployment infrastructure

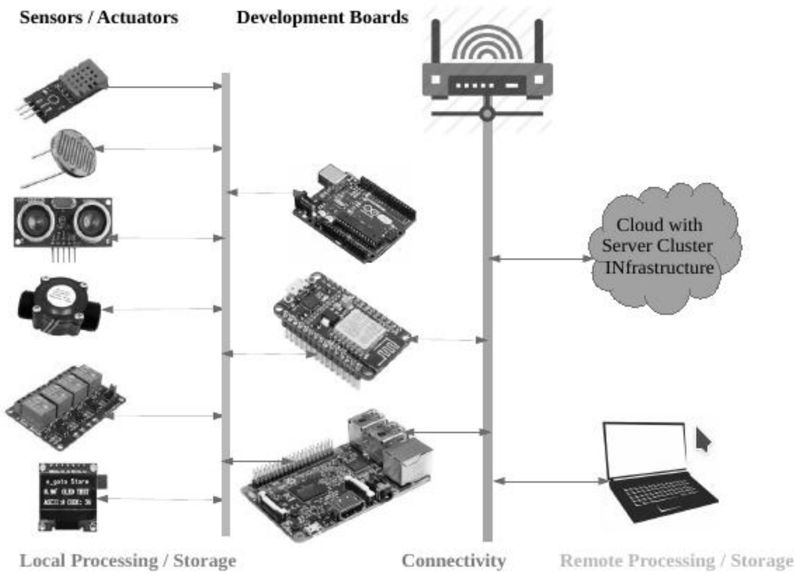

Fig 1. Components of a typical IoT solution

Automating the process of programming the physical world to monitor or control a physical quantity using IoT needs upskilling in the following areas [7-8]:

- Basic knowledge of the physical phenomena and their properties in the physical world
- Fundamentals of current, voltage, resistor, transistor, capacitor
- Fundamentals of programming using high level programing languages

As per the predictions of the industries and markets, enormous amount of data is generated through the exponential increase of sensors across industries and technology users. Collecting, visualizing, and analyzing data decision making based on the data analysis is a key business across all verticals and domains [9-10] which demands skilled human resource.

2.3 IoT Startup and Industry Expectations

Present market needs demand that the human resource be conversant with appropriate skillset. Table 1 shows a comprehensive list of the expected skillset.

Table 1 IoT Enabling Technologies, activities and expected skillset

IoT Enabling Technology	IoT activities and associated skillset expected
Sensor Development and Embedded Systems	Product (sensor) Design and Development, Sensing mechanism, Sensor Data Conversion techniques, Driver development for different architectures
Networking and Communication technologies IT Infrastructure	Building a Secured Communication Network for sensors/actuators and development boards to communicate with others similar boards or computing nodes. Setting up secured computing and storage environment Local processing and storage or remote processing and storage Setting up web, file, networking services to generate alerts in various forms and cloud services Device to device communication Mesh Networking with Custom Firewall Communication via Bluetooth, Wi-Fi, UWB, LoRa, LAN, WAN,..
Application Development with Visualization and Analytics	Sensor Data Logging Application, Sensor Data Visualizing Application, Mobile Application to view and monitor devise activities, Data Visualization and Analytical tool Gateway Application to integrate third party services Web Framework like django, cakephp, django Mobile Application Development on Android or PWA
Cloud Computing	Local or Remote Processing, storage, computing services and integration of other third party services
Communication Protocols / Models and Standards	Http, ssh, ftp, MQTT, COAP, RS485, i2c,spi Request-Response, Publish-Subscribe, Pull-Push and REST Api

3.0 Typical IoT Modules developed

IoT solutions were developed for several applications. IoT enabled Aquaponics, weather monitoring, home automation and Bluetooth communication are presented in Fig. 2.

