Digitalization of Gas Detectors Using IoT and Cloud Computing

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Abstract— Many industrial processes produce harmful and poisonous gases and vapors which can burn when mixed with air, sometimes violently. Gas detectors can make a valuable contribution to the safety of these processes. They can be used to trigger alarms if a specified concentration of the gas or vapor is exceeded. This can provide an early warning of a problem and help to ensure people's safety. However, a detector does not prevent leaks occurring or indicate what action should be taken. It is not a substitute for safe working practices and maintenance. Dusty, corrosive or damp environment will affect the frequency of inspection, maintenance and calibration. This paper presents the role of IoT and embedded technologies to design and development of centralized real time continuous monitoring and alarming system. This system used for detection and measurement of harmful and poisonous gas and for higher level communication and transmission and have been effectively implemented in the Steel Manufacturing scenario in applications which have added value to the Bottom and Top Line of the company.

Keywords: CO Gas Detector; Cloud Computing; IoT, Lora WAN; Embedded Universal Sensor; Carbon monoxide sensor; Remote maintenance; Gas Safety

I. INTRODUCTION

The uncontrolled leak of different gases can be very dangerous for human life and health, e.g., carbon monoxides lead to suffocation and natural or liquefied petroleum gas lead to fires or explosions [1, 5]. CO is a gas that can build up to dangerous concentrations indoors when fuel-burning devices are not properly vented, operated, or maintained. In high concentrations, it may even kill a human being within a few minutes [2]. CO is a colorless, odorless and tasteless gas and potentially lethal. Many of people in each year die due to CO gas because they are not aware that they breathe in poison. CO is invisible and smell less gas [3]. CO at different concentration levels has harmful effect on human body. At low concentration, CO causes fatigue in healthy people and chest pain in people with heart disease whereas at moderate concentrations, angina, impaired vision and reduced brain function. At higher concentrations, CO causes impaired vision and co-ordination, headaches, fatal, dizziness, confusion, nausea and causes flu like symptoms [4]. These examples of incidents annually consume many lives and expose the company to great financial losses [6, 8]. Therefore, engineers and scientist constantly create new systems to prevent these type of incidents [7].

When the decision is taken on adopting implementing Industry 4.0 in steel manufacturing industries many levels of mature Automation and Sensorization already exists and the technology providers are hard pressed to find use cases for the technologies which can add real value to the organization in its bottom line rather than remain a white Elephant acquisition and an embarrassment.

In this paper, we describe cloud based centralized real time monitoring system for remotely placed CO gas detectors. Therefore, we create cloud platform with sensor hardware to collecting, processing, and sending data. In any steel manufacturing plant several gas detectors have been installed across works and nonworks area. These detections are local and generates local alarms.

Fig. 1.0: CO Gas Detector in Tata Steel Works

Technologies such as Sensorization and Digitalization, Data Analytics etc. are familiar to process managers and can be assimilated into the existing Automation Framework, while other levers such as wireless sensor data transmission, Smart edge analytics and cloud-based CO gas detections etc. have difficulty in finding realistic use cases and applications.

This case study demonstrates the system to transmit device output signal onto the IOT platform via LoRa WAN network to serve enhance sensor coverage and data connectivity.

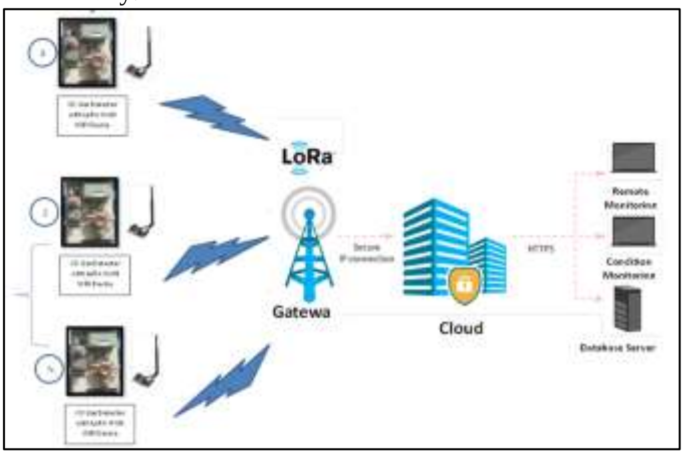


Fig. 2.0: Architecture Diagram

The platform can host an application which will showcase the significance of the amp current value to application value. Further data will be stored in database and used for real time monitoring and analysis. We have designed in-house sensors with on-board diagnostics and wireless transmission using Long Range Low Power technology to know status of gas concentration centrally. Also, In-house cloud-based application helps for monitoring and analysis data properly for immediately preventive measures.

