UNIVERSITÀ DEGLI STUDI DELL'AQUILA

SMART DRAINAGE SYSTEM

Software Engineering For Autonomous systems Project

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Abstract

One of the important needs of keeping the city clean was a perfect drainage system so each and every city has its own drainage system. We need to maintain those systems perfectly, sometimes the manual monitoring is incompetent which leads to the blockage and overflow of the drainage system. Due to lack of knowledge the worker may meets to an accident as they have no idea how will be the condition in those manholes. To overcome this situation, we proposed a smart drainage system which will monitor the flow, chemical content and the blockage in the system.

Introduction

Sewage system is present in each and every city. Increasingly, the drainage system are becoming underground. Pipelines are being laid underground and these pipes are used to carry the sewage across the city. As the sewage pipelines are underground, the maintenance of these pipes become difficult. Due to different effluents that travel through the sewage, at times, the sewage get blocked. Since the sewage system is underground, it becomes difficult to detect the blockage. The problem arise in such drainage system can cause serious issue in daily routine of the city. Not only the blockage the problem such as sudden increase in the water level as well as various harmful gases can also produce some problem if the proper cleaning actions are not taken time to time.

Today's drainage system is not computerized due to which it is hard to know where the blockage is. Also sometimes due to the waste in those drainage lines can produce various gases like methane (CH_4), carbon monoxide (CO), etc. which are harmful and can cause serious problem if inhaled by humans in large amount and these problems are generally faced by the drainage workers due to which death can occurs. Also we don't get early alerts of the blockage or rise in amount of those gases or the increase in water level.

OBJECTIVE OF OUR PROJECT

1. Finding the blockage in the pipelines.
2. Finding the level of poisonous gas in the pipeline.
3. To find the water level in the sewage system.
4. Intimating the concern people if there is an problem.
5. To keep the city clean and healthy.

Proposed System

1. Sensors to detect blockages, gas and excess of water.
2. System identifies location of the blockages and gives the location to the municipality.
3. System senses the hazardous gases like Methane and Carbon monoxide.
4. As the gas level increase, our system automatically opens the emergency vents and sends an notification to the health department to take necessary actions.
5. As the water level increase our system automatically opens the emergency outlet to reduce the possibility of flooding and intimate to the concern department to take necessary actions.

Working Principle

Each and every drainage channels are covered with manholes, we are placing our sensors in those manholes to detect the required details and to transfer the sensed data about harmful gases, water level in the system and flow rate of the water. Using the communication modules it will communicate with the sensor node placed at nearby manholes. This data will be then transmitted to the base station for further analysis. Based on the data values given by the sensors in the drainage system along with the location ID, will send to the gateway and to processing unit. The processing unit will decide what action should be taken.

Sensors we are using.

1. Gas sensor.
    1. MQ7
    3. MQ2
2. Water level sensor.
3. Flow sensor.

The sensor that we need is water level sensor, sensor for blockage detection (flow sensor) and gas detection sensor. Water level sensor is used to determine the water level. If the water level increases while the rainfall and water discharge normal it means that occurs salutation in the channel. Similarly the gas sensor is used to measure the presence of particular gases as well as amount of those gases. Various gas sensors are MQ2 and MQ7 which are used to sense the gases such as carbon monoxide (CO) and methane (CH_4).

Architecture.

The architectural style used is based on the MAPE-K loop. Our architecture is composed of five components that communicate with each other. The data is monitored by the component 'Monitor', analysed by the 'Analyzer' and, based on the policies of our system some actions are planned by the "Planner" and executed by the "Executor". The component 'Knowledge' takes care of predict whether there will be a blockage, the gas level is going to be high or whether the water lever will change based on the record.

Block Diagram.

