CESaRE

THE JOURNAL OF CARIBBEAN ENVIRONMENTAL SCIENCES AND RENEWABLE ENERGY

the OPEN ISSUE 2020

December, Vol. 3, Issue 2

doi.org/10.33277/cesare/003.002/01

Development of Lora P2P Network for Autonomous Seawater Quality Monitor for Green Powered Desalination Project

Authors: Zachary Williams, Jean-François M. Dorville, Michael A. Taylor

Journal of Caribbean Environmental Sciences and Renewable Energy

Development of Lora P2P Network for Autonomous Seawater Quality Monitor for Green Powered Desalination Project

Authors: Zachary Williams, Jean-François M. Dorville, Michael A. Taylor

Department of Physics, University of The West Indies, Kingston, Jamaica
The Caribbean Geophysical and Numerical Research Group, Baie-Mahault, Guadeloupe

Journal of Caribbean Environmental Sciences and Renewable Energy
Vol. 3, Issue 2, 2020 doi.org/10.33277/cesare/003.002/01

ABSTRACT

Scarcity of freshwater pushes countries impacted by climate change to investigate new sources of supply. Desalination plants powered by renewable energy can be the solution for a tropical developing country. Collection and treatment of seawater to produce freshwater generate an imbalanced water mass. In the case of a Reverse Osmosis Desalination Plant which pumps seawater to produce freshwater and brine as waste, the most important factor is the seawater quality, only available by observation. The design of a plant and its execution will depend on factors such as ambient temperature, salinity, and TDS. The main needs for a good multi-probe marine observation system are low energy consumption, simple monitoring, and coverage of a large area. For the sake of autonomy and ease of use, a functional and robust circuit can be set up using calibrated probes, micro-controllers, and small programmable boards. The use of programmable boards and connected probes are set up as network 'nodes' to send in-situ data measured from the water body. These nodes send the data using radio signal with LoRa protocol to a 'gateway' to store or transfer them. The parameters were measured at different time intervals, water depths, and distances from the coastline to observe how said factors affect the measurements. The results from the data collected are used to compare ocean modelling and satellite data. We present in this study the implementation of a long-range wireless autonomous sensor network and first validation tests in Jamaica and how it fills lack of information for a desalination project. Results indicate a good correlation between measure, modelling, and remote sensor. LoRa P2P network allows at an affordable price continuous monitoring of remote areas with great autonomy and resilience; results showed a successful transmission of >80% within the network.

Keywords: Desalination, seawater, water quality, monitoring, LoRa

INTRODUCTION 1.0

Water is one of the most important resources for human existence. It is one of the most important resources in the world, however, of all the water that exists, only less than 4% is freshwater. There is not enough freshwater readily available for the world's growing population as 70% of the earth's surface is composed of water but not potable.

Many factors affect the expected shortage of water, namely climate change and population growth [1,2]. One of the main factors causing water shortage is the fast increase in population. According to the United Nations World Water Development Report, upwards of 1.1 billion persons lack water and over 2.7 billion find water scarce for at least one month of the calendar year [3]. Water demand is forecasted to increase by 55% globally [4]. Another main factor causing water shortage is climate change. There is expected to be more variability in climate and environmental conditions. This will also bring more extreme weather events.

Desalination is seen as a solution to the water crisis being experienced across the globe. However, one main drawback of desalination is energy usage [5]. As desalination is considered an energy-intensive process, there need to be ways to cut down on the cost of the energy needed to power these processes [6]. The use of renewable energy sources is one solution to cut these costs and has been gaining more attention in recent years. Renewable energy sources such as solar energy, wind energy, and wave energy have been used in pilot and commercial desalination projects worldwide.

Green powering is related to all renewable sources of energy such as solar, wind and wave. The fluctuation of the renewable resource obliges to count in detail, the energy needs for the running of the desalination plant. The energy need of this kind of plant depends on the raw material and the coastal seawater. Good information on the seawater quality will help to determine the energy needs.

Production of freshwater, particularly that which is drinkable requires the application of high-quality standardized processes. Desalination processes must also respect the sanitary standards. As presented by Buros (2000) [7] desalination plants can be represented as a black box with two inputs: energy and seawater (Figure 1). Both are essential for the quality and quantity of the final product.

