Multi-Protocol Interoperability Between Distributed Cyber-Physical Systems Towards Industry 4.0 Collaborative Optimization

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Resume

MD SABBIR BIN AZAD

Proactive self starter with curiosity to learn, research, design and prototype innovative solutions for residential and industrial aspects in the context of Industry 4.0. 5+ years of experience in leading technical projects and full stack development.

EDUCATION

- **M.A. Sc. in Industrial Engineering**, *Polytechnique Montreal*, Montreal, QC, Canada Jan2020-Jul2022

Research on Industry 4.0 .

- **B.Sc. in Electrical & Electronics Engineering**, *BRAC University*, Dhaka, Bangladesh Jan2010-Dec2013

Major in Electronics.

PROFESSIONAL EXPERIENCE

- **Graduate Research Assistant**, *Polytechnique Montreal*, Montreal, QC, Canada Jan2020-Jul2022

Research on Industry 4.0 .

- **Team Lead-Embedded Systems** , *Btrac Solutions*, Dhaka, Bangladesh Sep2014-Dec2019

Major in Electronics.

PUBLICATIONS

- Industry 4.0 Digital Transformation Model for Mining Industry Towards Developing the Digital Capabilities and Boosting Profitability
- Real-time Vehicle monitoring for traffic surveillance and adaptive change detection using Raspberry Pi camera module

2017 IEEE Region 10 Humanitarian Technology Conference (R10-HTC), 481-484

- Development of electric stove for the smart use of solar photovoltaic energy

2014 IEEE Region 10 Humanitarian Technology Conference (R10-HTC)

- Development of electric stove for smart use of Solar Photovoltaic energy with national grid

BRAC University

Outline

Chapter1: Introduction

Chapter2: Research Design

Chapter3: Research Development

Chapter4: Validation

Chapter5: Conclusion

Chapter6: Future Work

Chapter 1: Introduction

1.1 Background

Industry 4.0, fourth industrial revolution brought about by introduction of IoT and CPSs (Kagermann, Helbig, Hellinger, & Wahlster, 2013), has emerged as a promising approach to provide extensive connectivity in manufacturing environment (Li, Lai, & Poor, 2012)

One of the challenges that arises as a result of this evolution is the growing need for interoperability at various levels of the manufacturing ecosystem (Zeid, Sundaram, Moghaddam, Kamarthi, & Marion, 2019).

1.2 Problem Description

1.2.1 Interoperability Challenges

1.2.2 Limitations of Existing Interoperable Standards

1.2.3 Research Context

The main issue with current interoperable solutions is that there isn't a method that fits well with integration of IoT multi protocols in a gateway and effective full duplex interoperable communication to interconnect the sensors, IIoT devices, and machines and cloud integration for compatible platforms.

A low-cost interoperable IoT system to interconnect IoT objects and heterogenous devices and machines with different access protocols to support interoperability across the small and large-scale enterprises is a must.

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Introduction(Cont’d)

1.3 Research Questions

Q1: How can an IoT interoperable system assist structuring any data to interconnect heterogenous devices with different access protocols?

Q2: How can we make this interoperable system cost effective for small and medium enterprises?

1.4 Research Methodology

Phase1: Design Protocol Selection Framework

- Identification of MQTT, CoAP, HTTP, WebSocket and ModbusTCP protocols
- Capabilities and Requirement Analysis
- Conceptual Framework

Phase2: Develop Interoperable Multiprotocol System

- Build platform in a low-cost Gateway
- Implement full duplex communication between heterogenous systems
- Access multiple database and other platforms

Phase3: Validate the Developed Gateway

- Demonstrate with a case study
- Implement on a third-party platform
- Cloud Implementation

