‘EnphytoBox’ IoT System Design

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Abstract

EnphytoBox is a low-energy, nature-based water treatment solution contained within a modular container. The EnphytoBox contains sensors and actuators used to monitor and operate the device. Currently, remote monitoring and operation of the EnphytoBox requires using multiple online services, creating a barrier to using the captured data. Syrinx requires a solution that meets two key objectives: 1. Integrate EnphytoBox monitoring and control into a single interface, and 2. Determine ‘fit-for-purpose’ communication technologies for any given deployment. Meeting key objective 1 will benefit Syrinx by centralising all interactions with all EnphytoBoxes. This will improve operator experience and encourage data driven decisions in the operation of EnphytoBoxes. Syrinx requires key objective 2 to be met to ensure EnphytoBoxes can be remotely monitored and operated in remote deployments.

1. Introduction

EnphytoBox is a sea container sized device that provides water treatment. It is specifically designed for remote deployments. The water treatment process developed by Syrinx uses nature-based technology to achieve zero waste, zero emission and low energy consumption. EnphytoBox modularises this process, making it highly scalable and easy to transport and deploy to remote locations.

An EnphytoBox contains multiple sensors and actuators. Some of the sensors are used to automatically operate actuators to keep the EnphytoBox operational, such as overflow sensors that determine when to open valves. Other sensors are used to evaluate the water treatment process. Analysis of this data can identify whether certain interventions are required to improve the treatment process. Changes to the treatment process are made through a touchscreen based Human Machine Interface (HMI) interface onboard the EnphytoBox. This interface is also accessible securely over the internet so changes can be made from Syrinx’s office. The EnphytoBox also has onboard cameras for remote visual inspection of the water treatment process and tracking of control room access.

A prototype EnphytoBox is currently deployed in a landfill site in Tasmania. Monitoring and remote operation of this prototype requires several different user interfaces, each maintained by separate companies. Having multiple interfaces has made sensor data extraction less efficient than desired.

Loss of communication has resulted in lost data, as the current prototype requires communication to a cloud service to store sensor data. This issue would be amplified for future EnphytoBoxes that are likely to be deployed in remote areas with poor or no conventional communication network coverage.

This project aims to extend the design of the EnphytoBox to create a system that meets the following key objectives:

1. Integrate EnphytoBox monitoring and control into a single interface.
2. Determine 'fit-for-purpose' communication technologies for any given deployment.

Both objectives are addressed through the design of a state-of-the-art "Internet of Things" (IoT) system, which will guide the future development of the system and ensure that Syrinx's requirements are met. It is paramount that the unique characteristics of the EnphytoBox are considered in the design to ensure that the system does not inherit any limitations of conventionally constrained IoT systems.

1.1. Literature Review Summary

Jasmin et al. (2016) introduced an abstract architecture of an IoT system to use as a reference for comparison between IoT platforms. In this model, the overall system is organised as a layered architecture with each layer responsible for different functionalities, as seen in Figure 1.