Authors: Zachary Williams, Jean-François M. Dorville, Michael A. Taylor

Department of Physics, University of The West Indies, Kingston, Jamaica
The Caribbean Geophysical and Numerical Research Group, Baie-Mahault, Guadeloupe
Journal of Caribbean Environmental Sciences and Renewable Energy
Vol. 3, Issue 2, 2020 doi.org/10.33277/cesare/003.002/01

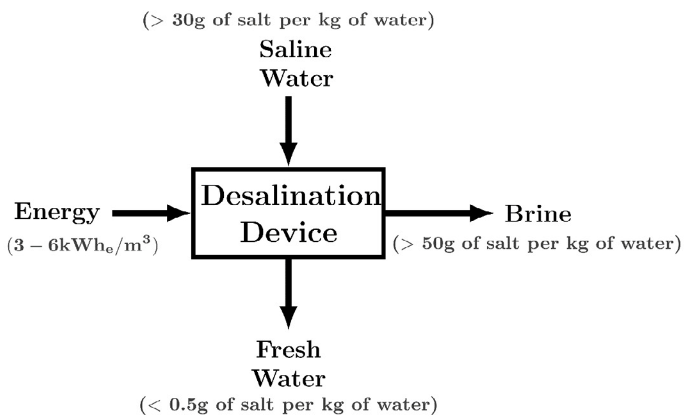

Figure 1. Basics of desalination principle with values of the input and output (modified from Buros 2000)

Very few data sources are available on seawater quality (i.e. salinity, temperature, dissolved oxygen, turbidity, etc.), particularly in a developing country such as Jamaica. This is mainly because the area to be sampled is large with excessive costs.

Recent investigations into water quality monitoring using IoT components show good results and demonstrate the feasibility of the concept [8]. The main hypothesis of this project is coupling sensors in a network can improve spatial monitoring and cross-data. That was proved in the case of the fast modeling of flash floods in Brittany [9]. There is the possibility to properly qualify seawater quality (salinity, temperature) which will help to better model the running of a desalination plant.

Interest to use IoT as an autonomous communication using marine probes in the field of desalination and marine science is growing. The only limitations as mentioned before are the high costs, coupled with the large risk of losing equipment at sea. Over the past half-decade, programmable boards have become more powerful and less expensive.

Equipment allowing long-range transmission over radio frequency such as LoRa have become more affordable. This along with the low cost of probes make it simple now to set-up an adapted device of measure using the concept of Do It Yourself (DIY) [10].

We build a prototype of Lora P2P marine probes using three nodes, one as gateway and atmospheric probe and two mobiles marine probes.

The document is organized as follows: Section 2 presents the methodology used to build and test the network sensor, section 3 presents the results of the two experimentation ran to test the prototype, section 4 discusses the validation of the measurements and the prototype, and section 5 concludes on limitations of the method, the future experimentation and improvement of the prototype.

METHODOLOGY 2.0

Our main aim is to build and investigate the application of LoRa technology to transmit data from a 'node' to a 'gateway' set up using small board computers and single-board microcontrollers along with various probes from measuring data [9,11,12]. The main constraint of the project is the need to operate the devices in a coastal area with high temperature and high humidity.

The suitability and efficiency of using LoRa 'senders' and 'receivers' for a project such as that of measuring salinity and temperature data of seawater are investigated. The communication protocol concept of the project can be sketched by the following drawing (Figure 2).

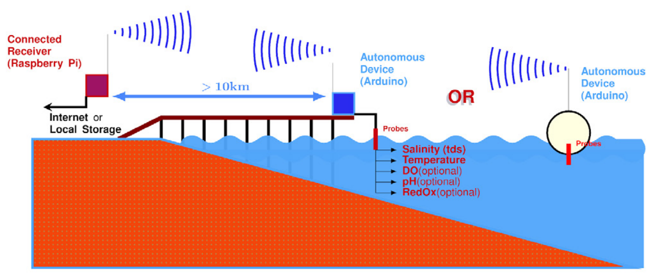

Figure 2. Sketch of the LoRa P2P probes in their marine environment in a fixed and mobile configuration

The methodology used to set and test the protocol was tested and adjusted. The diagram of our process is presented in Figure 3.

Authors: Zachary Williams, Jean-François M. Dorville, Michael A. Taylor
Department of Physics, University of The West Indies, Kingston, Jamaica
The Caribbean Geophysical and Numerical Research Group, Baie-Mahault, Guadeloupe
Journal of Caribbean Environmental Sciences and Renewable Energy
Vol. 3, Issue 2, 2020 doi.org/10.33277/cesare/003.002/01

