Est. 1841 | YORK ST JOHN UNIVERSITY

Towards Building a Low-Cost IoT-Based Real-Time System for Remote Monitoring of Sensitive Facilities

Aminu Usman, PhD, SFHEA
Associate Head of Computer & Data Science

Presented at the 9th International Conference and Workshop on Basic and Applied Sciences
10th May 2023

Outline

- Sensitive Facilities
- Challenges of Monitoring Sensitive Facilities
- Internet of Things?
- Environmental sensors
- Enabling technologies for Monitoring Sensitive Facilities using IoT-based Solutions
- IoT Communication Protocol
- A case study - System Architecture

Sensitive Facilities

- Sensitive facilities refer to buildings, areas, or sites that house critical infrastructure and assets.

- Refineries
- Nuclear power plants
- Chemical plants
- Biomedical engineering labs
- Pharmaceutical factory.
- Aerospace factory
- University labs

Monitoring Sensitive Facilities

- Sensitive facilities are typically protected by a combination of physical security measures, such as fences, barriers, and guards, as well as advanced electronic security systems

- We want to detect, identify, and monitor high-value physical assets
- Assets of interest include building rooftops, pipelines, plant, equipment and industrial facilities.

Est. 1841 | YORK ST JOHN UNIVERSITY

Challenges of Monitoring Sensitive Facilities

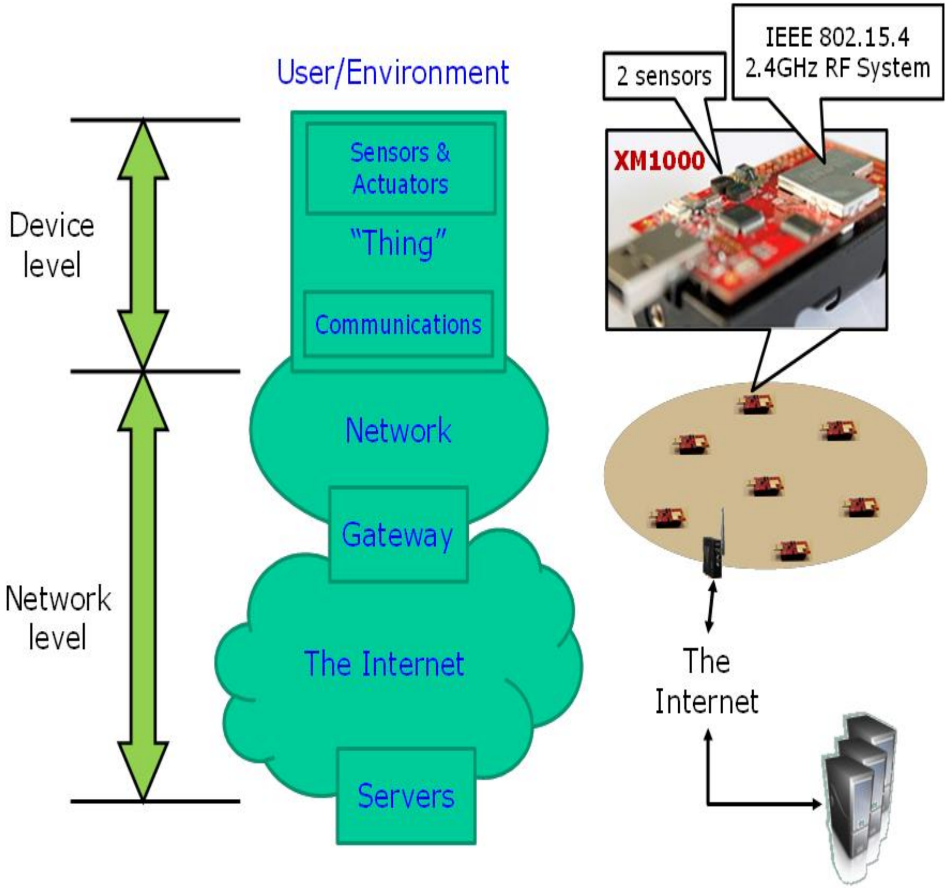
- Traditional manual ways of inspecting sensitive facilities made data collection difficult, time-consuming and labour-intensive.
    - Security Threats - Sensitive facilities are often targets for attacks by individuals or groups seeking to cause damage, steal information or materials, or disrupt operations
    - Technical Complexity - Some sensitive facilities may involve complex systems and equipment that require specialized knowledge and skills to monitor effectively
    - Cost - Monitoring sensitive facilities can be expensive, requiring significant investments in technology, personnel, and infrastructure.