IoT enabled weather monitoring system (Fig 2a) includes connecting of several components such as electronic gadgets, sensors and automotive electronics. The system deals with monitoring and controlling the environmental conditions like temperature, relative humidity, light intensity and CO level with sensors and sends the information to the web page and then plot the sensor data as graphical statistics. The data updated from the implemented system can be accessible in the internet from anywhere in the world. IoT based Aquaponics (Fig. 2b) is a food production method which combines traditional hydroponics with aquaculture in a symbiotic relationship. It facilitates a sustainable system with necessary input as water and nutrients to grow terrestrial plants and aquatic life. IoT enabled Bluetooth communication (Fig. 2c) entails two main system; an acquisition system and a central server, under the Client-Server paradigm and the IoT technologies. The system has modules such as measurement (Bluetooth beacons), data aggregation and transmission, storage, web-interface and cloud services for data, and results visualization. Home automation combined with IoT (Fig. 2d) aims to control home electrical appliances resulting in affordable lighting solutions and optimum utilisation of energy. It is meant to control all the devices of a smart home through internet protocols or cloud based computing.

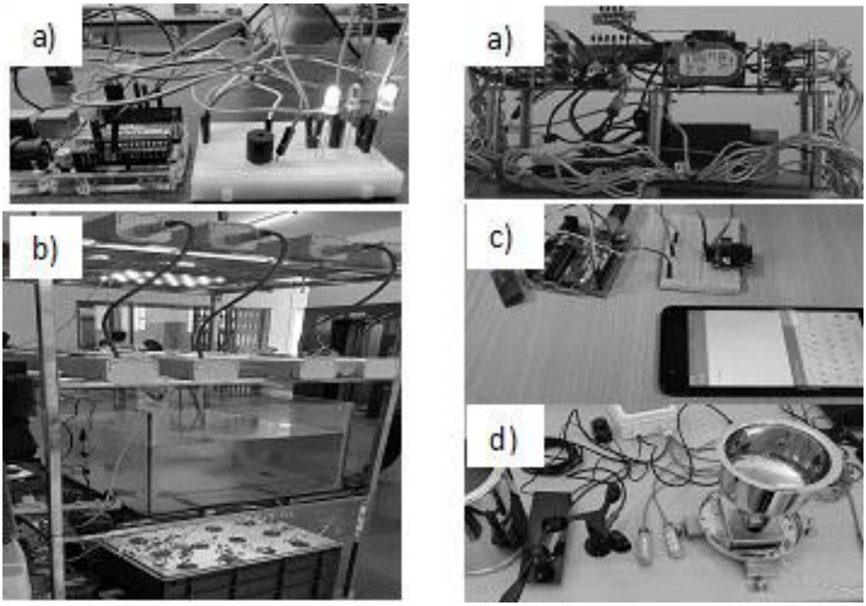

Fig. 2. a) Weather monitoring, **b)** Acquaponics, **c)** Blue tooth communications and **d)** Home automation

The technologies, framework and hardware required for developing IoT applications are presented in Fig. 3.

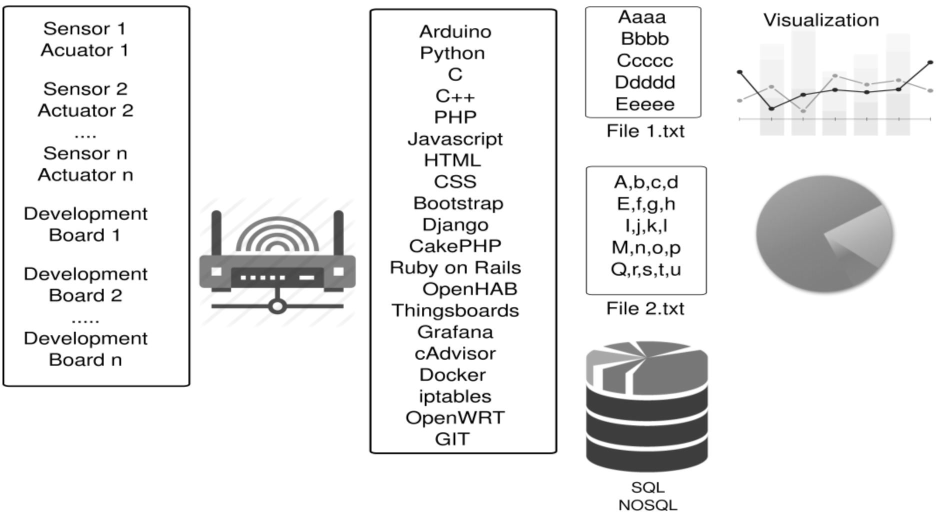

Fig. 3. Technologies, Framework and Hardware needed for while developing IoT Application

4.0 Conclusions

The multidisciplinary domains of Internet of Things, the major components involved in IoT application development, the IoT enabling technologies, activities in IoT design and expected skillset by the industries are highlighted. Technologies, framework and hardware required for developing IoT are identified. Typical IoT applications are presented.