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Chapter 2: Research Design

2.1 Proposed Architecture

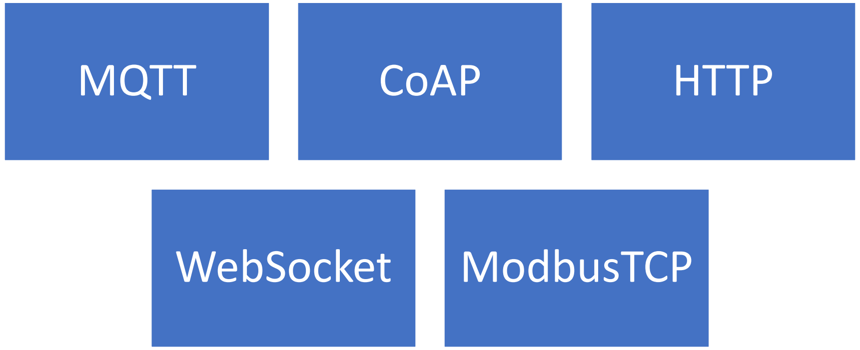

Figure 2.1: Proposed Access Standards for Interoperability

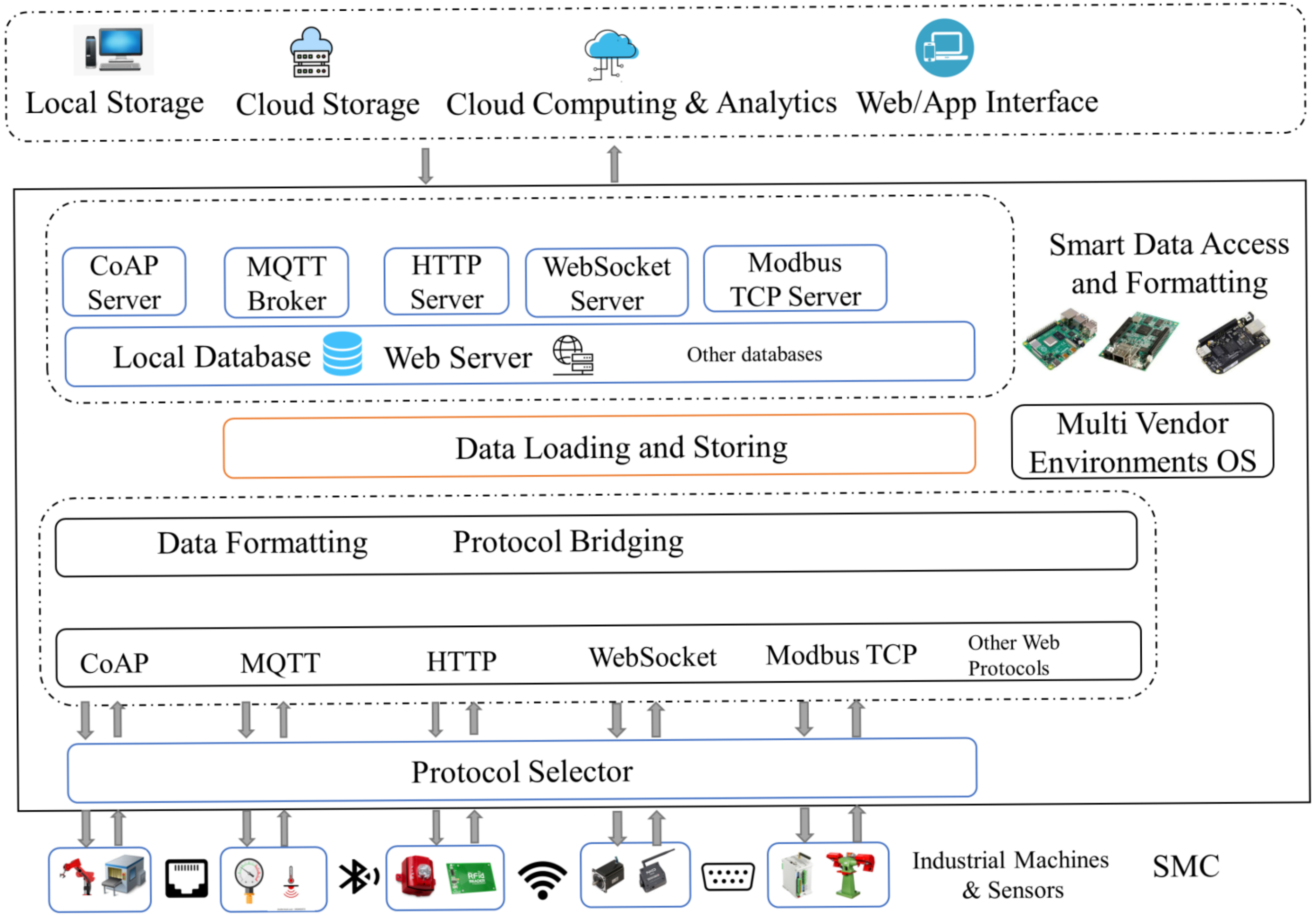

Figure 2.2: Proposed Architecture for Interoperability

Research Design(Cont’d)