Internet of Things

Automating the monitoring of sensitive facilities with IoT can help increase efficiency, reduce costs, and improve safety and security, while also providing valuable data for analysis and decision-making.

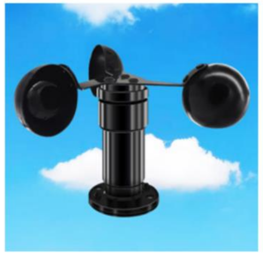
IoT Applications for Environmental Monitoring

Energy saving management	Safety and security sol.	Maintenance cost-saving
Data connectivity integration	Real-time Data management	Maximise technical performance
Improve building comfort	Optimising asset utilisation	Conserving Natural Resources
Reduce global warming	Health care improvement	Water Management



IoT- A network of physical objects, or "things," that are embedded with sensors, software, and other technologies to connect and exchange data with other devices and systems over the internet.

Environmental Sensors

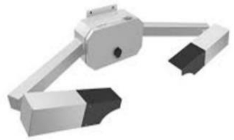


Wind speed and direction sensor

Temperature and humidity sensor

Solar Radiation Sensor

Evaporation sensor



Atmospheric visibility sensor

Illumination sensor

Barometric pressure sensor

Rain Gauge

Temperature, Pressure, Humidity Sensor

Motion Sensors

Gas sensor

Water Leak sensor

Type of Sensor	Purpose	Examples
Temperature sensor	Measures temperature	Thermocouples, thermistors, RTDs
Humidity sensor	Measures humidity	Capacitive, resistive, thermal conductivity
Pressure sensor	Measures pressure	Strain gauge, capacitive, piezoresistive
Motion sensor	Detects motion or movement	Infrared, ultrasonic, microwave
Vibration sensor	Measures vibrations	Piezoelectric, capacitive, strain gauge
Light sensor	Measures light levels	Photodiodes, phototransistors, light-dependent resistors
Gas sensor	Detects gas concentrations	Electrochemical, infrared, semiconductor
Smoke sensor	Detects smoke particles	Ionization, photoelectric
Water leak sensor	Detects water leaks or flooding	Conductive, capacitive
Sound sensor	Measures sound levels	Microphones, piezoelectric, accelerometers

Enabling technologies for Monitoring Sensitive Facilities using IoT-based Solutions

Collaborative Sensing Intelligence (CSI)

Dynamic collaboration processing

Intelligent Internet of Things - IIoT

Data processing and analytics techniques for IoT-based real-time system for remote monitoring of sensitive facilities

- **Anomaly detection**
  - Examples: Statistical methods, machine learning algorithms
- **Predictive modeling**
  - Forecasts future behavior based on historical data: Examples: Regression, time-series analysis
- **Data fusion**
  - Combines data from multiple sources to improve accuracy. Examples
    Kalman filtering, Bayesian inference
- **Data preprocessing**
  - Cleans, filters, and transforms raw data. Examples: Smoothing, normalization, outlier detection
- **Pattern recognition**
  - Identifies patterns and trends in data. Examples: Clustering, association rule mining
- **Decision-making**
  - Determines the appropriate action based on analyzed data.Examples: Rule-based systems, or decision trees