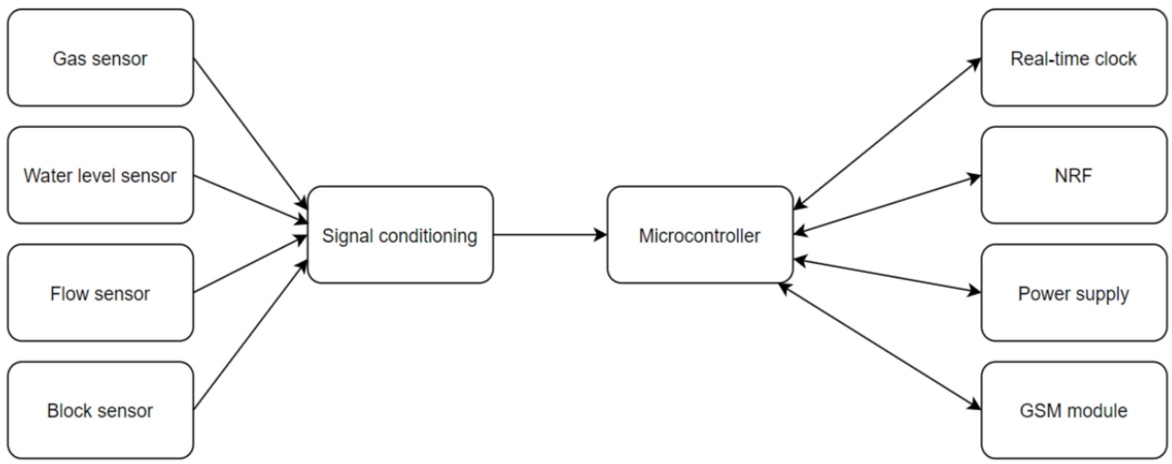

Fig 1 : Block Diagram

Fig 1 represents the block diagram of our system.Each sensor senses the data and send those data to the microcontroller. The real-time clock set the time of data collection and then NRF module sends the data to other sensors. The power supply unit can be solar or a battery unit. The entire data collected is sent to the cloud or server using GSM module.

Component diagram.

The components which are used in the projected are expressed through the component diagram Fig.2 which is given bellow. The component diagram is showing us all the software components and what they require and provide in order to accomplish the system requirements.

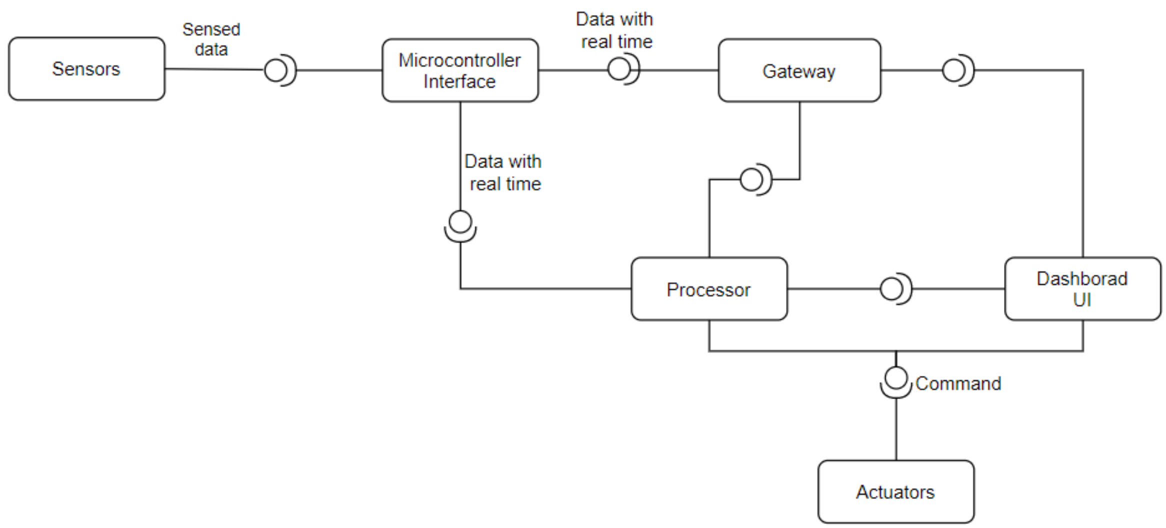

Fig 2: Component diagram

Sensors: Component which are used for sensing the data.

Microcontroller Interface: Consist of RTC and RF module and supply unit.

Gateway: Is sensor node that has additional functions to send data to the server.

Dashboard: It’s a user interface act as a platform between user and the server.

Processor: Component which collects the data and perform the operation.

Actuator: Component used to perform the operation given by the processor.

The fig 3 represents the sensors present in the component module sensors. The sensors present in the module are gas sensor (MQ2, MQ3, MQ7), water level sensor, flow sensor.