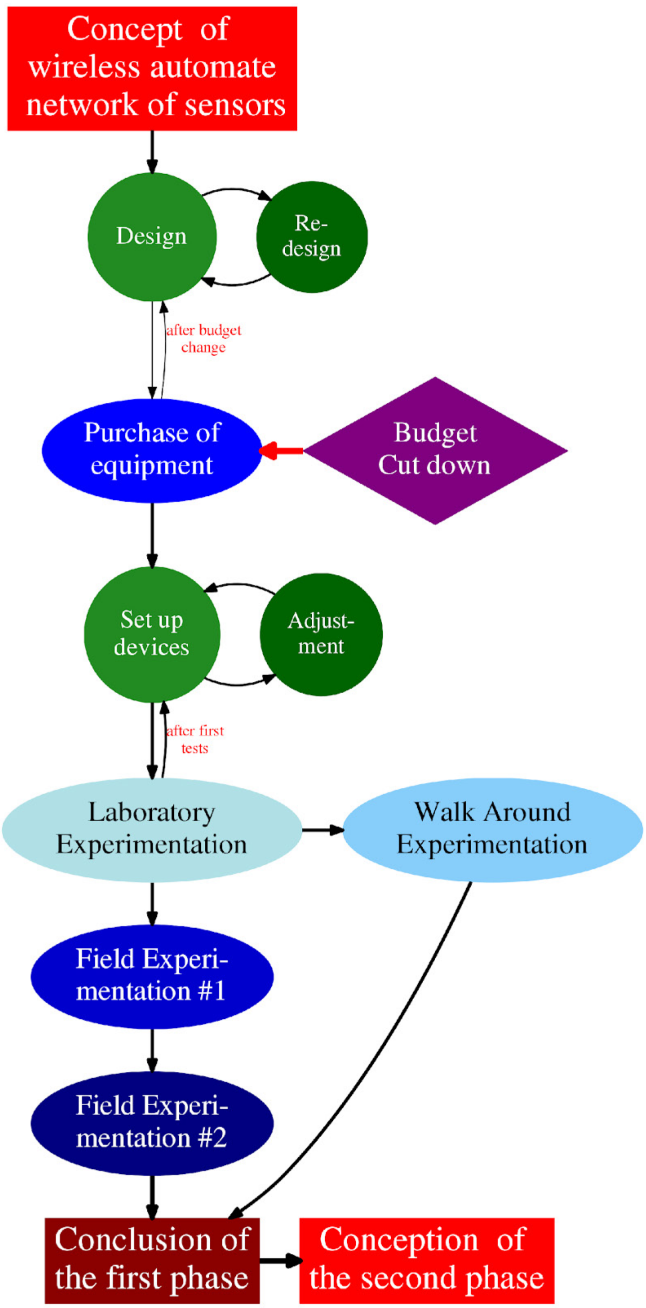

Figure 3. Sketch of the method used in conception, realisation, and validation of the LoRa P2P probe

The aim of the project:

- Shows that LoRa technology can be used to transmit data from a 'node' to a 'gateway' over a long distance in coastal areas
- Shows feasibility of an autonomous network of sensors
- Shows that continuous measures can be used to ease the design of desalination plants

The validation of the project was executed in two phases (Figure 3). The first phase in laboratory conditions to prove the efficiency of the probe in controlled conditions and configuration of the radio data exchange using a LoRa P2P setup and local memory storage. Assessment of communicability of the nodes was done with the walk around experimentation.

The second phase was done in field conditions at the coastline. Two locations were chosen for the experiment with respect to defined specifications.

The validation of the project was executed in two phases (Figure 3). The first phase in laboratory conditions to prove the efficiency of the probe in controlled conditions and configuration of the radio data exchange using a LoRa P2P setup and local memory storage. Assessment of communicability of the nodes was done with the walk around experimentation.

The second phase was done in field conditions at the coastline. Two locations were chosen for the experiment with respect to defined specifications.

2.1 EQUIPMENT AND DEVICE SET UP

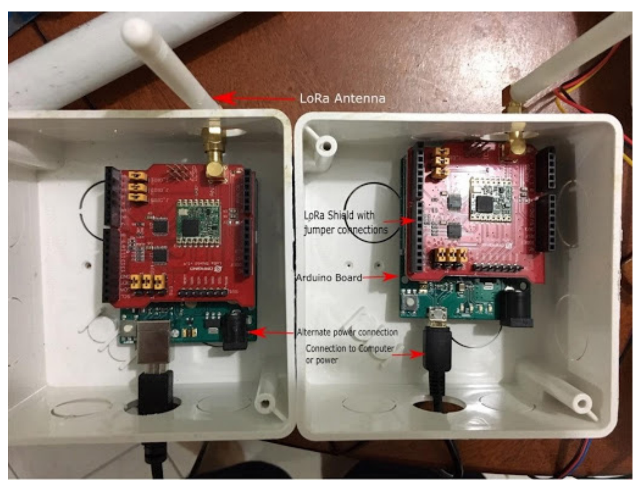

Figure 3. Sketch of the method used in conception, realisation, and validation of the LoRa P2P probe

Authors: Zachary Williams, Jean-François M. Dorville, Michael A. Taylor
Department of Physics, University of The West Indies, Kingston, Jamaica
The Caribbean Geophysical and Numerical Research Group, Baie-Mahault, Guadeloupe
Journal of Caribbean Environmental Sciences and Renewable Energy
Vol. 3, Issue 2, 2020 doi.org/10.33277/cesare/003.002/01

Equipment used included:

• Two Arduino boards equipped with two temperature probes, one TDS probes and a LoRa shield powered by external battery sources

• One Raspberry Pi board equipped with a temperature probe and a LoRa 'hat' module connected to a laptop
The full equipment costs approximately 500 USD, which is much less than a handheld salinity meter.

The set-up of the gateway and the two nodes was made in a two-week phase after the selection and reception of the equipment.

The configuration of the board was done using the Arduino sketch software to upload the correct sketch with the compatible probe. All the sketches include a LoRa component to ensure the transmission of the data.

