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A Multi Platform for Utility using open FMB^{TM} Reference Architecture: Chalenges and Lessons Learned

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***Abstract:** The exponential growth of smart micro grids is making centralized control unmanageable. Data generated by grid-edge devices are also inaccessible due to the installation of private micro grids with proprietary communication protocols. The OpenFMB^{TM} reference architecture solves this interoperability issue and eases the manageability of huge data by creating a virtual node that would allow exchange information between field devices with the use of publish/subscribe paradigm. However, the OpenFMB^{TM} framework is yet to be adopted by industries but researches related to the implementation of this framework is being conducted with the aim to find out the cost and reliability on performance issues such as accuracy, scalability and security. Smart Grid Interoperability Panel (SGIP) provided a live demonstration of OpenFMB^{TM} framework at DistribuTECH conference. DistribuTECH demo provides a guideline to setup simulators deployed in a single Linux machine. This paper discusses about the simulation demo and lessons learned to further developing the project. The implemented demo focuses on the use of MQTT communication protocol for transport layer data transfer. The experiment uses the guidelines of the DistribuTECH demo and addresses the challenge of deploying the framework in real devices at industry level.*

Keywords: Open Platform, Smart Grid, OpenFMB, Interoperability

I.INTRODUCTION

The idea of having standard reference architecture is to harmonize the different proprietary communication protocols so that the field devices can exchange data with each other via centralized systems [1]. OpenFMB^{TM} is being developed to achieve the smaller step of this big idea of interoperability between grid-edge devices [2]. The organizations involved in the OpenFMB^{TM} project achieved some big milestones that gave a greater hope to move forward with the actual tests in a Microgrid environment [3]. In 2016, the Smart Grid Interoperability Panel (SGIP) provided a live demonstration of OpenFMB^{TM} framework at DistribuTECH conference [4]. The demo was more of a proof of concept of OpenFMB^{TM} framework with a vision of how the future of Microgid management will look like.

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It did not only open the door for research in the area of interoperability but also provided an opportunity to know how the interoperability is going to work on different proprietary protocoled devices. The SGIP shared the project in GitHub repository for public so that other organizations can contribute ideas into the framework [5]. The project consists of simulation of framework with two proprietary communication protocols and two transport protocols [6]. The main contributions of this research are as follows:

- The explanation of OpenFMB^{TM} reference architecture data flow to understand how the architecture behaves to meet interoperability.
- The challenges of deploying OpenFMB^{TM} framework in real devices at industry level
- The simulation description based on SGIP's reference implementation (DistribuTECH demo) and lessons learned from this experiment.

This paper is organized as follows: Section 2 introduces the OpenFMB^{TM} reference architecture and the role of key components to fulfill interoperability. Section 3 addresses the challenges of using OpenFMB^{TM} framework at industry level. Section 4 describes how the simulation works by using MQTT transport protocol. The lessons learned from the demo are described in section 5. Finally, section 6 draws the conclusion and future work.

II.OPENFMB^{TM} REFERENCE ARCHITECTURE

The OpenFMB^{TM} reference architecture is North American Energy Standards Board (NAESB) standard ratified in 2016 which standardizes a common communication protocol for grid edge devices [7]. One of the main objectives of OpenFMB^{TM} is to bring together different industry standards to one common ground so that devices can interoperate with each other regardless of their internal communication protocols [8]. It extends the concept of using an enterprise service bus to an integration framework which can be installed at the grid edge nodes to process data locally and transfer to the data center for reporting [4]. It uses peer to peer communications with a standard semantic model for data exchange [2]. The semantic model enables the development of adapter to gain system generated data from devices with legacy protocols [4]. There are two key components of an OpenFMB^{TM} adapter which need to be addressed such as utility standardized semantic models or a common data model and industrial IOT (Internet of Things) publish/subscribe transport protocol.