This paper was based on the experiences gained as part of the activities of CISCO-RVCE-Centre of Excellence in Internet of Technologies. The Centre provides guidance on IoT prototype solutions by collaborating with industries. The participants of the upskilling programmes undergo experiential learning in IoT application development enabling conceptualization of the protocols and algorithms along with the knowledge and skills for identifying the IoT components and the interconnectivity.

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Centre of Excellence Computational Genomics

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The Centre has several research projects sponsored by Department of Biotechnology, New Delhi. The projects are undertaken in collaboration with Central Sericultural Research and Training Institute, Mysore, Gandhi Krishi Vignana Kendra, University of Agricultural Sciences, Bangalore and Premier Universities and Institutions in India and abroad.

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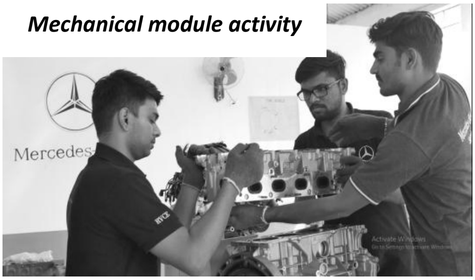
Aggregate lab

Mechanical module activity



Electrical Lab

Car Bay

Centre of Excellence on Macroelectronics

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Interdisciplinary Research Center (IDRC) is established under the CoE to leverage the institutional interdisciplinary expertise and collaboration with industries for research and development in thin film sensors and Nanocoatings. The research infrastructure is developed through sponsored research projects of DST, DRDO, UGC, AICTE, VGST, TEQIP – II [sub component 1.2 and 1.2.1] grants and Rashtreeya Sikhana Samithi Trust (RSST) funds.

Major processing infrastructure of the centre includes sputtering system (Metallisation unit), Plasma enhanced CVD, Evaporation unit, Dual coating system (Sputtering and PECVD), Plasma Deposition System, Laser writer, Sono Scan and Plot, Cathodic Arc System, Ball Mill, CO_2 Laser, Spin Coater and Electrospinning System. Characterisation systems include FTIR, UV Vis Spectroscopy, Scanning nearfield Optical Microscope, Surface Profilometer, Atomic Force Microscope, Nanoindentation, SEM, Microhardness Tester, XRD, Zeta Potential (Particle Analyser), Thickness Measuring Unit, DSC, Micro Raman and Electrical Resistivitymeter.

Major projects undertaken under the centre include, Design and fabrication of hetero-junction amorphous silicon solar cells for superior efficiency, Oxide nanoparticles of novel metals for plasmonic amorphous silicon solar cells, Development of Diode and Amorphous Silicon TFT, Growth and Characterisation of ZnO thin films, room / low temperature grown Nanocluster carbon based TFT, Metal Oxide Thin films, Doped Metal Oxide films for sensor applications, PVDF and PVDF / nanofiller films for sensor and multilayer electrospun nanofibres for protective clothing.

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CISCO-RVCE Centre of Excellence in IoT

Centre of Excellence (CoE) in Internet of things is a joint initiative of RVCE and the Networking giant CISCO. The centre aims to develop skills for design and implementation of IoT solutions in different domains through upskilling, research, innovation and incubation.