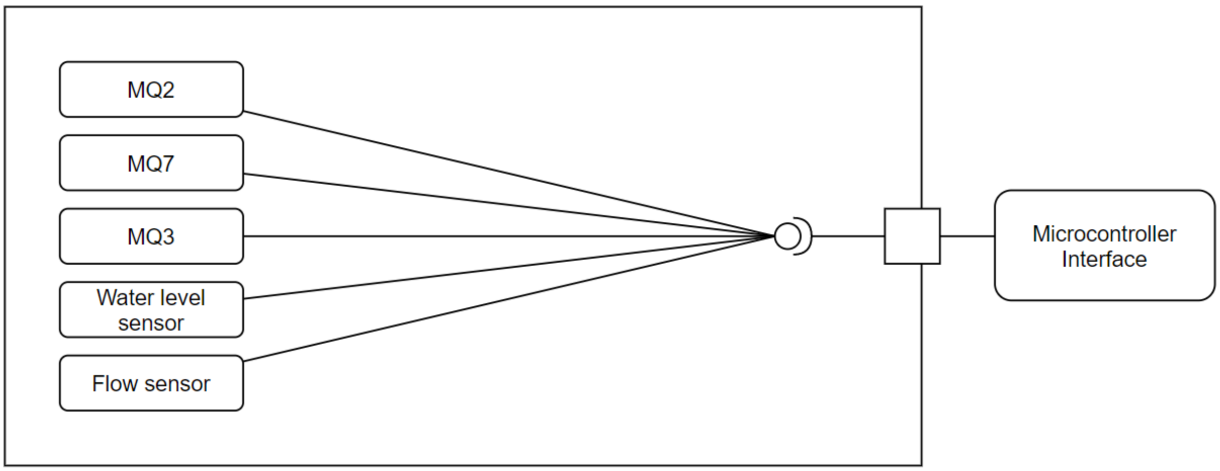

Fig 3: Component diagram of sensor

The fig 4 explains about the components inside the Microcontroller interface The RF module that used is NRF. This module requires minimal power and provides reliable delivery of data between remote devices. The modules operate within the ISM (Industrial, Scientific and medical) 2.4GHz frequency band. The output of water level sensors, gas sensor and flow sensor conditioned as standard input signal for microcontroller. Output of signal conditioning will be input to the internal ADC (Analog to Digital Converter) of Microcontroller. RTC set the time of data collection and then RF Module (NRF) send the data to other sensor nodes. Supply unit can be either battery or solar cell give the power to the sensor node.

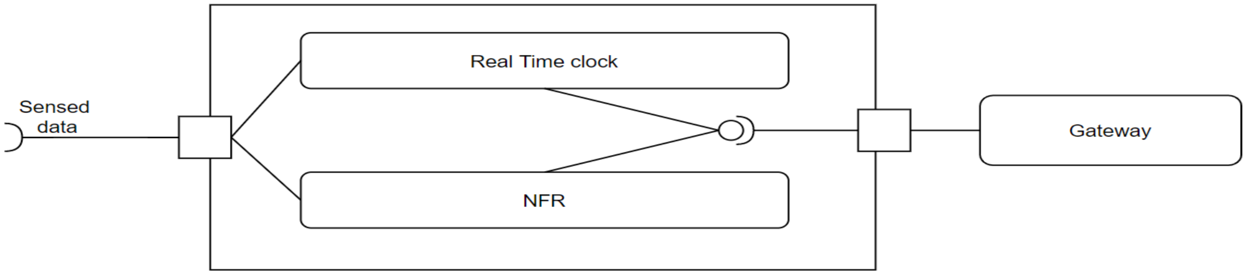

Fig 4 : Component diagram of microcontroller interface

Sequence diagram:

The following diagram represents the flow and sequence of the system how it will perform. The fig 5 represents how the data gets collected and how all the components are added in the data. For every five minute the sensor will collect the data and send those data to the microcontroller interface where the components like time are added. From there the data are send to the gateway.

