Sound Quality Monitoring System

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ABSTRACT

Sound intensity in the air is evaluated in this research so that we can consider the quality of the sound in some specific area whether it is good or not via Decibel (dB) parameter. Many types of sounds we hear every single days in modern life through discussion, talking, vehicles, entertainments,... Not most of them are exactly what we expect to hear, aside from charming and valuable sound, there are also annoying ones which is all called noise in general and they seem profitless until now, they might cause bad effects on us – human being like bothersome noise come from the factory, loud sound from transporting vehicles when you are moving on the road or just living nearby and maybe it is from your household electrical appliances; Their source appear arround our activities, poor urban planning may give rise to noise disintegration or pollution, side-by-side industial and residential buidings can result in noise pollution in residential areas. So we decided to do this project with the goal of measuring acoustics in a certain area and Raspberry Pi Zero W is a decent device for this project due to its Wifi connection comes with module microphone ICS43434 MEMS Breakout that support I2S - an indispendable part in our analysis there are also extra library code that we need to have sound magnitude measured such as pyaudio and spl_lib(sound pressure level), recorded signal is processed and then being uploaded to Firebase realtime database service. This result could be premiss for later advanced studies in the future.

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1. INTRODUCTION

Nowadays, noise pollution is becoming more and more common, it directly affects humans and animals so it needs more research. Not all sound is considered noise pollution. The World Health Organization (WHO) defines noise above 65 decibels (dB) as noise pollution. To be precise, noise becomes harmful when it exceeds 75 decibels (dB) and is painful above 120 dB. There are many causes of noise pollution such as traffic noise, air traffic noise, construction sites, catering and night life, animal,…Effects of noise pollution, as well as damaging our hearing by causing – tinnitus or deafness, constant loud noise can damage human health in many ways, particularly in the very young and the very old, here are some of the main ones:

Physical: Respiratory agitation, racing pulse, high blood pressure, headaches and, in case of extremely loud, constant noise, gastritis, colitis and even heart attacks.

Psychological: Noise can cause attacks of stress, fatigue, depression, anxiety and hysteria in both humans and animals.

Sleep and behavioural disorders: Noise above 45 dB stops you from falling asleep or sleeping properly. Remember that according to the World Health Organization it should be no more than 30 dB. Loud noise can have latent effects on our behaviour, causing aggressive behaviour and irritability.

Memory and concentration: Noise may affect people's ability to focus, which can lead to low performance over time. It is also bad for the memory, making it hard to study. Interestingly, our ears need more than 16 hours' rest to make up for two hours of exposure to 100 dB.

SOLUTIONS TO REDUCE NOISE POLLUTION:

International bodies like the WHO agree that awareness of noise pollution is essential to beat this invisible enemy. For example: avoid very noisy leisure activities, opt for alternatives means of transport such as bicycles or electric vehicles over taking the car, do your housework at recommended times, insulate homes with noise-absorbing materials, etc. Educating the younger generation is also an essential aspect of environmental education.

Governments can also take measures to ensure correct noise management and reduce noise pollution. For example: protecting certain areas — parts of the countryside, areas of natural interest, city parks, etc. — from noise, establishing regulations that include preventive and corrective measures — mandatory separation between residential zones and sources of noise like airports, fines for exceeding noise limits, etc. —, installing noise insulation in new buildings, creating pedestrian areas where traffic is only allowed to enter to offload goods at certain times, replacing traditional asphalt with more efficient options that can reduce traffic noise by up to 3 dB, among others.

Sound quality monitoring is also one way to address and limit noise pollution. So this project is put into research

The goal of the project is to build a measuring and monitoring system for sound through the internet, as follows:

- Collects sound intensity calculation and communicates with microcontroller via interface standard I2S (Inter-IC Sound), bypassing analog signal processing (ADC).
- The system coverage over the sensor nodes (Node) and the central processor (Gateway) can be very far apart, coverage with a range of km^2.
- Data storage that can be retrieved on cloud database.
- Observe the device location on the map The topic is also the prerequisite for developing projects related to audio signal processing because this is a very potential area for development.

I²S (**Inter-IC Sound**), pronounced eye-squared-ess, is an electrical serial bus interface standard used for connecting digital audio devices together. It is used to communicate PCM audio data between integrated circuits in an electronic device. The I²S bus separates clock and serial data signals, resulting in simpler receivers than those required for asynchronous communications systems that need to recover the clock from the data stream. Alternatively I²S is spelled **I2S** (pronounced eye-two-ess) or **IIS** (pronounced eye-eye-ess). Despite the similar name, I²S is unrelated to the bidirectional I²C (IIC) bus.