IoT Communication Protocol

Protocol	Range	Data Rate	Multimedia Support
WiFi	30-100 meters	11 Mbps - 10 Gbps	Yes
Zigbee	10-100 meters	20-250 kbps	No
Bluetooth	10 meters	1-3 Mbps	Yes
LoraWAN	Up to 10 km	0.3-50 kbps	No
NB-IoT	Up to 10 km	50-250 kbps	No
Sigfox	Up to 40 km	100 bps - 1 kbps	No
Z-Wave	Up to 100 meters	9.6-100 kbps	No
Thread	Up to 700 meters	250 kbps	Yes
6LoWPAN	Up to 100 meters	250 kbps	Yes
MQTT-SN	Up to several kilometers	10-250 kbps	No
CoAP	Up to several kilometers	10-250 kbps	Yes
LoRa	Up to 10 km	0.3-50 kbps	No
NB-Fi	Up to 5 km	100-250 kbps	No

- Two main categories of IoT Communication Protocols
- 2.4GHz IoT protocols.
  - **Wi-Fi**
  - **Bluetooth Low Energy (BLE)**
  - **Zigbee**
  - **Thread is a newer 2.4GHz IoT protocol**
- Sub-GHz IoT protocols
  - offers long-range, low-power connectivity and are suitable for a wide range of IoT applications, especially those that require coverage over large areas.- LPWAN
  - **LoRaWAN**
  - **Sigfox**
  - **NB-IoT**
  - **Weightless**

Est. 1841 YORK ST JOHN UNIVERSITY

A Case Study

- Develop a low-cost innovative technology for environmental monitoring of the sites' physical data such as:

  - Detecting toxic gas in a highly dynamic production environment based on temperature, humidity, light intensity, and carbon monoxide.

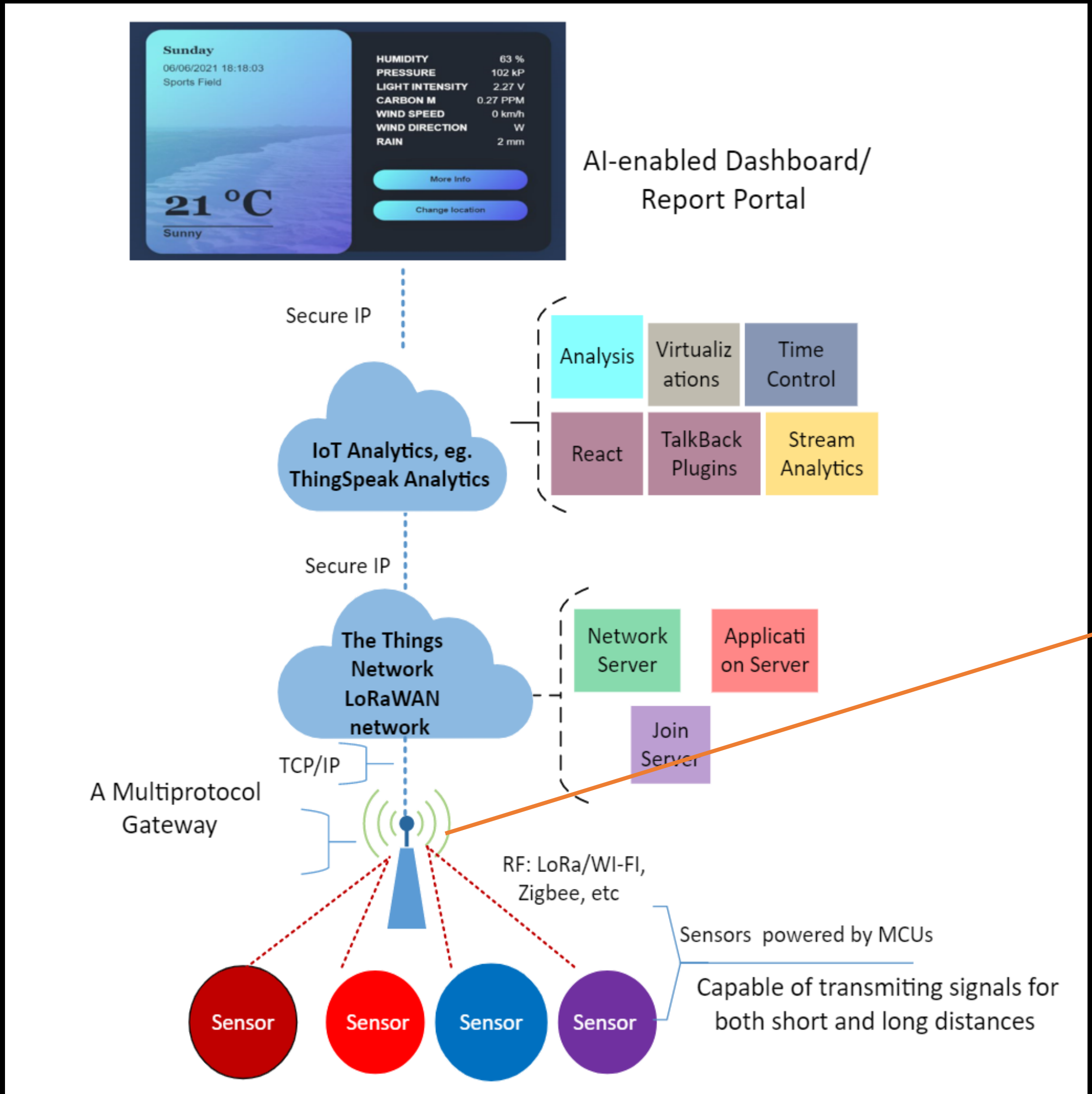
  - Detect early warning of water effects - to detect water leaks in real time and send SMS and email alerts to site management.