2.2 Software Architecture
- 2.2.1 Set Access Protocols
- 2.2.2 User Interface

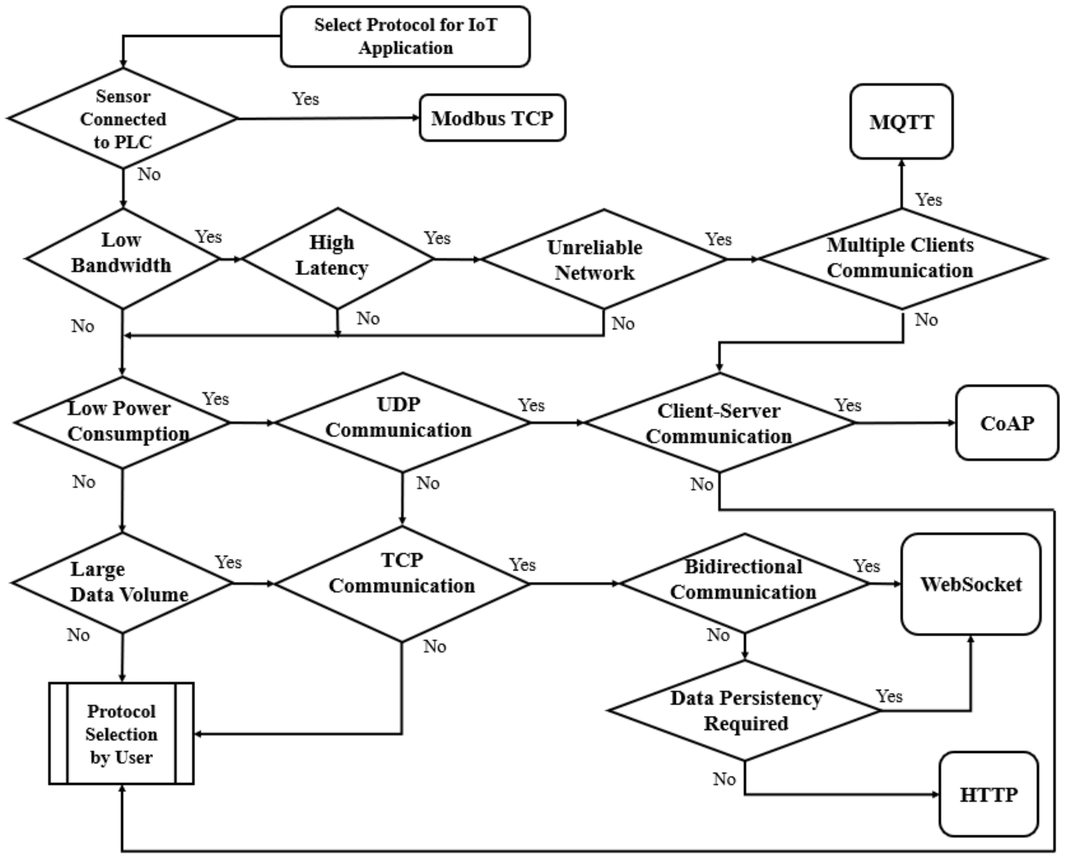

Figure 2.3: Protocol selection block diagram for applicable IoT systems

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Research Design(Cont’d)

2.3 Gateway Architecture

- 2.3.1 Data Formatting
- 2.3.2 Protocol Bridging
- 2.3.3 Nodes-Gateway Communication
- 2.3.4 Data Process and Storage