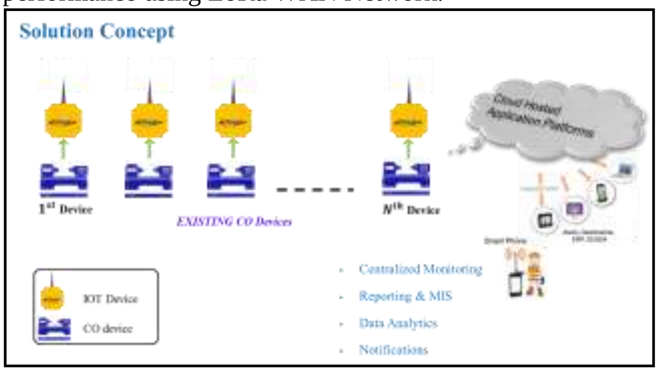
II. HARDWARE DESIGN

In general, the CO detector device output signal shall be 4 to 20 mA or HART. The combustible sensor/transmitter will be a sourcing type of signal capable of operating into a 600-ohm load. The toxic gas or oxygen sensor/transmitter will operate on a 2-wire or 3-wire current loop. Sensors shall be contained in sensor modules mounted external to the main enclosure. All sensor modules shall have the capability of replacement while the unit is under power (hazardous areas) without the need for tools. Sensor modules shall contain all relevant sensor information within the module. Data from each detector which is required to be captured and send to cloud server are:

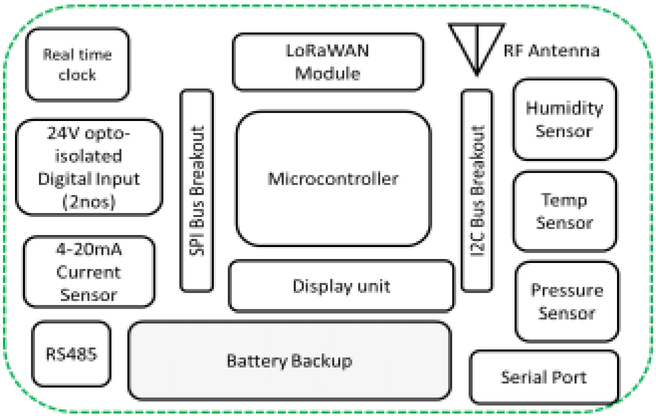
- Sensor ON/OFF - Machine ON/ OFF data will be used to find whether machine is ON or OFF.
- Sensor Data
  1) Sensor ID,
  2) Gas type,
  3) Gas Concentration in PPM

A. LORA WAN

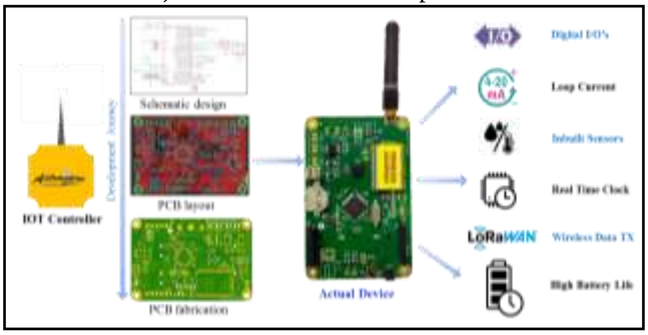
LoRa (Long Range) is a low-power wide-area network (LPWAN) protocol developed by Semtech. It is based on spread spectrum modulation techniques derived from chirp spread spectrum (CSS) technology. LoRa WAN is a cloud-based medium access control (MAC) layer protocol but acts mainly as a network layer protocol for managing communication between LPWAN gateways and end-node devices as a routing protocol, maintained by the LoRa Alliance [9]. An experimental setup has been made with a type 'A' LoRa WAN device for testing the data transmission performance using LoRa WAN Network.