Modules of Upskilling and Research offered by CISCO-RVCE CoE:

- Intelligent Analytics - Data Analytics and Predictive Analytics, Machine Learning Algorithms, Tools: R, Hadoop, Weka and Matlab
- Embedded Systems for IoT- Hardware and Software of Embedded Systems
- IoT Application Development - Basics of IoT and Electronics, Rasberrypi, Arduino, and nodemcu, interfacing the sensors with Arduino boards and Webpearl with nodemcu and JavaScript based applications.
- Intelligent Transportation Systems - Design of IoT enabled safer, smarter and sustainable transportation systems
- Networking for IoT - Networking Architecture, Computing approaches, Techniques and protocols
- Industrial Internet of Things (IIoT) - IoT enabled Industrial Automation, intelligent industrial operations through advanced data analytics for controlling machines
- RF System Design for IoT Networking - Zigbee, Wi-Fi, Lora based networks

The Centre has established similar centres in Jawaharlal Nehru National College of Engineering (JNNCE), Shimoga and Gogte Institute of Technology, Belagavi. Setting up of CoE and IoT lab in YMCA Faridabad is in process.

The centre has conducted upskilling programmes in IoT in RVCE and elsewhere in India along with quiz and Hackathon on IoT.

Centre of Excellence for e-Mobility

The Centre of Excellence in e-Mobility is established in collaboration with Greeves Cotton Limited with an aim to create a platform for academia and industry to interact, innovate and co-create newer technologies for the EV industry. The centre is engaged in developing futuristic electric vehicle solutions in areas such as Next Generation Controllers, Battery, Thermal Management, embedded design for connected vehicles and application development for electrical mobility.

Graves Cotton Limited is committed to develop competence in RVCE through its UG and PG Students Internship, and Exchange program for training in following areas:

- Electric vehicle Design
- Electric vehicle Architecture
- Functional Safety in Electric vehicles through ISO26262
- Vehicle Styling and Industrial Design
- Sub Systems Design like Controller, Motor, Battery Systems, Regenerative Braking, Connected Vehicles etc.
- Verification and Validation of Sub Systems and Reliability Engineering
- Concepts of HALT, HAST and MEOST in Accelerated testing
- EMI/EMC of sub systems and Vehicles

The centre has identified the following projects for the first year of its operations:

- Controller Design for 1.2 kW and 3 kW BLDC Traction Motors
- BMS Design for Lion battery
- CAN Based telematics Gateway Unit for Preventive Diagnostics
- Application Software for special features in EV – IP shared by RVCE and GCL
- Development of Hybrid battery solution with Ultra Capacitors

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BOSCH REXROTH – RVCE Centre of Excellence in Automation Technologies

The Centre of Excellence in Automation technologies is established for upskilling, research and development and industrial consultancy in diverse areas of automation with hydraulics and pneumatics. The interdisciplinary centre is engaged in building hydraulic and pneumatic circuits, designing ladder logic circuit using PLC and demonstrating automated assembly sections using Mechatronics systems for various applications. The centre is equipped with high end equipment such as hardware training kits, PLC which support internet gateway for cloud communication, motion control PLC and CNC simulator MTX.

The centre is upgraded with Industry 4.0 kit, high end XM PLC, L65 PLC to cater to the training needs of one of the modules of CISCO-RVCE in IIoT. The centre is engaged in training industrial professionals, students of RVCE and Institutions elsewhere in Karnataka. Major industrial consultancy projects undertaken by the centre include: Design and Development of 4 degrees of freedom Collaborative Robot which can pick 3 kg load with a reach of 550 mm, Development of Electric and Pneumatic actuation based Cartesian robot for pick and place operation and Design and development of robotic arm to place toys on the conveyor.

Centre of Excellence in Smart Antenna Systems and Measurements (SAS)

The center of excellence in smart antenna systems and its measurements (SAS) specializes in the analysis, design, optimization and measurement of RF and microwave devices for wireless and defense applications. This facility is for characterization of Antennas and also doubles as an EMI/EMC test facility. This large Electromagnetics and Microwave facility will be utilized for multiple activities R & D activities for funded projects, Lab facility for Antenna and EMI/EMC measurements that are a part of our PG programs and Consultancy activities for outsourced measurements.