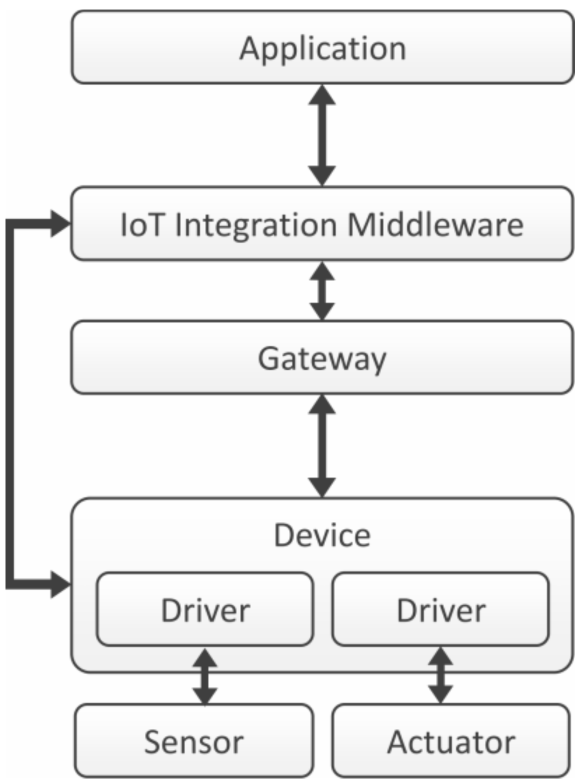

Figure 1 Reference Architecture from (Jasmin, Breitenbucher, Falkenthal, Leymann, & Reinfurt, 2016)

IoT security is a key requirement for IoT systems due to its prolific use in high-risk fields with sensitive personal data such as healthcare, or the ability to cause physical damage or harm through actuators such as industrial appliances. Ammar et al. (2018) highlights the large threat surface that IoT devices present. Some threat vectors are specifically due to conventional IoT devices being constrained devices, such as limited encryption due to computation constraints. Other threat vectors come from standard practice, such as the inability to change keys or encryption algorithms due to an inability to update devices.

Dolui et al. (2017) explores edge computing, which is an architecture that uses the storage and processing power of 'edge' devices that can handle some of the functionality of a conventional monolithic server system. These devices are located within the chain of devices that connect an IoT device to a conventional (usually cloud based) server. This can reduce latency and provide real-time handling of some requests.

Sinha et al. (2017) provides a comparison between two leading Low Power Wide Area (LPWA) technologies: "Narrow Band Internet of Things" (NB-IoT) and "Long Range" (LoRa). The comparison explores various factors such as network architecture, quality of service, battery life, latency, network coverage and range among many other factors for each technology. NB-IoT was found to have better quality of service and less latency than LoRa. LoRa by contrast was better for low-cost applications.

2. Process

Key objective 1 for this project requires integration of monitoring and control of all EnphytoBoxes into one interface. To achieve this, an entire system is required to provide the interface. This system must receive sensor data captured by all deployed EnphytoBoxes and make it available to operators. It must also communicate back to EnphytoBoxes to send commands, even in remote deployments where no conventional network coverage, such as Cellular or WiFi, is available.

An overall system design for a state-of-the-art IoT system has been developed to meet key objective 1. This design provides a set of requirements that have been compiled from both Syrinx and state-of-the-art research. Interviews were conducted to elicit requirements from Syrinx. State-of-the-art requirements were extracted from a literature review of IoT systems. The requirements of Syrinx and state-of-the-art were then synthesised into a single set of requirements by merging both sets together. Careful considerations were made to ensure that the final set of requirements were not contradictory and that the requirements remained relevant to the context of the project.

The synthesised set of requirements were organised into system components, which were the layers from the abstract reference architecture in Jasmin et al. (2016). Therefore, the design provides a set of system components, each of which outlines a set of requirements that must be met to ensure correct and secure operation of that component. Technologies that meet the requirements for each component will be suggested to ease with development.

The communications design meets key objective 2 by providing options for available remote communication technologies and exploring their feasibility in different deployment scenarios. State-of-the-art IoT communication technologies were determined from a literature review. These technologies are to be examined through properties that are relevant for choosing a communication technology for an EnphytoBox deployment. These properties include network coverage, data throughput and limits, cost, power usage, latency, and connection reliability (Sinha et al. 2017). An estimator for EnphytoBox data throughput has been developed in an Excel spreadsheet, which will be used to determine the feasibility of a communication technology for an EnphytoBox.

Once all communication technologies and their properties are determined, the communications design will further explore them using deployment scenarios. Each scenario will represent a common and/or difficult deployment of an EnphytoBox and will provide location and required data to be communicated. Location will include the environmental factors such as weather and climate, along with network coverage status (i.e., Whether the location is covered by a given communication network). The required data will include the amount of sensor data that must be sent monthly, maximum allowed latency, and maximum allowed communication downtime. Using the location and data requirements, the best fitting communication technology will be matched to each scenario.