2.1 Utility Industry Standardized Semantic Models

The National Institute of Standards and Technology defined interoperability as the ability of different systems to exchange meaningful, actionable information in support of the safe, secure, efficient and reliable operation of electric systems [9]. The common data model is one of the key factors of OpenFMB™ framework for providing interoperability solution. In the first reference implementation which is shared by SGIP, IEC's Common Information Model (CIM) is used as the common data model for all the proprietary protocoled devices [10]. In the demonstration, DNP3 and MODBUS protocols are used as proprietary protocols. These protocols are then translated into CIM to create a common ground so that devices can understand each other. Currently, SGIP is in the process of harmonizing CIM model with other models such as IEC 61850 [10]. Other standards or platforms like Volttron, OpenADR are also considered to leverage all standards existed in the market [10].

2.2 Industrial IOT Publish/Subscribe Protocols

Publish/subscribe transport protocol plays a vital role in OpenFMB™ framework. The data need to be transported to other devices so that they can make use of the data according to their needs. OpenFMB™ reference implementation was done with two different transport protocols [6]. MQTT and DDS both protocols can support publish/subscribe paradigm for data exchange. By using these protocols, devices are able to publish data to the global data space and subscribe the data at the same time. Currently, MQTT, DDS and AMQP protocols support OpenFMB™ framework [10]. Other IOT pub/sub standard protocols are considered for future implementation [10].

The ability of OpenFMB™ adapter to translate native communication protocol to a common data model was tested by SGIP. The adapter can host different transport protocols such as MQTT or DDS to transfer data in a peer to peer communication environment. In our research, MQTT publish/subscribe model is used to exchange data among node devices as well as to send data to the data center for reporting. SGIP's demo at DistribuTECH conference uses dummy devices to generate the test data for testing multiplatform interoperability. In the open source project, there are two legacy protocols such as DNP3 and MODBUS protocols which are referenced by dummy devices. Because of that, the data generated by the devices are in DNP3 and MODBUS protocols which are then formatted into CIM models. The flow of the data in the adapter based model from one end devices to another is described below based on Figure 1.

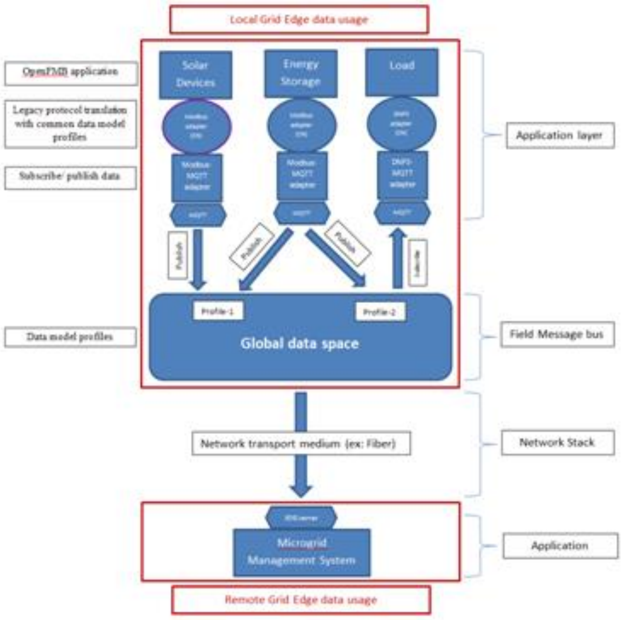

Fig.1 Data flow of OpenFMB framework

- The data is generated by dummy Grid edge Solar and Energy Storage devices.
- The generated data is in proprietary MODBUS protocol format which need to be translated into a common data model.
- To translate the data from legacy protocol to common protocol, MODBUS ADAPTER is used to format the data to a common data model profiles.
- Once data is modeled into a common format, a transport protocol such as MQTT is used to publish profile data into the Global Data Space which is then accessible by other nodes in the network.
- The Global Data Space is a virtual bus in the MQTT broker that handles publish/subscribe of the profile data.
- Referring to the OpenFMB™ framework, a device can publish data to multiple profiles/topics. In the diagram, Solar device publish data to Profile-1 whereby Energy Storage device publish data to Profile-1 and Profile-2.
- Similarly, a device can subscribe to multiple profiles/topics. In the diagram, Load device subscribe data from Profile-2 and Microgrid Management System subscribe to all the profiles in the Global Data Space by establishing connection from HMI server to MQTT broker.