A) Solution Concept



B) Universal Sensor Components



C) PCB Design

Fig. 3.0: Hardware Design A.) Solution Concept B) Universal Sensor Components C) PCB Design

We have designed Universal Sensor Platform that enable the machines and sensors to connect wirelessly to the network and are the actual 'Things' in the 'Internet of Things'. Followings are the main components of Universal IoT Sensors:

- Microcontroller: AVR core microcontroller with sleep current less than 1uA
- Real time clock (RTC): Real time clock with independent battery backup for clock synchronization and trigger
- Battery Backup: Battery Backup: Minimum 3 three years which extremely low self-discharge type cell and ultra-low quiescent current (1uA).
- LoRaWAN Module: As per TCL network parameter requirements, preferably microchip module
- Current Sensor: Fully isolated high accuracy 4-20 mA current sensor
- Display unit for continuous update of sensor data and monitoring
- Humidity sensor: 0 to 100 %RH, Resolution: 0.04 %RH
- Digital Input: Optically isolated, 5-40 VDC input voltage
- Temperature Sensor: -40 to 125°C, Resolution: 0.04°C
- Serial port: For connecting with PC and local debugging through USB port.
- Antenna: Suitable antenna for 865-867Mhz with adequate gain
- RS485 communication port for PLC
- Breakout option for microcontroller SPI and I2C bus for future expansion

After designing of Universal IoT controller, one add-on current sesnor card has been added, which provides 4-20 mA loop current output. This output can be further converted to CO PPM concentration and can be transmitted using LoRa WAN network. Next phase is development of edge algorithms that describes business logic for interface design and development between IoT sensor device and cloud platform.

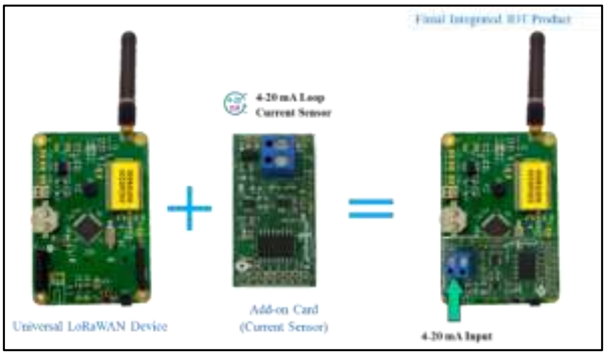


Fig. 4.0: Final Product with Add-On Current IoT Sensor

III. SOFTWARE DESIGN

Software design using cloud platform is very crucial in overall system development architecture. This layer defines actual implementation of business requirements and processing of sensor data. To allow IoT sensor to send data using LoRa WAN protocol, web APIs needs to be developed. These APIs will fetch data from cloud platform and update the system database with real time values. We are using oracle database for storing and processing of sensor data.

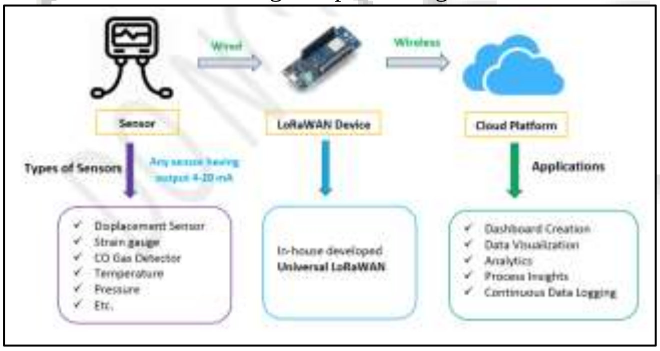


Fig. 5.0: Conceptualization of Software design

Further the cloud platform is designed for Data visualization and further data analytics. The IoT platform enables operators/users to visualize current CO PPM concentration across the plant or any gas hazardous area.

A. Data Packets:

In data communication using web APIs we are using 26 Bytes packet size. Embedded sensors are sending CO detector ID, Gas Type, Gas concentration and power status in every 1-hour frequency. These data web APIs are capturing and storing in database. Sensor is sending raw 4-20mA current value in data packet and at server side, web APIs are converting amp current value to equivalent Gas concentration in PPM. To save battery life we have defined sending/triggering threshold to >50 PPM, whenever current sensor output exceeding threshold value, sensor triggers data packet instantaneously having following data source.

Data Source	Data Size	Data Transfer Condition	
		Frequency	Trigger
Date Time Stamp	12 Bytes	*1 hour*	>50 PPM
Sensor ID	3 Bytes	*1 hour*	>50 PPM
Gas Type	3 Bytes	*1 hour*	>50 PPM
Gas Concentration	5 Bytes	*1 hour*	>50 PPM
Battery Power (%)	3 Bytes	*1 hour*	>50 PPM
Total	26 Bytes		

Fig. 6.0: Data Packet for IoT Sensor

Here we are using 3- tier software architecture for IoT Cloud system design. In 3 tier architecture, the client machine acts as the front end and doesn't contain any direct database calls. The client end communicates with an application server, usually via a form interfaces. The application server in turn communicates with a database system to access data. The 3-tier applications are more appropriate for these type of large applications, and the applications that run on the web.