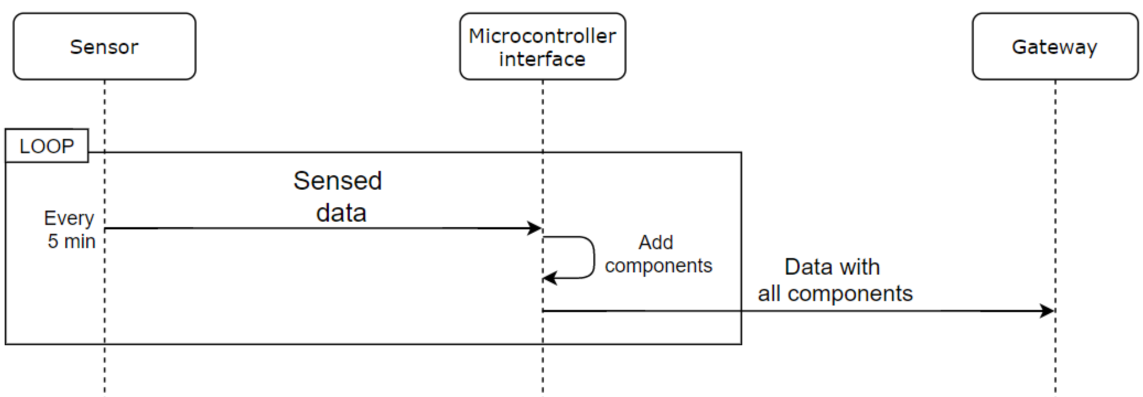

Fig 5 : Sequence of data collection

The fig 6 represents the functions of the system. When the processor receives the data from the gateway it will do the following function.

1. If the gas level is high than the maximum level then the processor will give a notification to the dashboard along with the sensors details which includes its location and instruct the actuator to open the emergency vent.
2. If the water level is high than the maximum level it will give a notification to the dashboard along with the sensors details which includes its location and instruct the actuator to open the emergency outlet.
3. If the speed of the waterflow differs from one sensor to other it will notify the dashboard along with the sensors details which includes its location.

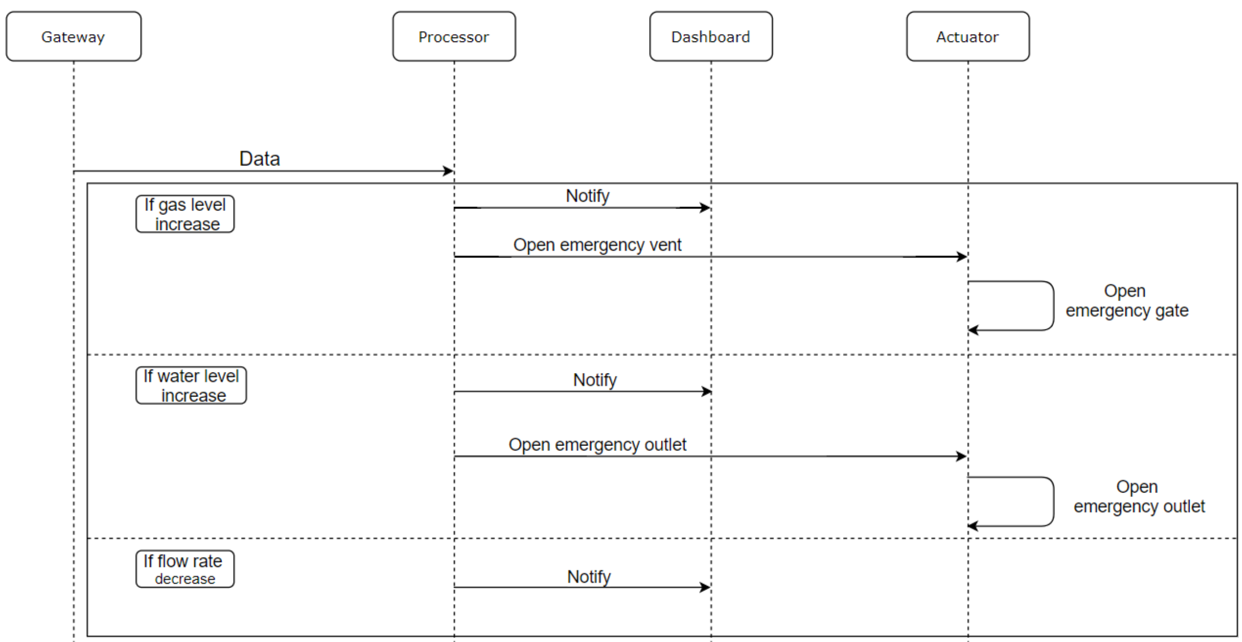

Fig 6: Sequence of work process

MAPE K

The MAPE K consist of 5 major components which are Monitor, Analyse, Plan, Execute and Knowledge. The following diagram explains the architecture of MAPE K.