The set-up of the gateway and the two nodes was made in a two-week phase after the selection and reception of the equipment.

The configuration of the board was done using the Arduino sketch software to upload the correct sketch with the compatible probe. All the sketches include a LoRa component to ensure the transmission of the data.

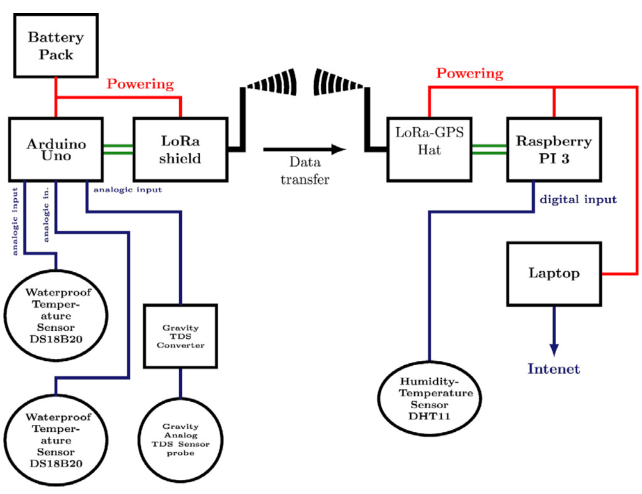

Figure 5. Sketch of set up of 'gateway' and 'node' equipment

The first phase of the experimentation was in a laboratory at UWI Mona and equipment was calibrated.

The total dissolved solids (TDS) probe was calibrated using a known concentration of salts and the other probes were tested in a laboratory situation to ensure correct functionality. Solutions of known concentrations of sodium chloride were prepared and tested to ensure calibration of the TDS probe was accurate.

The temperature probes were tested over several hours and validated by weather station values at UWI Mona.

The seawater temperature probe was tested with freshwater cooled with ice to validate response time and control by mercury thermometer.

The LoRa protocol was also tested within the lab confines by sending temperature readings from one node to the gateway at several distances (<10 m) [11].

For the LoRa protocol, a test was carried out by walking around the campus of the university with a photoresistor connected to a node and the gateway Raspberry Pi was situated in the lab at a distance away. This distance was varied while walking around the campus as shown in Figure 6. The site is located at 187 m of altitude, and during the experimentation, the weather was good with relatively clear skies.

The seawater temperature probe was tested with freshwater cooled with ice to validate response time and control by mercury thermometer.

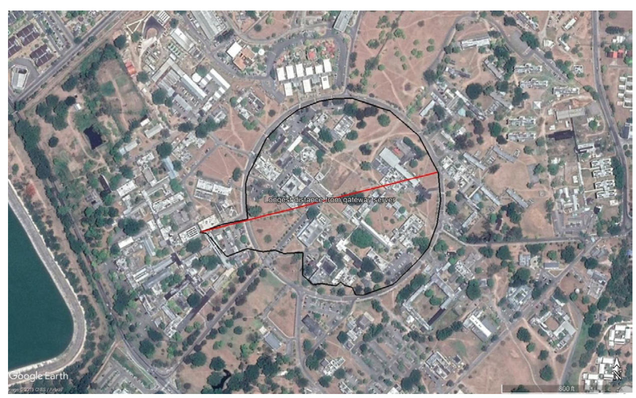

Figure 6. The location of the 'walk around' experiment at the University of the West Indies Mona Campus from satellite view -Google-Earth-.

2.3 FIELD EXPERIMENTATION

One small board computer – a Raspberry Pi 3 was set up as a gateway for the LoRa protocol and Arduino UNO R3 microcontrollers were set up as the nodes with the measurement probes connected. Small-scale probes mostly used for hobby purposes were employed. A DHT 11 sensor was used to measure ambient temperature conditions whereas a DS18B20 temperature sensor retrofitted to be waterproof was used to measure the sea surface temperature. An Analog TDS sensor was used to measure the relative salinity of the seawater.

The locations of experimentation were chosen with a few considerations in mind:

Ease of access to seawater – Flat terrain with easy entry into the seawater was sought as the experimenter would have to hold the equipment in the seawater at different depths for different periods

Authors: Zachary Williams, Jean-François M. Dorville, Michael A. Taylor
Department of Physics, University of The West Indies, Kingston, Jamaica
The Caribbean Geophysical and Numerical Research Group, Baie-Mahault, Guadeloupe
Journal of Caribbean Environmental Sciences and Renewable Energy
Vol. 3, Issue 2, 2020 doi.org/10.33277/cesare/003.002/01

therefore a comfortable location in the seawater would be most suitable.

Safety using equipment - To reduce the risk of theft, the equipment should be kept in an area with restricted access. The LoRa equipment should be operated in calm, sheltered areas and not be operated when the weather is stormy and rough waves are present as the packaging of the equipment is not fully waterproof.

Ease of access to gateway and laptop to make changes to programs - A location where the seawater was close to the shore allowing access to the gateway and laptop to reset the gateway while the code was being changed. The microcontroller code was changed during different phases for several configurations [9,13].