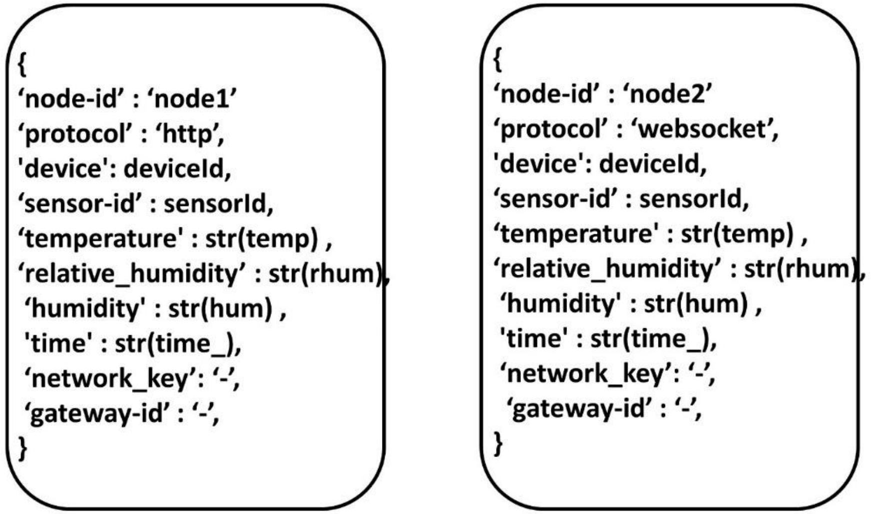


Figure 2.4: Example of systematized data format

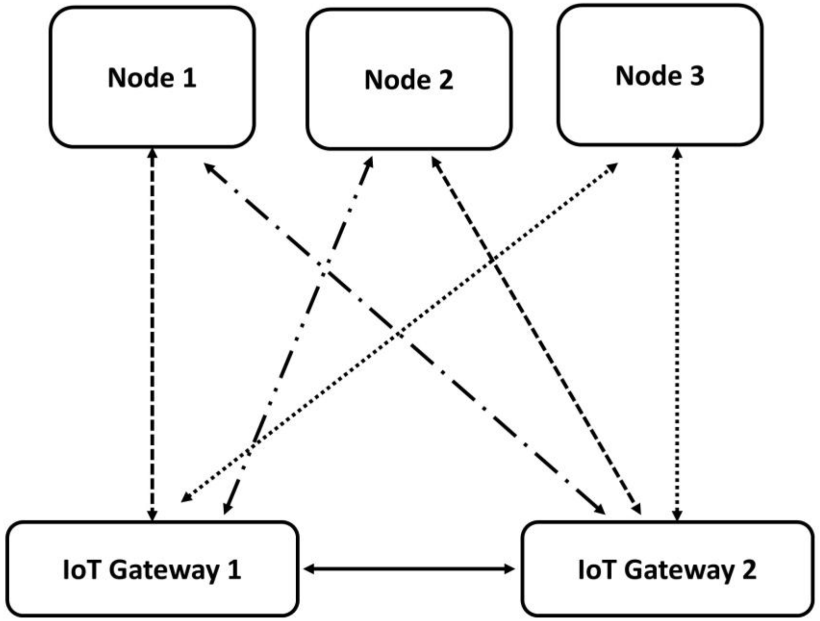


Figure 2.5: Nodes-Gateway Communication

Chapter 3: Research Development

3.1 Proposed Architecture Implementation

- Multi-Protocol Gateway Development
- Multi-Protocol Server Integration
- Microcontrollers-Sensors Integration
- Nodes to Gateway Interoperable Communication
- Full duplex communication
- Industrial Database and Cloud Integration