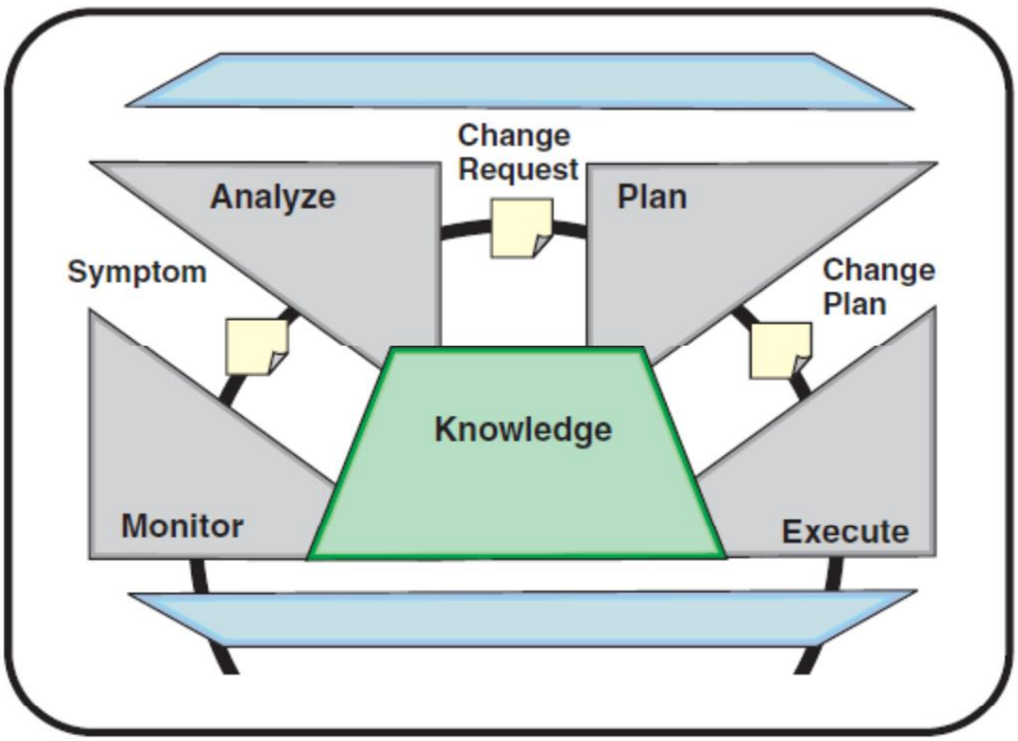

Fig 7: Architecture of MAPE K

Monitor:

The monitoring phase collects the details from the managed resources e.g. topology information, metrics (e.g. offered capacity and throughput), configuration property settings and so on. The monitor function aggregates, correlates and filters these details until it determines a symptom that needs to be analyzed. In our case we are publishing the data through MQTT box for publishing the data into our system. The following image represents the publication of the data into our system.