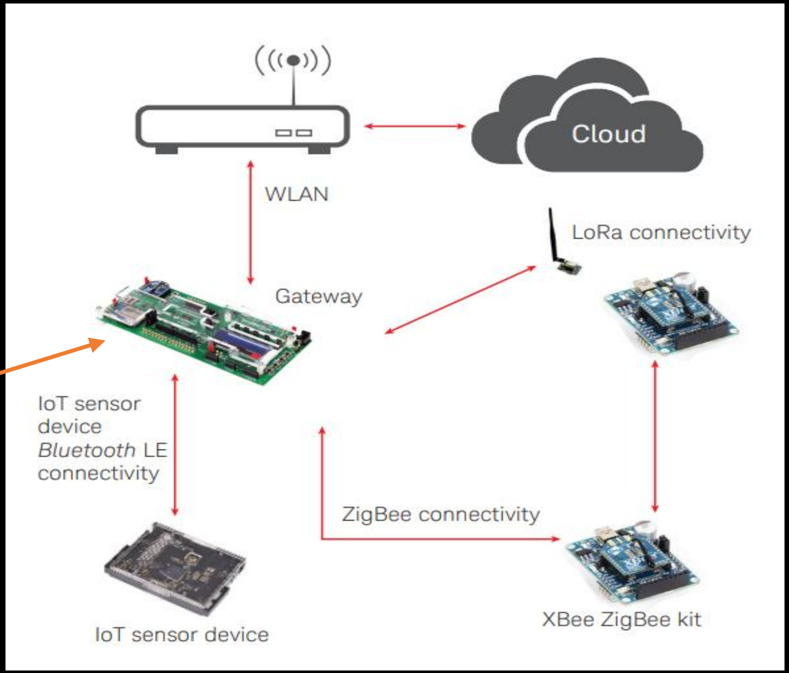
  - Monitoring air quality - Carbon Dioxide (CO_2), Nitrogen Dioxide (NO_2), Ozone (O_3), Total Suspended Particulates (PM100 –TSP), Temperature, Humidity, and Barometric parameters.