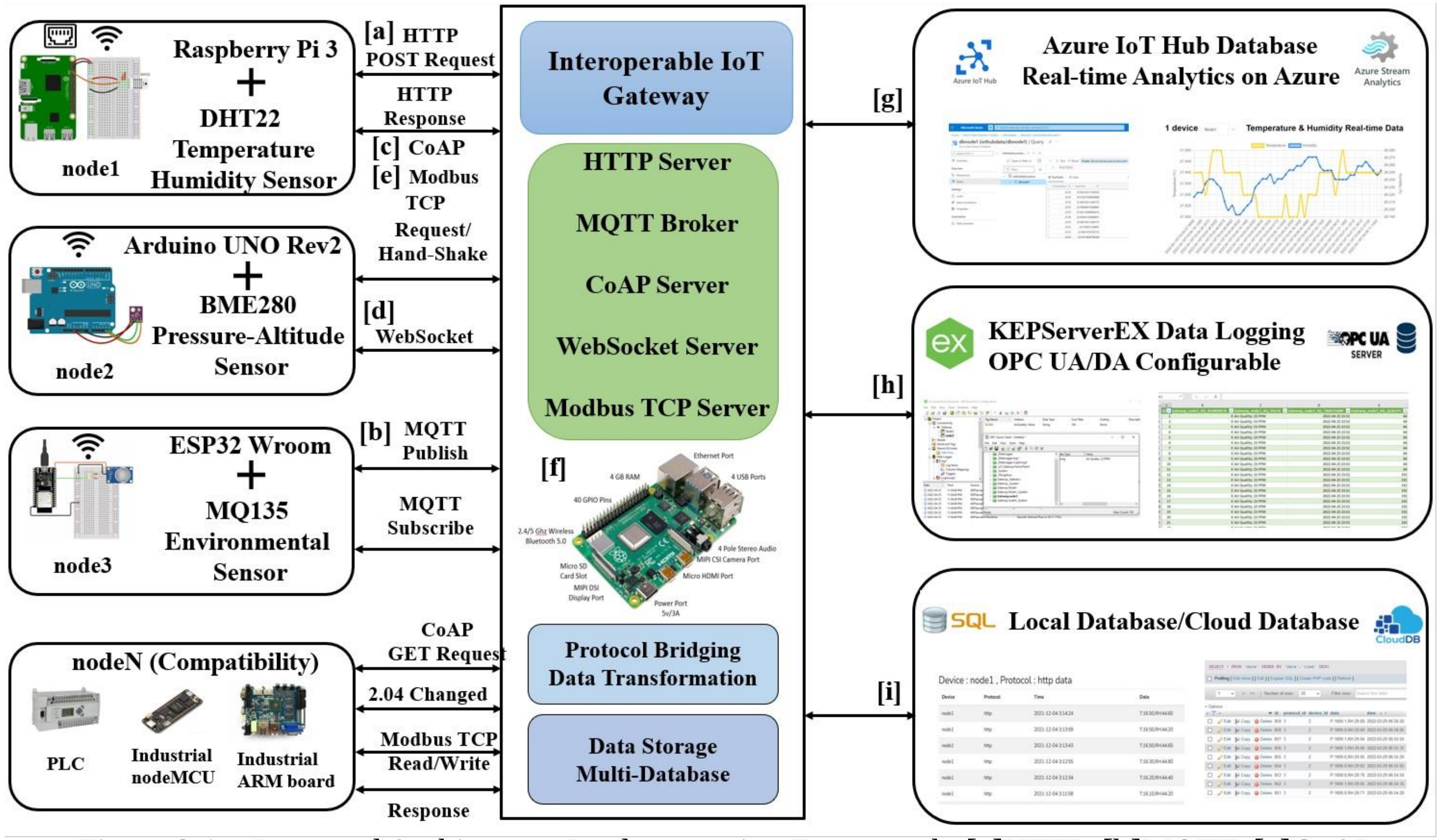
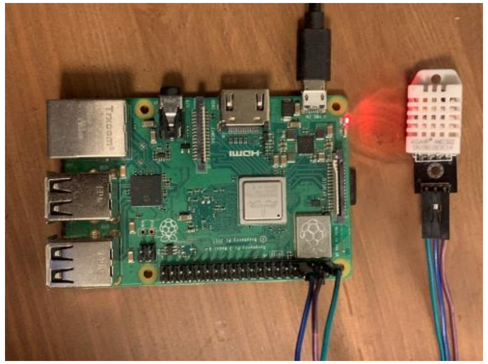


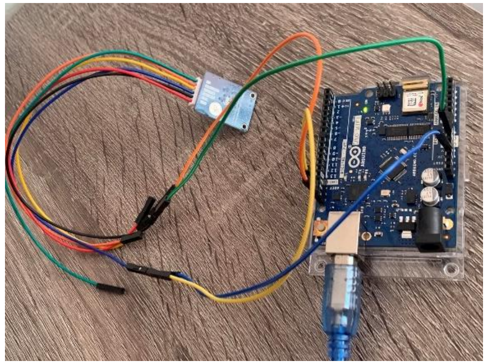
Figure 3.1: Proposed Architecture Implementation Framework, [a]HTTP, [b]MQTT, [c]CoAP, [d]WebSocket, [e]ModbusTCP, [f]Raspberry Pi 4 as Gateway, [g]Azure IoT Hub Database, [h]KepwareServer Data Logging, [i]Local/Cloud Database