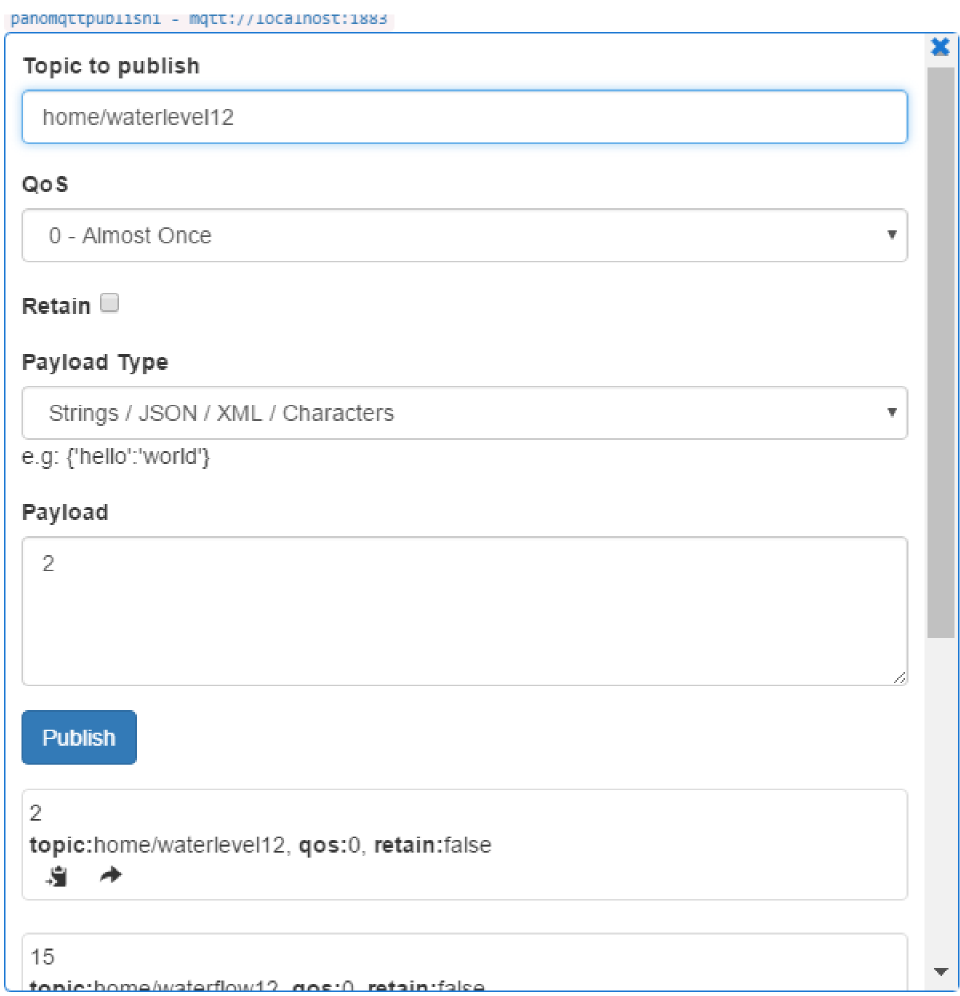

Fig 8: Publishing of data

Analyze:

Perform complex data analysis and reasoning on the symptoms provided by the monitor function. If changes are required, a change request is logically passed to the plan function. In our case

- For water level it will analyze whether the water level is going more than 15cm or not.
- For blockage it will analyze the flow of water if the flow of water reduced from sensor one to sensor two it will check the flow with the sensor three, if the flow is constant between sensor two and three it confirms the blockage is between one and two.
- For Gas level it will analyze whether the methane level exceeds than 6 g/cm and 7 g/cm for carbon monoxide.

```
rule "Methane/Monoxide level sensor 11"
    when
        Item MQTT_MQ211 received update or Item MQTT_MQ711 received update
    then
        if ((MQTT_MQ211.state > 6) || (MQTT_MQ711.state > 7)){
            if((MQTT_MQ211.state > 6)){
                sendCommand(EmergencyVent11, ON)
                sendMail("moisesromeroromo2@gmail.com", "High Methane Level in 1.1", "High Methane Level in 1.1")
            }
            if((MQTT_MQ711.state > 7)){
                sendCommand(EmergencyVent11, ON)
                sendMail("moisesromeroromo2@gmail.com", "High Monoxide Level in 1.1", "High Monoxide Level in 1.1")
            }
        }else {

        sendCommand(EmergencyVent11, OFF)

        }
    end
```

Fig 9: Analyzing of data

Plan:

Structures the actions needed to achieve goals and objectives. The plan function creates or selects a procedure to enact a desired alteration in the managed resource. The plan function can take on many forms, ranging from a single command to a complex workflow.