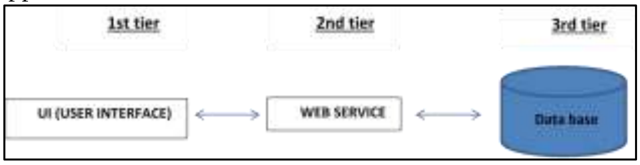


Fig. 7.0: 3- Tier Architecture

For user interface and dashboard development, we are using HTML-5, BOOTSTRAP, JAVASCRIPT, CSS and J-QUERY software tools and technologies. System database is designed using ORACLE 12C (64 bit) for processing and storage of sensor data. System contains different database units to store data for location details, sensor physical details, alarms details, Gas PPM details etc. For data analytics and modeling all data is historized at regular intervals to enhance system response. This will help operators to visualize and generate data trends.

B. Database Design:

The trickiest part of managing a cloud-based system is the management of persistent data. Cloud-based databases, have led to some rethinking about how we do database design for cloud-based systems. This system is designed as service-oriented architecture. Both services provide and consume data that exists within the growing cloud services catalog. We have designed database as autonomous unit so that many cloud based application can be hosted at same cloud architecture. Following are some examples of the database entities used for the system design:

1) Database design to store location-based information where gas detectors are installed.
2) Database are used to store real time sensor data received from IoT sensor with timestamp values.
3) Database tables to store all application user details with authorization and different level of operations.
4) Database tables for alarm generation and real time alerts. Various alerts APIs have been developed like mobile SMS, E-Mail APIs for sending real time alerts to users.
5) Database entities for historization and trend analysis.
6) Database design for data analytics on sensor data.

Following data flow diagram depicts model developed for real time alarm generation using the system.

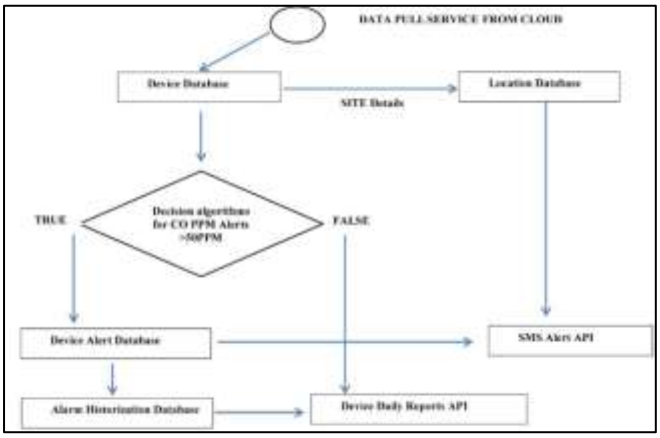


Fig. 8.0: Data Flow Diagram for Gas Detection

IV. IMPLEMENTATION

Fixed gas detectors are located remotely where people might rarely come into contact with a combustible or toxic gas until it is too late. On the other hand, there are many locations where the transmitter can be placed where it is more convenient and less labour intensive for factory technicians to review and confirm alarms, diagnostics data or make updates. For technology proof of concept, this system was implemented initially for approximate 100 numbers of remotely distributed CO detectors. Further system can be easily cover all type of gas detectors across geographically distributed locations. The cloud API converts the sensor amp current level to CO PPM level application value. Further data will be stored in database and used for real time monitoring and analysis. User Interface is device responsive smart application systems for data visualization, condition monitoring and trend analysis to enable preventive maintenance of the smart devices.

In System dashboard, one can see a summary of the CO gas detector which displays the device ID's of all the devices installed, their location, the concentration of CO ppm and their power status.

Fig. 9.0: Smart Solution for Gas Sensor

The chart reports give us a summary of the functioning of devices in the form of graphs and bar charts from a date to a specific date of a location as desirable by the user.

Fig. 10.0: Trend Analysis

V. CONCLUSION AND WAY FORWARD

This paper demonstrates how IoT and cloud computing technologies can be leveraged for implementation of gas safety standards at working place. Indigenous Universal sensor platform development with edge computing, enable the machines and sensors to connect wirelessly to the network and are the actual 'Things' in the 'Internet of Things'. Also, cloud based smart API and services used for visualization, condition monitoring and online reporting. This system can be deployed in all applications where toxic gas monitoring and preventive measure is crucial. Other critical gas hazardous applications include round the clock monitoring in remote places. Managers can access an emergency situation, and in the worst of situations can dispatch an emergency crew to the worker's exact location. It has the potential to save innumerable human life, valuable assets and properties by being properly utilized by Emergency response team itself also system can easily deploy for other manufacturing companies across the world for different applications.

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