III.CHALLENGES OF USING OPENFMB™ FRAMEWORK AT INDUSTRY LEVEL

Integration framework like OpenFMB™ provides ample advantages of minimizing cost and maximizing performances in regards to exchange data on different systems, but on the other hand, it can introduce other types of vulnerabilities to the grid system [11]. There are various challenges to implement the full-fledged OpenFMB™ architecture.

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The availability of adapters for all the existing industry specific protocols, cost of adapter creation and unintended points of cyber vulnerability induced by multiple systems/devices interacting together are few of concerns that needs more attention whenever OpenFMB™ framework is considered for implementation [12].

3.1 Customized Adapter Creation For Industry Specific Protocols

OpenFMB™ is a reference architecture that needs to be followed by the industry to make a customized adapter to support specific proprietary protocol translation. Among all the utility protocols existed in the market, only DNP3 and MODBUS are implemented with the reference implementation provided by SGIP [6]. Industry that wants to utilize this framework needs to make their own adapters align with the protocols used by the utilities in their Grid systems. Such adapter implementation needs in-depth analysis on the existing Grid-edge devices and their communication model. The contributions from different vendors for different protocol translations play a vital role to cover all the known proprietary protocols [5]. Apart from that, the relationship of cost and performance need to be analyzed as it applies to integrating adapters at the edge of the Grid devices. However, installation of new adapters does not require the need to modify other controllers [13].

3.2 Cybersecurity of Pub/Sub Communication Architecture

Grid systems require real-time balancing of power system demand and supply [4]. The increasing advanced infrastructure in grid network to achieve real-time balancing introduces possible vulnerable points which could be exploited to compromise a portion of the network. The grid efficiency and reliability vastly depends on automation of the grid network which uses internet connectivity for data transmission. Cybersecurity weakness in the network may pose a great threat to grid reliability [1]. The level of threat is further increased by the fact that physical devices are located outside of secured locations [13].

Security risks within grid communications mainly depend on the ways grid devices are accessed [1]. In a pub/sub communication environment, a brokered based model is more familiar so that the broker handles all the connections centrally and controls message distribution to and from all the devices. According to NIST, The implementation of security controls in the brokered based model degrade the real-time performance mainly because of extra work for establishing secured connection as well as validating messages to be sent and received. The timing latency of data and control signals resulting from cybersecurity of edge devices need to be properly investigated to have efficient Grid communications. The OpenFMB™ related organizations took cybersecurity initiatives to study and research on the area of Identity management, Network and System management and Dynamic Grid – Pub/Sub architecture.

IV.TESTBED SIMULATION AND DESCRIPTION

The first reference implementation of OpenFMB™ framework is shared by SGIP in the web based hosting service GitHub [6]. The OpenFMB™ open source project in GitHub repository is made available for different organizations to explore the framework and reference it with their own standards so that all proprietary protocols can be leveraged into common data model [5]. Different protocol translation adapter is needed to transform the data into common data profiles. The detailed steps to implement the simulation demo in a single machine are described in the Github wiki. During this research, OpenFMB™ project demo is being simulated using MQTT transport protocol as described in the GitHub wiki. The main tools and packages needed for the setup are Ubuntu operating system with JAVA installed, OpenFMB™ package, MQTT broker and Google Chrome. The testbed was setup in virtual machine by following the guidelines provided in the wiki. After completing the setup, all the processes can be started by running the *simgo.sh* file. The script calls all the simulators separately, start the MQTT broker and finally open the chrome to visualize the Microgrid devices. There are some options available as well to manage the devices.

The simulators are run manually as well to understand the communication better. The simulation mainly consists of HMI server, MQTT broker and the dummy devices (Recloser, Battery, Solar, Island balancer and Load). The MQTT broker runs in the background and waits to receive and send any sort of data passed to it. First, the HMI server is run to subscribe to all the data published in the MQTT broker as shown in Figure 2. “hmi.properties” file contains all the configurations to get all the profiles data from local MQTT broker.