Research Development(Cont’d)

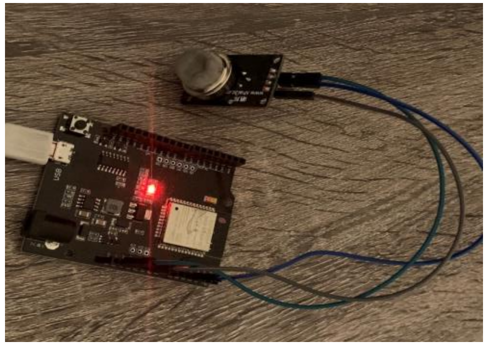


3.2 Multiple Node-Sensors Integration

3.2.1 Raspberry Pi 3 with DHT22 Temperature Humidity Sensor



3.2.2 Arduino UNO Wi-Fi with BMDE280 Pressure Sensor



3.2.3 ESP32 with MQ-135 Air Quality Sensor

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Research Development(Cont'd)

3.3 Multiple Nodes-Gateway Communication

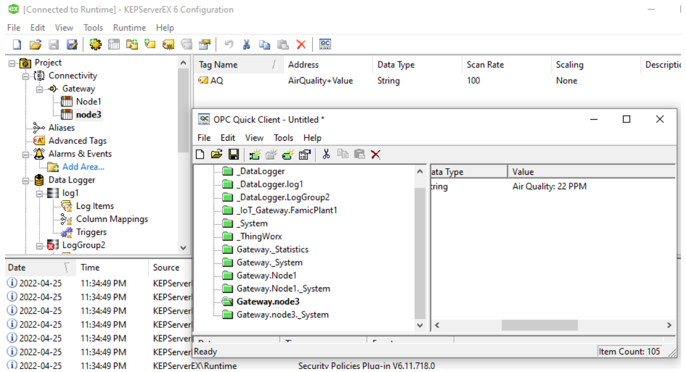
- 3.2.1 Communication Protocol Selection for Nodes
- 3.2.2 Data Interpretation Process
- 3.2.3 Data Formatting

192.168.0.106 Server Home Data

Device Name	Data	Select Protocol
node1	2022-05-31 14:15:04|T : 25.90, RH :56.50	http
node2	Pressure: 1010.79hpa , Approx. Altitude: 20.52meter	Websocket
node3	Air Quality: 73 PPM	MQTT

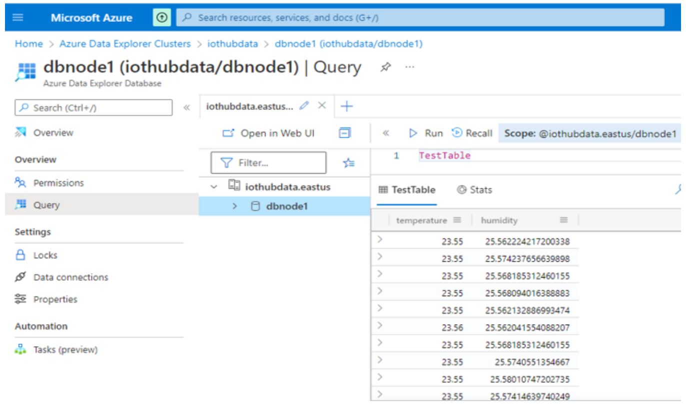
Figure 3.2: Gateway receiving data from node1,node2 and node3 over HTTP, WebSocket and MQTT protocol

Research Development(cont’d)