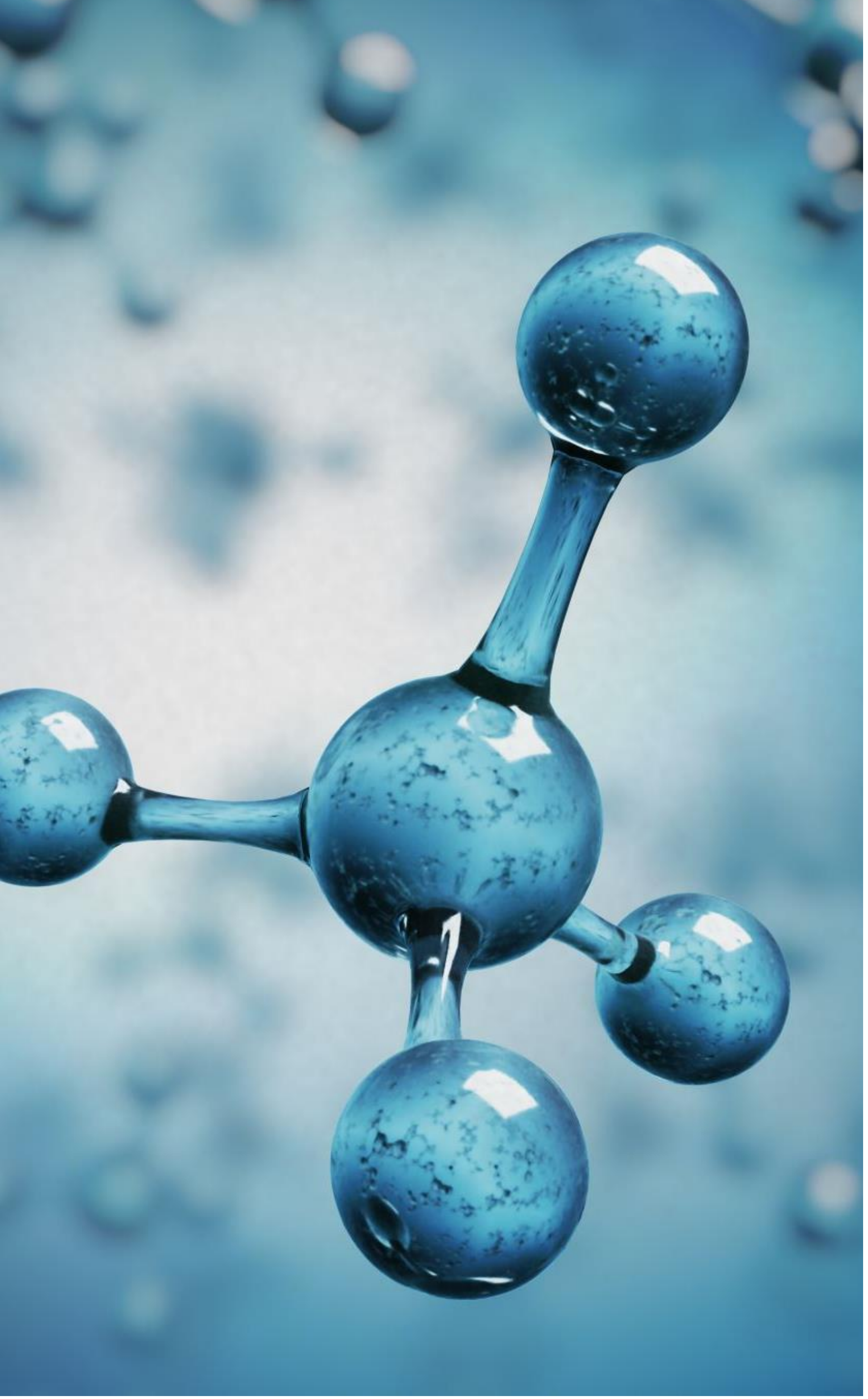
  - Change in vegetation around a site - The images from the Multi Spectral camera, as well as satellite photographs of the sites and the use of NDVI to identify plant index and the relationship between spectral variability and changes in the rate of vegetation growth.

  - Environmental impact on and around sites e.g. coastal erosion, monitoring a subsea wellhead and borehole on the seabed - A multi-temporal assessment of aerial photos to determine the rate of shoreline erosion surrounding sites using numerical models.