Minimal disturbance to coastal ecosystems - An area where there were minimal ecosystems to be disturbed by using the equipment was chosen. As the probes must be placed in the seawater at different depths, it is ensured that marine life was not excessively disturbed.

Suitability of location regarding data already acquired - Since the data acquired from the experiment will be compared with data obtained previously from satellite and modelling data.

Possibility of getting a range of readings - The locations were chosen at far relative distances to ensure that a range of readings was obtained. Locations from each coast, one being in the southeast and one on the northwest coast of the island (Table 1) to see how the seawater could be different.

Table 1. Coordinates of locations used in the experiment.

Location	Location Name	Latitude (deg:mm:ss)	Longitude (deg:mm:ss)	Elevation (m)
1	Kingston	17° 56' 13.3" N	76° 48' 14.8"W	0-1
2	Montego Bay	18° 29' 12" N	77° 55' 45"W	0-1

There were two sections, that being the Kingston sample (Location 1) and the Montego Bay sample (Location 2). Since the Location 1 sample was taken first, any perceived shortcomings with the equipment used or the methodology were adjusted to ensure the most efficient practices were in place.

Experimentation was done by one experimenter to prove the usability of the device.

To demonstrate the use of LoRa technology and gather useful data at the same time, probes measuring, ambient temperature, sea surface temperature and total dissolved solids were used [9,11]. The use of the LoRa network was limited to that of a local network, implementing a LoRa P2P network, instead of sending data through the Internet and utilizing the Internet of Things (IoT). This way, the data is stored locally on a memory card from the Raspberry Pi (gateway). Setups with varying factors to see how changes may affect readings were undertaken in the experiment. Factors manipulated were:

- Location - the locations were at each end of the island – Kingston (location 1) and Montego Bay (location 2)

- Depth of probes in seawater - depths of 1ft (30cm) and 2ft (61cm) were used as the length of the probe wires did not exceed 2.75m

- Time intervals of measurement - measurements were taken over a period of 5 minutes; Intervals in which data was sent from the nodes to the gateway were varied ranging from 1 second, 30 seconds and 1 minute.

- Distance between gateway and nodes - the distance was changed to see if the data was transferred effectively

- Power source - rechargeable power banks were implemented as well as 9V batteries to see the difference in power usage by the nodes

The gateway was set up with the laptop at one point and the nodes comprising the Arduino boards with the probes were deployed in the water body and recordings were taken. Once the period of the trial ended the transmission of data was paused and the experimenter adjusted the position (whether the distance and/or depth) of the nodes.

As mentioned, most of the probes used were simple probes not intended for heavy usage. The DS18B20 waterproof temperature sensor was reported susceptible to prolonged exposure to saltwater. Therefore, precautions such as using silicone to seal the ends and cleaning immediately after removal from seawater were taken.

RESULTS 3.0

3.1 WALK AROUND EXPERIMENT

The use of the devices was confirmed by the test carried out by walking around the university campus with the Arduino connected to a photoresistor to check the transmission of data to the gateway raspberry pi left in the laboratory. There was indeed transmission of data during the walk around the campus. The frequency of messages sent by the node to the gateway was set at 30 seconds. Light resistivity variation shows (Figure 7) the passage in shadowed areas during the track. This 'walk around' experimentation took around an hour between 9:42 am and 10:42 am on September 24th, 2019. The percentage of messages received was around 88% (Table 2). Some obstacles (i.e., building) block the signal at some point and can explain the 12% of missing data [11,12]. The missing data happened mostly outdoors as seen by the low value in photo resistivity and they can be attributed to the fact that there are many buildings close together on the campus that may cause blockage of the signal [9,11,12].

Authors: Zachary Williams, Jean-François M. Dorville, Michael A. Taylor
Department of Physics, University of The West Indies, Kingston, Jamaica
The Caribbean Geophysical and Numerical Research Group, Baie-Mahault, Guadeloupe
Journal of Caribbean Environmental Sciences and Renewable Energy
Vol. 3, Issue 2, 2020 doi.org/10.33277/cesare/003.002/01

Table 2. Statistics of the light photo resistivity measurements during the experimentation

Description	Value
Number of available data points	89
Percentage of available data	88.12%
Number of missing data points	12
Percentage of missing points	11.88%
Minimum value measured	5 kΩ
Average value measured	156 kΩ
Maximum value measured	624 kΩ
Standard deviation of values measured	200 kΩ
Percentile 5 of the set of measured	5 kΩ
Percentile 25 of the set of measured	11 kΩ
Percentile 50 of the set of measured	27 kΩ
Percentile 75 of the set of measured	302 kΩ
Percentile 95 of the set of measured	571 kΩ