In our case

- If water level goes higher than 15cm we planed to open the emergency outlet and intimate to the concern department (municipality department) through mail.
- If there is an blockage we planed to intimate the Sewage department through mail.
- If there is increase of hazardous gas we plan to open the emergency vent to dissolve the gas and intimate the Heath department through mail.

```
rule "Water level sensor 13"
    when
        Item MQTT_waterlevelsensor13 received update
    then
        if (MQTT_waterlevelsensor13.state > 15){

        sendCommand(EmergencyOutlet13, ON)
        sendMail("moisesromeroromo2@gmail.com", "High Water Level", "High Water level in 1.3. Emergency Outlet opened.")

        }else {

        sendCommand(EmergencyOutlet13, OFF)

        }
    end
```

Fig 10: Planning with the data.

Execute:

Changes the behavior of the managed resource using effectors Changes the behavior of the managed resource using effectors, based on the actions recommended by the plan function.

In our Case

- If water level goes higher than 15cm, the emergency outlet opens and intimate to the concern department (municipality department) through mail.
- If there is an blockage, the Sewage department is intimated through mail.
- If there is increase of hazardous gas the emergency vent is opened to dissolve the gas and we intimate the Heath department through mail.

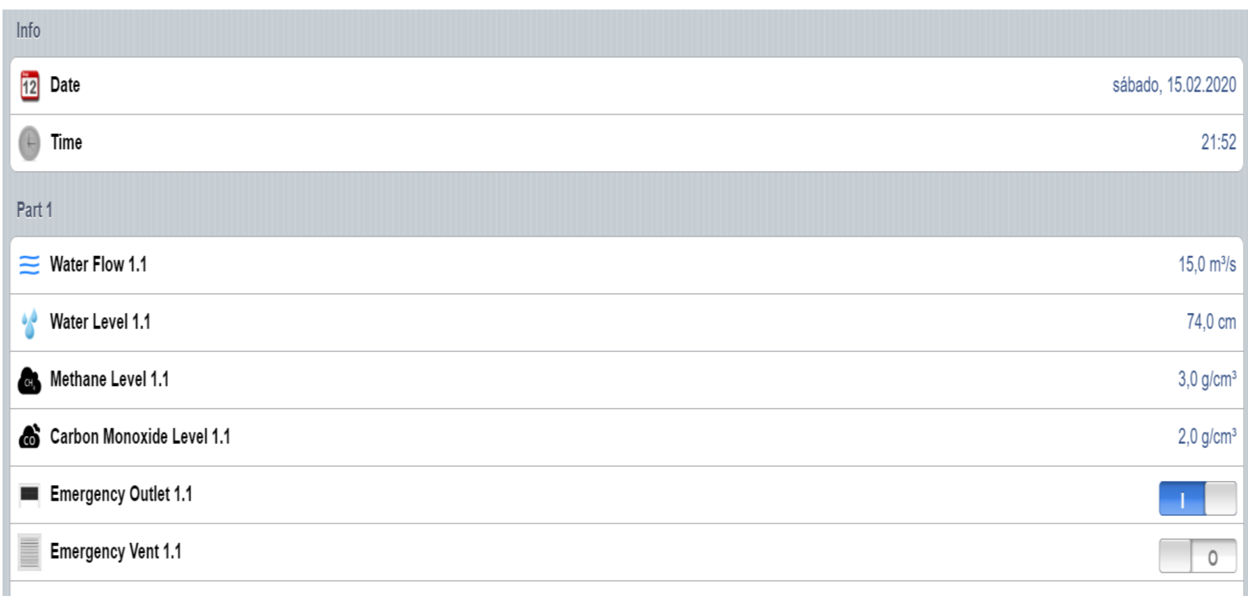

Fig 11: Execution of system (outlet open)