System Architecture



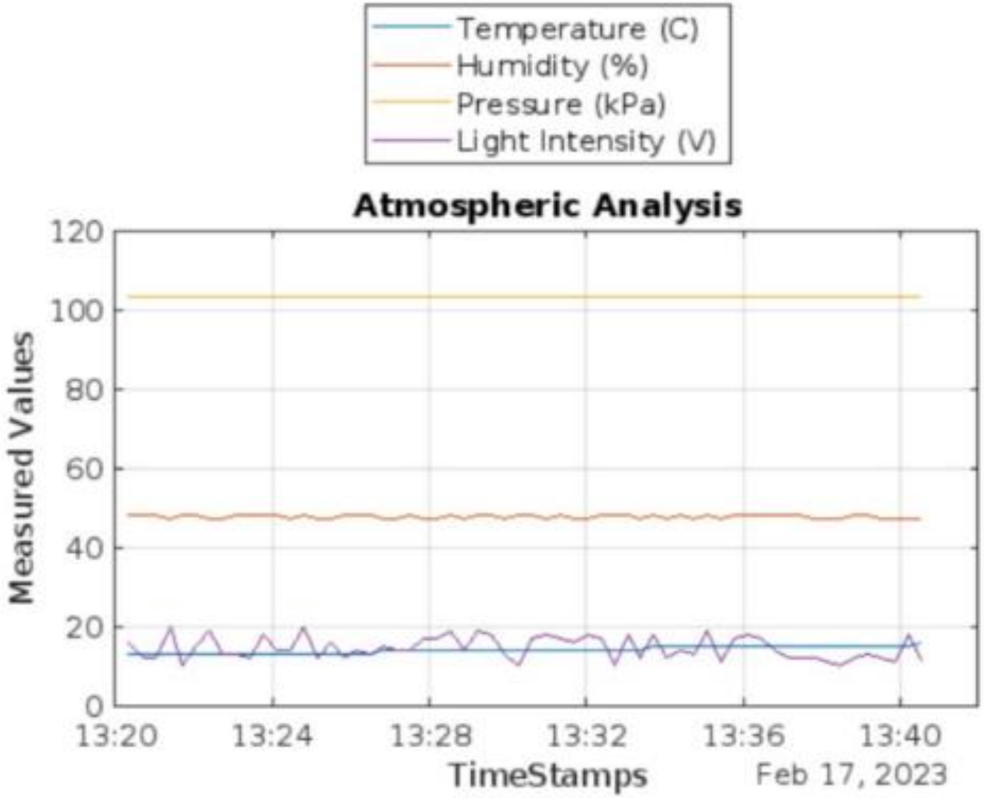




Calculating Concentration of Toxic Gas

- Let
  - T = temperature
  - H = humidity
  - L = light intensity
  - CO = carbon monoxide levels
- T_thr = 80-85 degrees Fahrenheit
- H_thr = 40-60% relative humidity
- L = between 40 and 50 foot candles
- L_thr, and CO_thr represent the thresholds for each parameter, above which the readings are considered to be indicative of the presence of toxic gas.
- The condition for detecting toxic gas can be expressed as:
  - If $(T > T_{thr}) \wedge (H > H_{thr}) \wedge (L < L_{thr}) \wedge (CO > CO_{thr})$