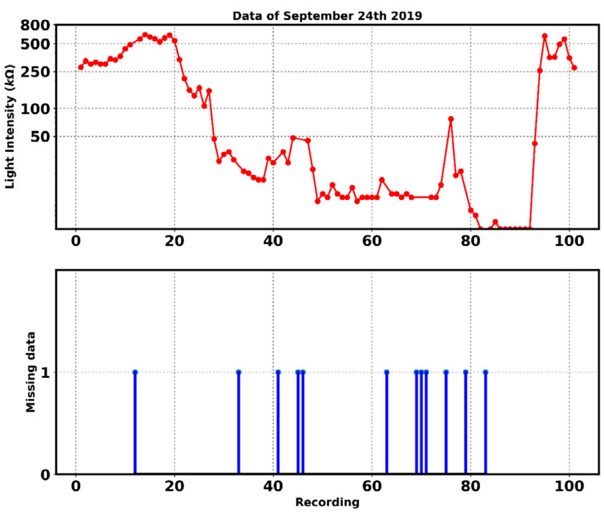

Figure 7. Time series of the Photoresistor and missing data during the 'walk-around' experimentation at the UWI Mona Campus

3.2 SEAWATER MEASURE

Results from the field experiment showed that it is indeed possible to transmit data from different sensory probes to a gateway receiver with the use of the LoRa network and the absence of the Internet. This was successfully done over two locations and varying distances. The sea surface temperature, TDS (salinity) of the seawater and ambient conditions (temperature) were measured. There was a slight difference in the average salinity measured at location 1 and in location 2 with the second location having a higher value. When the depth of the measurements was changed it also showed an increase in the salinity.

One factor to note, the fact that two sensors, the sea surface temperature and ambient temperature were on a single node, data was interchangeably sent to the gateway i.e. sea surface temperature one second then ambient temperature the next second and so on.

3.3 ENERGY CONSUMPTION ASSESSMENT

Other factors investigated were the use of different power sources [13]. In the location 1 segment of the experiment, two different rechargeable power banks were used whereas for the second location of the experiment, one rechargeable power bank was used and one 9 volts battery.

Table 3. Power Sources used in Location 1 Segment of Experiment

Source	Initial Value (V)	Final Value (V)
Rechargeable Power Bank A	4.71	4.70
Rechargeable Power Bank B	4.64	4.63

Table 4. Power Sources used in Location 2 Segment of Experiment

Source	Initial Value (V)	Final Value (V)
Rechargeable Power Bank	4.63	4.61
9V Battery	8.85	6.65

The data provided in Table 3 and Table 4 are used to show the suitability of using different power sources. It is not suitable to use a 9V battery as a power source rather than a rechargeable power bank (5v). The main reason being is the low capacity of a 9V battery causing it to drain much quicker. A typical 9V battery has a capacity of approximately 400 mAh while the capacity of the rechargeable power bank was 2000 mAh. This would mean that with the Arduino operating at 50mA, it would run a maximum of 8 hours on the 9V battery while it would run for 40 hours on the rechargeable power

Development of Lora P2P Network for Autonomous Seawater Quality Monitor for Green Powered Desalination Project
Authors: Zachary Williams, Jean-François M. Dorville, Michael A. Taylor
Department of Physics, University of The West Indies, Kingston, Jamaica
The Caribbean Geophysical and Numerical Research Group, Baie-Mahault, Guadeloupe
Journal of Caribbean Environmental Sciences and Renewable Energy
Vol. 3, Issue 2, 2020 doi.org/10.33277/cesare/003.002/01

bank. This is not considering other factors such as the fact that the LoRa shield was connected to the Arduino as well as the probes using power from the source as well. Also, it is to be noted that the Arduino runs on 5V, so the rechargeable power bank that is rated at 5 volts would have an advantage whereas the 9-volt battery would have to be converted to 5 volts. Most Arduino boards use a linear regulator to drop the voltage from 9 volts to 5 volts. Power is being wasted, if the Arduino is using 50mA, 0.2W is being wasted on the linear regulator, and 0.25 is used by the Arduino itself which is not very efficient hence the short life span of the 9V battery [13].

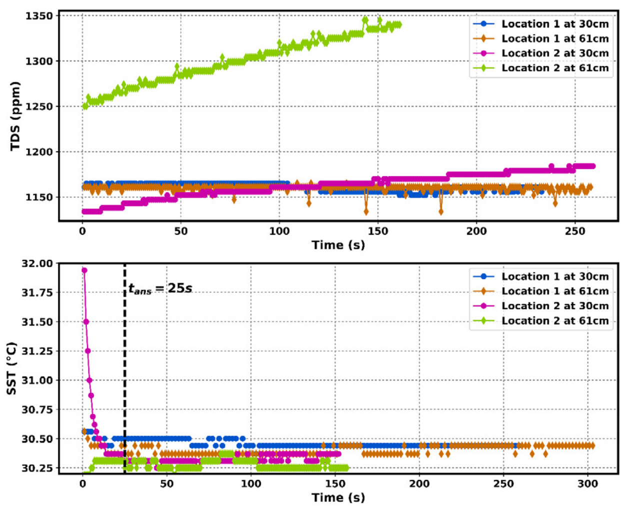

Figure 8. Salinity and sea surface temperature measurements from Location 1 and Location 2 sample