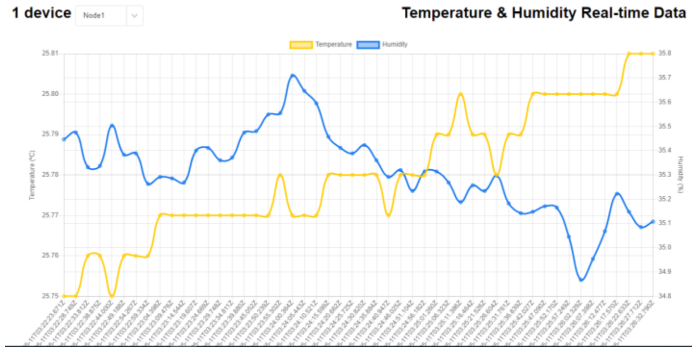


3.4 Industrial OPC Server and Cloud Integration

3.4.1 KepServerEX Data Logging and Communication



3.4.2 Azure IoT Hub Databases



3.4.3 Cloud Databases and Analytics

Chapter 4: Validation(Case Study)

4.1 Case Study
- 4.1.1 ThingsBoard Configuration
- 4.1.2 Gateway Configuration
- 4.1.3 Nodes-Gateway-ThingsBoard Interoperable Communication

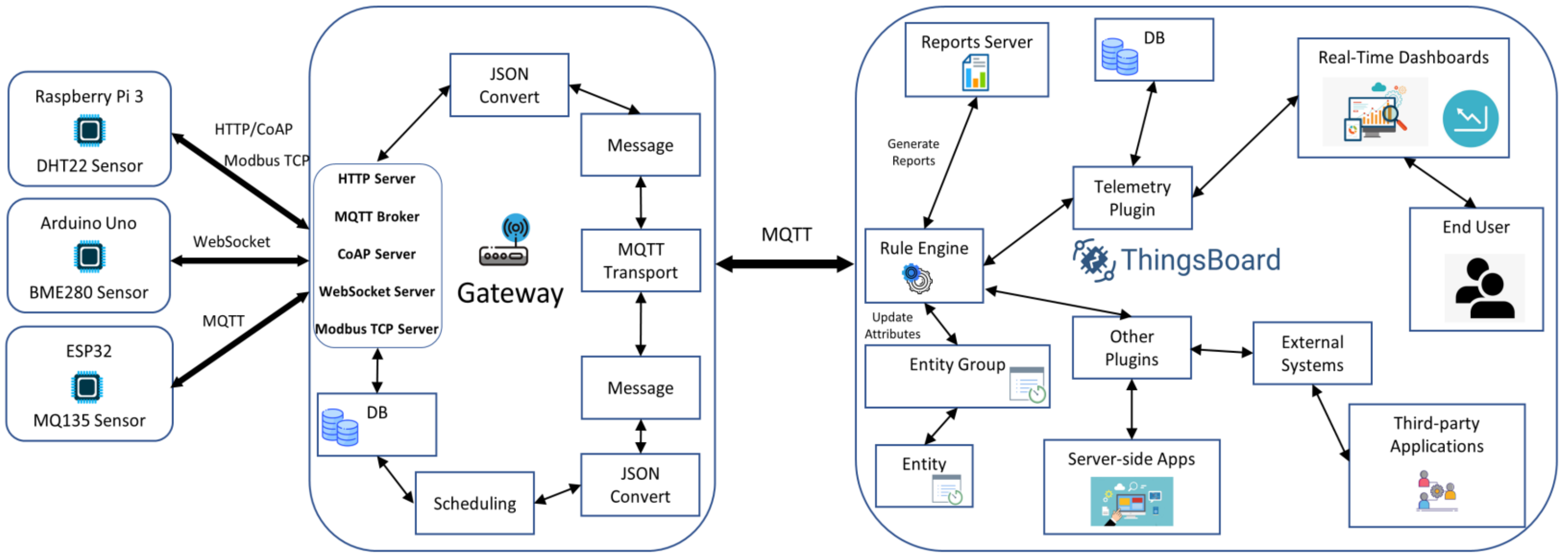


Figure 4.1: Implementation on ThingsBoard Platform

Validation(Cont'd)