3. Preliminary Results and Discussion

The abstract reference architecture from (Jasmin et al. 2016) provides structure to the overall system design and standardises component names for the system. The abstract nature of the architecture provides flexibility in design, reducing unnecessary constraints on the design such as programming language or device hardware. The overall system design is requirement-based to keep the design independent from implementation details such as programming language or frameworks. This will give the future developers flexibility to use tools they are familiar with, given such tools do not hinder the system.

Requirement synthesis from Syrinx and state-of-the-art requirements must be careful of context to ensure the design does not needlessly inherit limitations of conventional IoT systems that use computation and power constrained devices, such as the use of low power communication technologies or lightweight encryption algorithms.

Additionally, requirements must consider the context of remote deployment and the effect of unreliable communication in system operation. This requires that EnphytoBoxes leverage edge computing, which allows EnphytoBoxes to operate without connection to the rest of the system. This not only includes following simple rules based on sensor readings (as currently implemented in the prototype), but also keeping the “IoT Middleware Integration” up to date with sensed data whenever the communication can be established. Integrating edge computing into the EnphytoBox design allows the device itself to locally store sensor data and use it for limited rule-based automation locally.

Parameters	**Values**
Sensor datum size	4 bytes
Sensor datum label size	11 bytes
Transmission Frequency	Every 4 hours
Sensor count	30
Results	
Daily data usage for 1 sensor	90 bytes
Monthly data usage for 1 sensor	2790 bytes (2.72 kilobytes)
Daily data usage for all sensors	2700 bytes (2.64 kilobytes)
Monthly data usage for all sensors	83700 bytes (81.74 kilobytes)

Table 1 Parameters and results for EnphytoBox data throughput estimate

Table 1 provides the results for the estimate of sensor data, extracted from a developed Excel spreadsheet tool. The results indicate that a minimum throughput of 81.74 kilobytes is required to meet the demand of an EnphytoBox with the given parameters. This estimate does not yet consider the implications of data compression or encryption, which will alter these values depending on algorithm used. It also does not consider images captured by onboard cameras on the EnphytoBox, which will drastically increase the data throughput.

The parameters in Table 1 can be changed to calculate different data throughput requirements for different deployment scenarios. Given this monthly throughput, different communication technologies can be evaluated for deployment scenarios. Each scenario will be constrained to one of the following technologies: WiFi, LoRa, 4G / cellular, NB-IoT, or satellite internet. This constraint is based on the scenario location and data throughput requirements. The location of the scenario will be used to check for network coverage in the area and rule out any unavailable communication networks. Then, communication technologies will be eliminated based on data requirements.

4. Conclusions and Future Work

The overall system design applies the reference architecture from (Jasmin et al. 2016). Each layer of the architecture forms a system component, which has requirements from both Syrinx and the literature review to construct a state-of-the-art design. The scenario-based communications design provides a practical guide to the technically complex communications technologies. Both the overall system design and the communications design work together to meet all key objectives of the project.

There is potential to expand the set of communication technologies explored to include other technologies, such as nano-satellite networks. Some examples of nano-satellite networks are FleetSpace, Myriota and Starlink. Both FleetSpace and Myriota focus on IoT applications, whereas Starlink aims to provide internet globally. Expanding the communication technologies further will provide more options, especially considering the current IoT specific technologies explored are designed for low power applications (LoRa and NB-IoT).

Since EnphytoBoxes are planned to be deployed globally, further consideration must be made into data and communication regulations of countries globally. Such regulations will impact the choice of communication technology for a given deployment.

In future, the overall system design will be realised into a functioning system. The implementation of the design will have to consider features that may be required by Syrinx in future, such as complex sensor data analysis driving automation beyond the simple rules-based automation currently used. This may also involve using data captured from multiple EnphytoBoxes to make decisions or to learn patterns using artificial intelligence.

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