Key facilities of the centre are i. **Electromagnetic Simulation software**: The SAS center employs various methods for the analysis of radiating devices implemented in bespoke software codes. The commercial package ANSYS HFSS™ is used in conjunction with evolutionary optimizers to affect novel antenna design shapes to meet high performance goals. **ii. Microwave Test Equipment: Rohde & Schwarz Vector Network Analysers** : The R&S®ZVL6vector network analyser has Specified frequency range 9 kHz to 6 GHz with Frequency over range (unspecified): 5 kHz to 7 GHz With Improved trace noise characteristics **iii. Antenna Measurements in Anechoic Chamber:** Far field Antenna Radiation Patterns (700 MHz – 40 GHz): The measurement chamber is equipped with a turntable with ± 0.1° positional accuracy. Measurements are conducted with Broad-Band Horn Antenna reference standards. The SAS faculty has anechoic chamber for antenna measurements and characterization. The room dimensions approximately are Height=2.5 meters (from floor to beam), Length=4 meters and Width=3 meters. The electrical specifications are as follows.

Chamber dimensions	4m ×3m× 2.5m
Frequency range	700MHz-20GHz
Quiet zone size	$1m^3$
Reflection requirement in the QZ	-40dB below peak
Ripple requirement at the QZ edge	+/- 1.5dB
Test distance	5mt (Approx)
Near field or far field testing	Far Field

The key outcomes from this facility are some of the funded projects from DRDO, NRB, ISRO and private research organizations related to Antennas and electromagnetics. These projects demand the design and validation of the designed structures by characterizing in Anechoic chamber only. One patent has been filed based on the results obtained from the anechoic chamber. There are about 25 publications by faculty and students related to the results obtained from anechoic chamber in reputed IEEE conferences, which are available in IEEE digital explorer and indexed by Scopus. There are 40 designed and working models related to funded projects which are characterized in the anechoic chamber. These structures are available in the institution.

MI Incubation Center

MI Incubation Center is a privately funded Technology Business Incubator (TBI) established by RSST to activate Innovation and promote entrepreneurship development among students, faculty of RVCE and other RV Institutes such as, RV College of Architecture (RVCA), RV Institute of Management (RVIM) and RV Institute of Technology & Management (RVITM) and other higher educational institutes in the region.

The Centre is not just a co-working space but a startup hub which provides end to end ecosystem for entrepreneurship development, including state-of-the-art infrastructure, seed funding, access to a strong mentoring network of domain experts, business planning and execution, acceleration, marketing, product launch support, go to market strategies, etc.

The center also provides access to startups to get connected with investors, corporates and MSME's to support product and business development. MIIC has signed MoU with leading incubators, accelerators and other institutes of national importance such as IIT and IIM for mentoring and supporting business development of the startups which get incubated at MIIC.

Incubation Model

MI Incubation center has setup FOUR stages in its incubation program

Pre-Incubation – The Centre accepts startup applications at idea level from RVCE students, faculty as well as from non-RV group startups. MIIC screens such applications once a month to identity ideas which have innovative components, are original, technogically feasible and have the potential to develop into a business within a time span of two to three years.

Admission - The startups which are screened through the pre-incubation phase are then invited to give their presentation to a selection panel, which does a thorough feasibility study of the proposal.

Incubation - The startups which are admitted into the center are provided working space, access to all lab and research facilities of RVCE, seed funding (for RVCE student startups only), regular mentoring from domain experts and any other support to develop their product and business.

Graduation - MIIC assists startups to develop their business plans, marketing strategies, developing sales, product launches etc. so that the businesses may further sustain on their own without the support of the center. Once a business reaches a stage of self sustenance, they graduate from MIIC and venture out on their own.

Companies incubated at MI Incubation Center

1) Rubizon Pvt Ltd- Would healing technology (Bio-Med domain)

2) Caranrose Biosol Pvt. Ltd. - Flower preservation Technology (Bio-Tech domain)

3) Upride Network Pvt. Ltd - Socio Educational Platform (E-Commerce)

4) Suchandra Technologies Pvt. Ltd - Next Gen Power Bank systems (Electronic Hardware)

5) Maven - Social blogging platform (E-commerce)

6) Biozzy Pvt. Ltd. - Developing resins from wet waste (Bio Tech domain)

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3. This effect has been widely studied [1-3, 7]

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Patents: F Bischoff, Apparatus for vapour deposition of silicon, U.S. Patent 3 335 697, 1967

Thesis: R C Nongpiur, Near-End Crosstalk Cancellation in xDSL Systems, Doctoral thesis, University of Victoria, 2005.

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