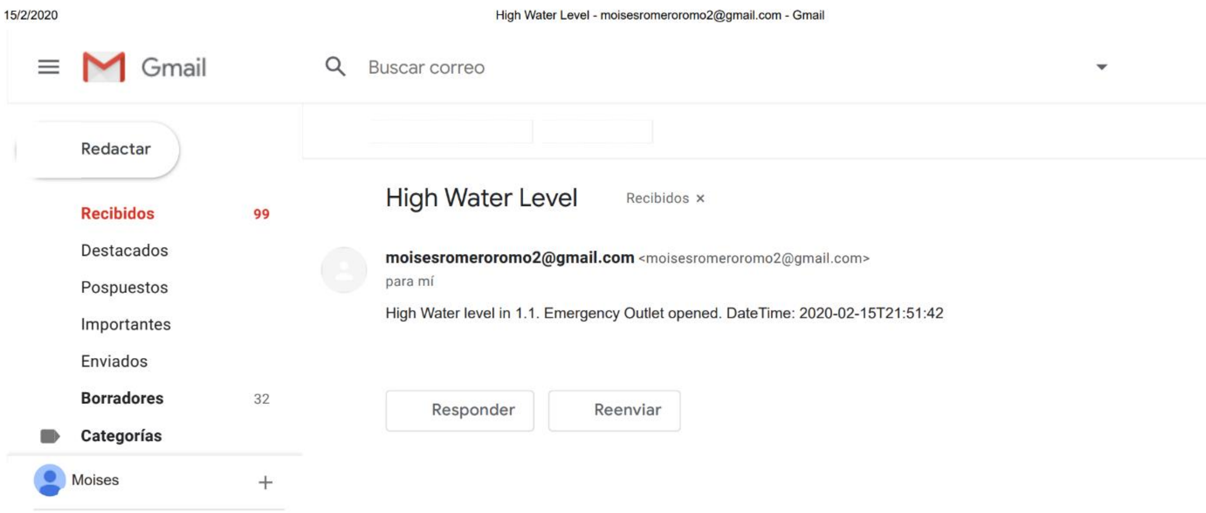

Fig 12: Execution of mailing (outlet open)

Knowledge:

Standard data shared among the monitor analyze plan and Standard data shared among the monitor, analyze, plan and execute functions. The shared knowledge includes data such as topology information, historical logs, metrics, symptoms and policies. Created by the monitor part while execute part might update the knowledge. We will get the knowledge about our system by the user interface.

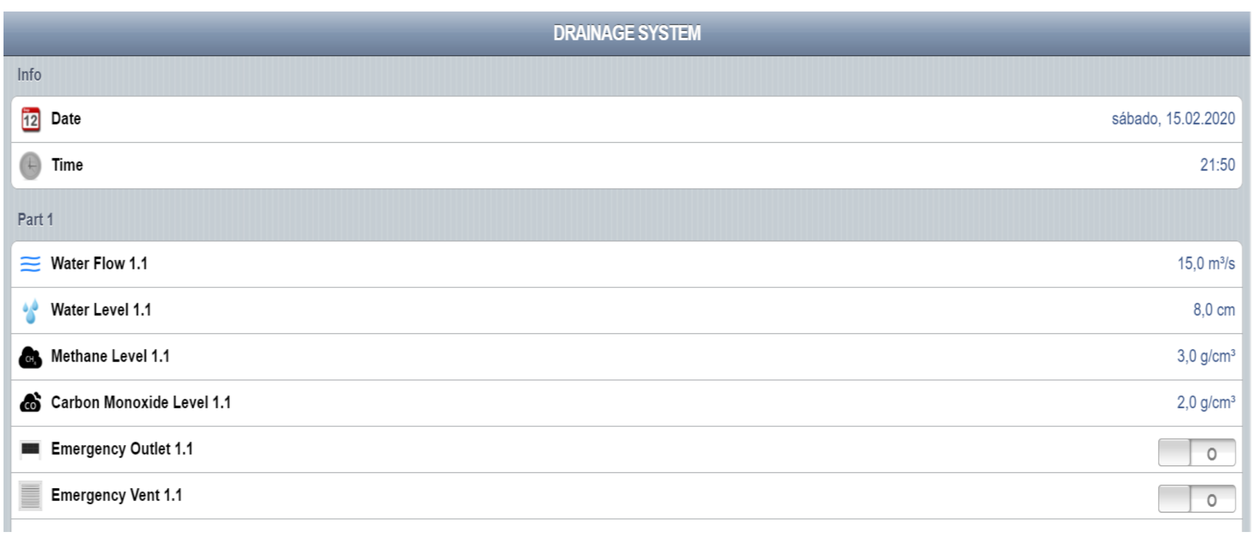

Fig 13: User Interface

Conclusion

By using various sensors such as gas detection, water level as well as blockage detection we can monitor the real time scenario of drainage system by for detecting the problems in drainage system. By doing this we can able to take particular action on the problems as we will receive the early alerts of blockage as well as increase. This paper can be used to design the smart and real time drainage system for monitoring as well as troubleshooting purpose.

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