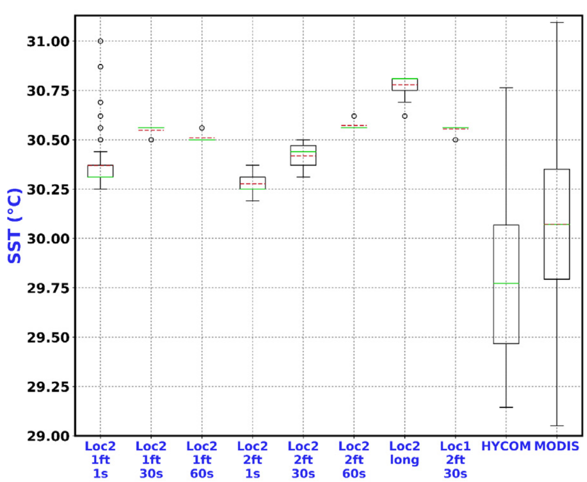

Figure 9. Box plots of sea surface temperature at location 1(Loc1) and location 2(Loc2) and HYCOM data

DISCUSSION 4.0

4.1 LAB PHASE

For the laboratory experimentation phase of the project, the probes were tested and calibrated successfully with the LoRa P2P gateway set on the same table, a photoresistor was also attached to the apparatus for testing of the LoRa signal at different distances. The Raspberry Pi was placed in the laboratory in the Physics Department of UWI Mona (third floor of the building) and the node with the photoresistor was walked around the campus to allow for transmission. The longest distance from the Raspberry Pi that the node was carried is about 0.40km in a straight line in an urban area [9,11,12]. As shown in Figure 7 the data was transmitted successfully, and it was seen that the light intensity changed as the probe was moved around campus and in between buildings as the path is shown in Figure 6.

4.2 FIELD PHASE

The DHT11 probe was damaged by corrosion due to splashing of seawater which caused some data points to not be available.

The field phase allowed for points of data from the two locations to be received remotely.

The total dissolved solids were steady for the most part at around 1150 ppm for the recordings at location 1 at 30cm (Figure 8), with there being one value below 950 ppm and this could be when the probe was being removed from the water and data was still being transmitted to the gateway. For the same location and same time interval but at a depth of 61cm there was a little more fluctuation in the salinity but at an average value of 1160 ppm with values reaching as high as 1165 ppm and this may be attributed to the fact that there is more mixing deeper in the water body. For the period of the experiment in location 1, it was also seen that as the depth increased there was a greater salinity content. This is accounted for by the fact that there is greater mixing at lower sea levels, so there would be a higher relative salt content. Few values went below the 1150 ppm mark, especially at the 30cm depth and this is just because it is close to the sea surface.

Values for the sea surface temperature were constant throughout the experiment at location 1 (Figure 8) with the values not being much greater than 30°C for each recording.

In terms of the ambient temperature recorded at location 1 of the experiment, the values stayed in the range of 32°C to 34°C for the most part with not much fluctuation. There were few anomalies present in the recordings for the measurements and this was because the probe (DHT11) had suffered from being splashed and corroded as these interval measurements were done one after the other.

The average values for TDS in location 2 were greater than those in location 1, with the lowest value recorded at location 2 being a little under 1200 ppm and the largest at around 2000 ppm (Figure 8). As with location 1 as the depth increased, the salinity increased, and this is also attributed to the fact that at that point in time there could have

Authors: Zachary Williams, Jean-François M. Dorville, Michael A. Taylor
Department of Physics, University of The West Indies, Kingston, Jamaica
The Caribbean Geophysical and Numerical Research Group, Baie-Mahault, Guadeloupe
Journal of Caribbean Environmental Sciences and Renewable Energy
Vol. 3, Issue 2, 2020 doi.org/10.33277/cesare/003.002/01

been greater mixing of the seawater. As seen in the time series, there was a gradual increase in the TDS recorded at 30cm and 61cm as the probe sat in the water.

The sea surface temperature gradually decreased as the probe was placed in the seawater at 30cm going from 32°C to around 30°C where it settled for that trial (Figure 8) whereas for the depth 61cm the temperature fluctuated little within the 30°C range as by this time it had acclimatized to the conditions. During most of this phase, the sea surface temperature was within the range of 30.25°C to 30.75°C with the values that are outside this range was at the beginning of the experiment during the acclimatization phase. In the future, the probe could have been placed in the water for a few minutes before starting the transmission of data.

The ambient temperature measured at the second location did not show great variation. At the beginning of the experiment for the recording at 30cm per second, the temperature was relatively high at 42°C and then it decreased and normalized at around 34°C. This high temperature is accounted for since the probes were kept in a plastic protective bag and were exposed to direct sunlight. For the 61cm per second measurement, it was seen where the temperature was constant at 34°C during the period of the experiment with one drop to 5°C which is attributed to a bit of malfunctioning due to inner corrosion of the probe. Throughout the rest of the phase, the temperature did not rise above 35°C and not below 32°C.