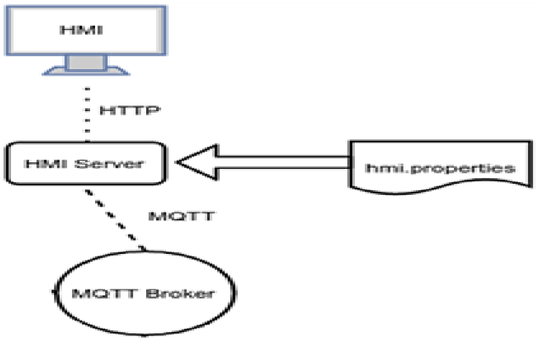

Fig. 2 HMI server is connected to MQTT broker

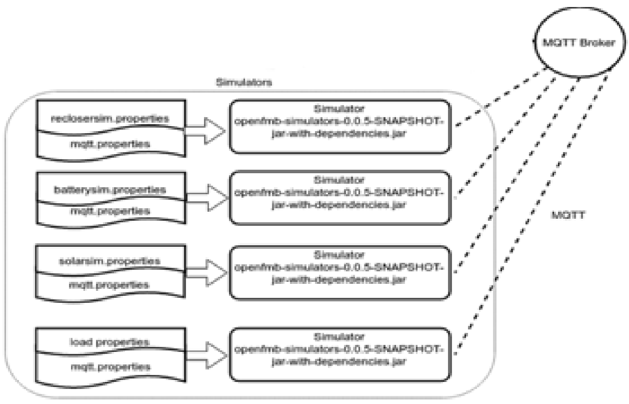

Fig. 3 Dummy devices are connected to MQTT broker

Once HMI server is connected to the MQTT broker, data is still not visible in the microgrid management system (browser in this case) because no profile is published in the MQTT broker. So, the dummy devices are run to generate the data and publish it to the MQTT broker. All simulator devices are located into *~/stage/sim* directory. A property file is associated with each device to publish the data to the broker as shown in Figure 3.

The main JAR file to start the simulators is openfmb-simulators-0.0.5-SNAPSHOT-jar-with-dependencies.jar.Since all the dummy devices are publishing data to the MQTT broker. The browser will show all the data subscribed by the HMI server as shown in Figure 4.

Fig. 4 Visualization of Microgrid using OpenFMB framework

V.LESSON LEARNED

The OpenFMB^{TM} open source project provides a simulation which uses dummy devices to simulate Microgrid edge devices. This simulation is a proof of concept which needs to be tested in real Microgrid environment to ensure that the framework will operate as intended when deployed into Microgrid systems. To achieve this, as a first step we have tried to setup the simulation in multiple environments. However, there are some challenges faced during the implementation of the further development.

The main problem faced was to configure the adapters. In order to modify the adapter, the source code needs to be downloaded and built using MAVEN built tools. The built was continuously failing because of dependencies problem. There are some dependencies which need to be downloaded from totalgrid repositories as part of the building process but the repository is currently unavailable. As a result, further work cannot be done as any change in the source code need to be built to produce the latest JAR file.

VI.CONCLUSIONS AND FUTURE WORK

OpenFMB^{TM} is merely a reference architecture, a framework which is designed to drive interoperability for multiplatform utility. Organizations can reference this framework and make their own adapters in regards to their own proprietary protocols to allow communications between different platforms. To achieve this, industries need to be cautious about the challenges of using this framework which are addressed in this paper.

The OpenFMB^{TM} project in GitHub shared by SGIP has all the necessary information to setup and run the simulation. However, further work on the project can be done by manually configuring the adapter to add new topic of new device to the MQTT broker. Currently, the dummy devices are publishing data to the MQTT broker and resource module/ HMI server is subscribing all the data and visually representing it to the browser. In addition to that, the adapter can be used to create a second solar device to publish device data in the network.

To explore further with the OpenFMB^{TM} reference implementation, the project can be setup in multiple machines such that one machine can be acted as HMI server subscribing to all the topics in the MQTT broker and another machine can be acted as the dummy devices publishing data to the broker. This can be the first step to test the ability of OpenFMB^{TM} transport protocols to handle remote connections. Once the transport of data to remote machine is achieved, the project can be further developed by setting up real test-bed with the actual Grid edge devices.

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