4.2 Results

4.2.1 Gateway Publishing Data to ThingsBoard

4.2.2 Successful Integration

4.2.3 Real-time Visualization

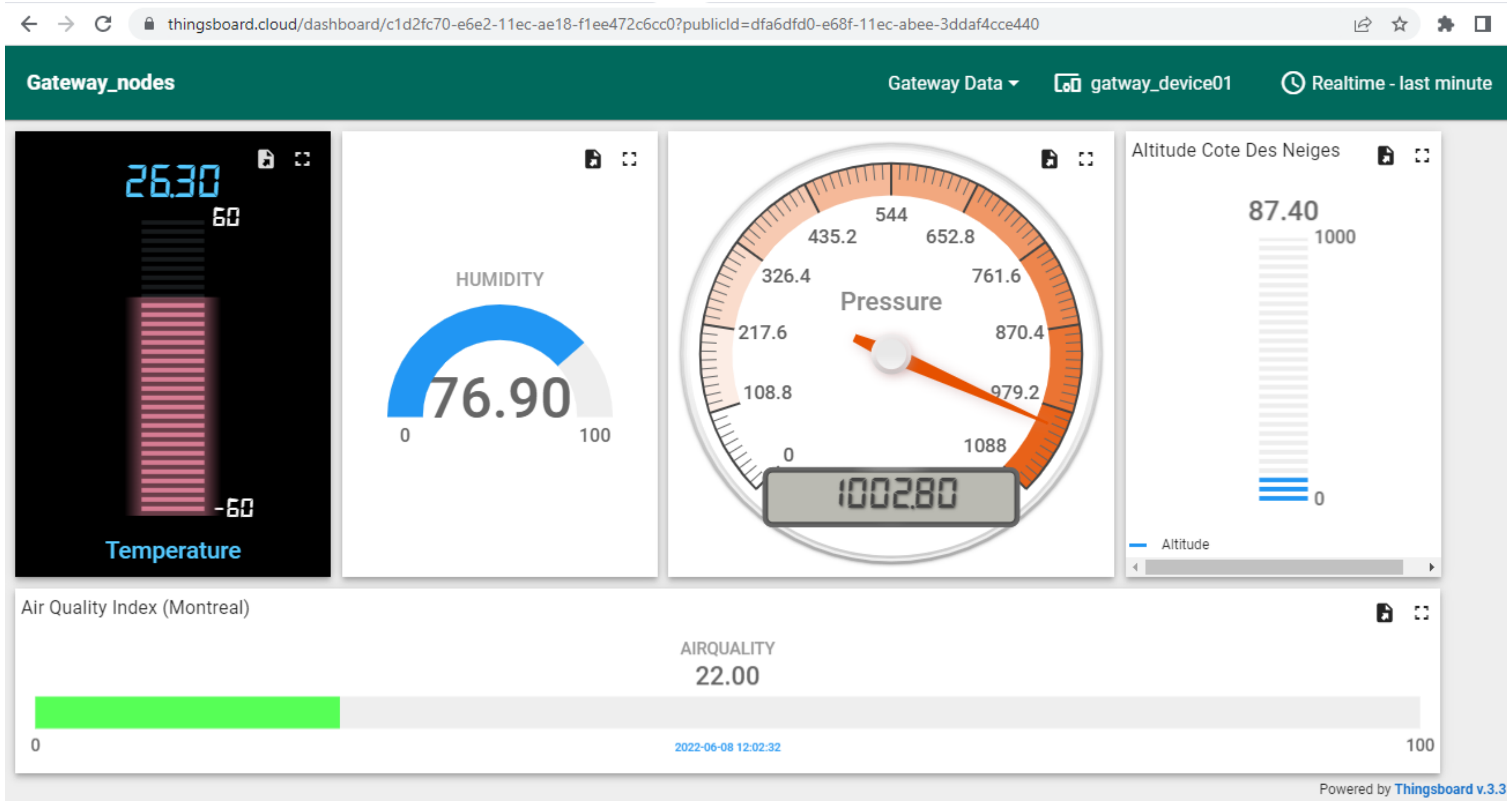


Figure 4.2: Real-time data visualization dashboard on ThingsBoard platform

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Chapter 5 and 6: Conclusion and Future Work

5.1 Conclusion
- 5.1.1 Limitations
- 3.2.2 Common Data Format
- 3.2.3 Interoperability Management by Middleware Gateway

6.1 Future Work and Recommendation
- 3.2.1 Expanding Supported OPC UA Service
- 3.2.2 IoT Security via IoT Edge Gateway
- 3.2.3 Fog and Edge Computing Paradigm

6.2 Potential Commercial Application
- 6.2.1 Open Protocol Management Controller for SMC
- 6.2.2 Industrial Automation Data Converter