The data for the sea surface temperature for the different depths and time intervals were compared against HYCOM retrieved data for both locations (Figure 9). The bulk of the HYCOM data had values lower than those recorded in the experiment and this could be due to the equipment or just the length of time in which the readings were taken.

4.3 MAIN ISSUES FACED DURING THE FIELD EXPERIMENTATION

During the period of the experiment, several issues were faced as with any other experiment. Issues in terms of location, equipment as well as data were all faced throughout.

Finding suitable locations proved to be somewhat difficult as locations had to be easily accessible by vehicle and with enough space for setup of the gateway. The seawater had to be calm enough to utilize the equipment so as not to damage it as well as allow for it to be held without disturbance.

The main challenge faced during the experiment was that of the equipment used. Since low budget equipment had to be used, some were not very suitable for the job. The so-called waterproof DS18B20 sensor had to be reinforced with silicone to prevent water from seeping into the connectors.

Also, the probes had to be cleaned with freshwater after every recording to prevent corrosion. The DHT 11 sensor was splashed with seawater and there was immediate corrosion causing some inaccurate readings. The connector for the DS18B20 sensor was also splashed and there was also immediate corrosion. However, this connector was salvaged as alcohol was used to clean the contacts and remove the corrosion.

In terms of the data, due to the corrosion of some of the probes, some trials had to be abandoned at the location 1segment to allow for cleaning.

CONCLUSION 5.0

It was proved that the LoRa protocol can be efficiently implemented to monitor water quality which is beneficial to investigate remote locations where the number of nodes may be modified along with measurement intervals. There is a possibility to employ such a setup in a populated environment resulting in more than 80% of the signal received. The quality of the probe determines the accuracy of the sensor network. In this phase of experimentation, the budget was forcefully cut significantly restricting the use of low accuracy probes. Future investigations can be undertaken to determine the optimal measurement frequency to increase accuracy related to environmental conditions.

Funding: *Experimentation was done as part of the project, "Renewable Energy for Desalination and Environmental Impact Considerations" funded by The Caribbean Geophysical and Numerical Research Group.*

The authors would like to thank the Physics Department of UWI Mona for the technical support.

REFERENCES

OPEN SOURCE CLOSED SOURCE

[1] Vörösmarty, C. J., Green, P., Salisbury, J., & Lammers, R. B. (2000). Global water resources: Vulnerability from climate change and population growth. Science, 289(5477), 284–288.

[2] Hanjra, M. A., & Qureshi, M. E. (2010). Global water crisis and future food security in an era of climate change. Food Policy, 35(5), 365–377

[3] UNESCO-WWAP. (2003). Water for People Water for Life. The United Nations World Water Development Report. In Water. Unesco Pub

[4] Rosegrant, M., Cai, X., & Cline, S. (2002). Global Water Outlook to 2025: Averting an Impending Crisis. In Agriculture, and the Environment Initiative. International Food Policy Research Institute/International Water Management Institute. Washington DC.

[5] Elimelech, M., & Phillip, W. A. (2011). The future of seawater desalination: Energy, technology, and the environment. Science, 333(6043), 712–717

[6] Schiffler, M. (2004). Perspectives and challenges for desalination in the 21st century. Desalination, 165(SUPPL.), 1–9

[7] Buros, O. K. (2000). The ABCs of Desalting. In International Desalination Association,Topsfield, Mass (Issue 2)

[8] Geetha, S., & Gouthami, S. (2017). Internet of things enabled real time water quality monitoring system. Smart Water, 2(1), 1

[9] Truong, T., Pottier, B., & Huynh, H. (2018). Cellular Simulation for Distributed Sensing over Complex Terrains. Sensors, 18(7), 2323

[10] Yousuf, A. M., Rochester, E. M., & Ghaderi, M. (2018). A low-cost LoRaWAN testbed for IoT: Implementation and measurements. 2018 IEEE 4th World Forum on Internet of Things (WF-IoT) 361–366

[11] Ameloot, T., Van Torre, P., & Rogier, H. (2018). A Compact Low-Power LoRa IoT Sensor Node with Extended Dynamic Range for Channel Measurements. Sensors, 18(7)

[12] Petäjäjärvi, J., Mikhaylov, K., Pettissalo, M., Janhunen, J., & Iinatti1, J. (2017). Performance of a low-power wide-area network based on LoRa technology: Doppler robustness, scalability, and coverage. International Journal of Distributed Sensor Networks, 13

[13] Bouguera, T., Diouris, J.-F., Chaillout, J.-J., Jaouadi, R., & Andrieux, G. (2018). Energy Consumption Model for Sensor Nodes Based on LoRa and LoRaWAN. Sensors, 18(7)

CESaRE

CESaRE - Journal of Caribbean Environmental Sciences and Renewable Energy

www.cesarejournal.org