A Dashboard



A time series graph

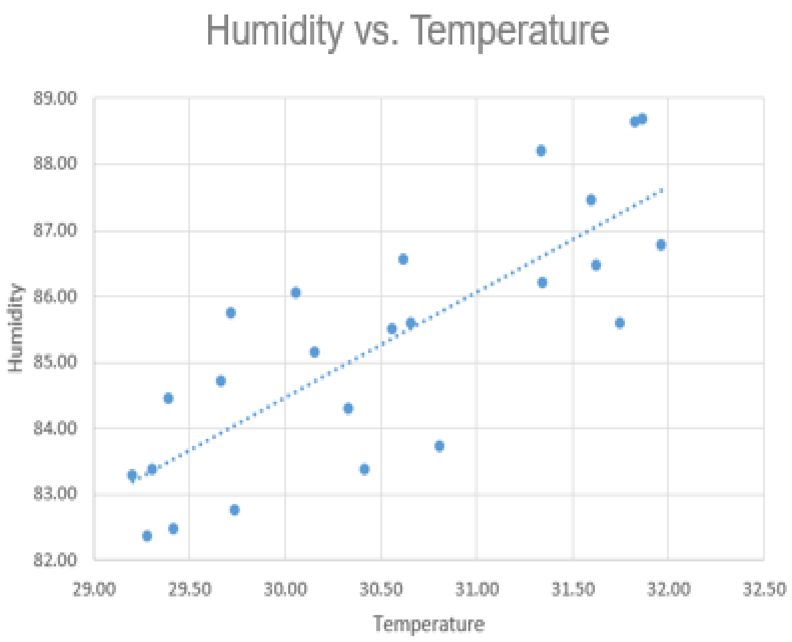
Data Visualization

Est. 1841 YORK ST JOHN UNIVERSITY

Visualization

Scatterplot

- A scatter plot is often used to identify the relationship between two quantitative variables. The following graph illustrates the relationship between humidity and temperature in a room.



- Trend lines can be added to scatterplots to see how the data correlate.

Visualization - Map-based visualization

- In IoT, besides basic visualization, location-based visualization is very popular.

- Many mobile devices are GPS-enabled. Therefore, location analytics allow us to make more sense out of collected data.

Advantages of a low-cost IoT-based solutions

- In comparison to more expensive system, a low IoT-based real-time system have a number of benefits, including:

    - They are far less expensive than high-end weather stations, making them more accessible to a larger variety of consumers.

    - Wireless and multiprotocol connectivity: a low-cost IoT-based real-time system come with wireless connectivity options, making it easy to access data from anywhere.

    - IoT-based real-time system are small and light, which makes it easy to move them from one place to another

Est. 1841 YORK ST JOHN UNIVERSITY

Challenges and Research Problems

- Collaborative sensing intelligence (CSI)
  - Selfish and non cooperative routing behaviour of sensor nodes can impact the performance and reliability of sensor networks.
    - reputation-based routing mechanisms to incentivize nodes to behave cooperatively
    - game-theoretic approaches to model and predict node behaviour and to encourage cooperation

- Dynamic collaboration processing of Sensor data
    - Algorithms to make senses of the data from different collaborative data source and in different data types for discovering useful knowledge

- IIoT – Intelligent Internet of Things
  - Edge analytics algorithms to enables real-time analytics and decision-making at the edge of the network.

How to Get Started? (1)

- Building a low-cost IoT-based real-time system for remote monitoring of sensitive facilities is certainly feasible with the right approach. Here are some steps you can take to achieve this:

1. Define your requirements
    - What are the sensitive facilities you need to monitor
    - What parameters do you need to measure
    - What is the frequency of data collection
    - What are the critical events that require immediate attention

2. Define the connectivity requirements.
    - Do you need to have the information available remotely?
    - How often do you need the information?
    - Do you need the data in real-time?
    - What levels of security and reliability are needed?

How to Get Started? (2)

3. Choose the right hardware
   - What Sensors do you need?
   - You also need a microcontroller to collect data from the sensors and send it to the cloud
   - There are many low-cost microcontrollers available in the market, such as Arduino and Raspberry Pi.

4. Define the data collection requirement
   - Do not underestimate the amount of data that can be generated by a collection of sensors.
   - The collected data needs to be stored and analyzed in the cloud.
   - You can choose a cloud platform that provides IoT services such as Microsoft Azure, Amazon AWS IoT, or Google Cloud IoT or ThingSpeak IoT analytics.
   - These platforms provide features such as data storage, real-time data analysis, and event-based triggers

5. Develop a web or mobile application (Dashboard) that can display the data collected from the sensors in real-time. You can use a web or mobile development framework such as React, Angular, or Flutter.

How to Get Started? (3)

6. Secure your system

- Security is a crucial aspect of any IoT system, especially when dealing with sensitive facilities. You need to ensure that your system is secure from data breaches and cyber attacks. You can use encryption and authentication mechanisms to secure your system.


Thank you for listening
Questions ?

References

- MODE, T., MODE, S. and MODE, S., 2016. Keysight Technologies.

- Dajnowski, N., Usman, A.B. and Guest, A., Building Low-Cost IoT-Based Meteorological Stations Using LoRaWAN.

- Wells, A. and Usman, A.B., 2023. Trust and Voice Biometrics Authentication for Internet of Things. *International Journal of Information Security and Privacy (IJISP)*, *17*(1), pp.1-28.