Advantages of the I2S standard:

- Using separate Clock and serial data line should have a simpler design than other asynchronous systems.
- Reliable data synchronization thanks to Master device.
- The results obtained are of good quality, high stability.
- Output is purely digital due to the removal of ADC / DAC and preamplification components commonly found in legacy standards (as can be seen in firuge 1).

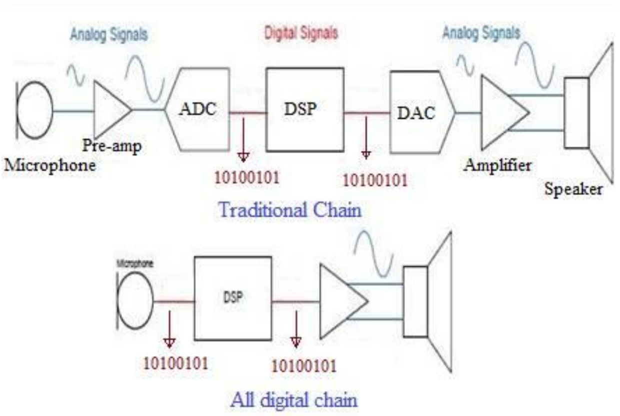

Figure 1. Diffrence between I2S and ADC

HARDWARE USED IN THE PROJECT

- **Module MEMS Microphone ICS43434**

The ICS-43434 is digital I²S output bottom port microphone. The complete ICS-43434 solution consists of a MEMS sensor, signal conditioning, an analog-to-digital converter, decimation and antialiasing filters, power management, and an industry standard 24-bit I²S interface. The I²S interface allows the ICS-43434 to connect directly to digital processors, such as DSPs and microcontrollers, without the need for an audio codec in the system. The ICS-43434 has multiple modes of operation: High Performance, Low Power (AlwaysOn), Sleep. The ICS-43434 has high SNR and 120 dB SPL AOP in all operational modes. The ICS-43434 has a high SNR of 64 dBA and a wideband frequency response. The sensitivity tolerance of the ICS-43434 is ±1 dB, which enables high performance microphone arrays without the need for system calibration. The ICS-43434 is available in a small 3.50 mm × 2.65 mm × 0.98 mm surface-mount package. The ICS-43434 is function-compatible with the ICS-43432 while providing equivalent electro-acoustic performance at lower power consumption and in a smaller package.

Figure 2. Module MEMS Microphone ICS43434

- **Transmit RF signals**

In this project we use the LoRa Ra-02 module to transmit audio data from the sensor nodes to the gateway, because:

Advantages

- Cheap price
- Easy to buy

Disadvantages

- Limited transmission distance
- susceptible to interference

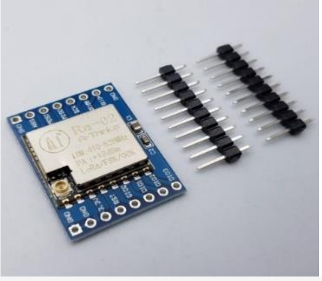

Figure 3. LoRa Ra-02 SX1278

Raspberry Pi 3B and Raspberry Pi zero

In this project we use: Raspberry Pi 3B embedded computer as gateway to capture data from sensor nodes and then upload to cloud database. At the sensor nodes we used a Raspberry Pi Zero embedded computer to capture audio data and GPS coordinates and send it to the gateway.

The Raspberry Pi 3B is powerful enough to be a Gateway and has support for both wifi and an enthernet gateway to reliably upload data to the cloud database. Also on the sensor button we chose raspberryPiZero because it is powerful, supports the I2S standard and is reasonably priced.

	Raspberry Pi 3B	**Raspberry Pi Zero**
SoC	BCM2837	BCM2835
CPU	Quad A53 @ 1,2Ghz	ARM11 @ 1Ghz
GPU	400Mhz	250Mhz
RAM	1GB	512MB
Bộ nhớ	Micro SD	Micro SD
Ethernet	10/100Mbps	None
Wifi	Wifi	None
GPIO	40	40
I2S	I2S	I2S

Figure 3. Raspberry Pi 3B

Figure 4. Raspberry Pi Zero

The module used for positioning is GPS U-Blox-7N with high accuracy and fast response time

Figure 5. GPS U-Blox Neo-7N

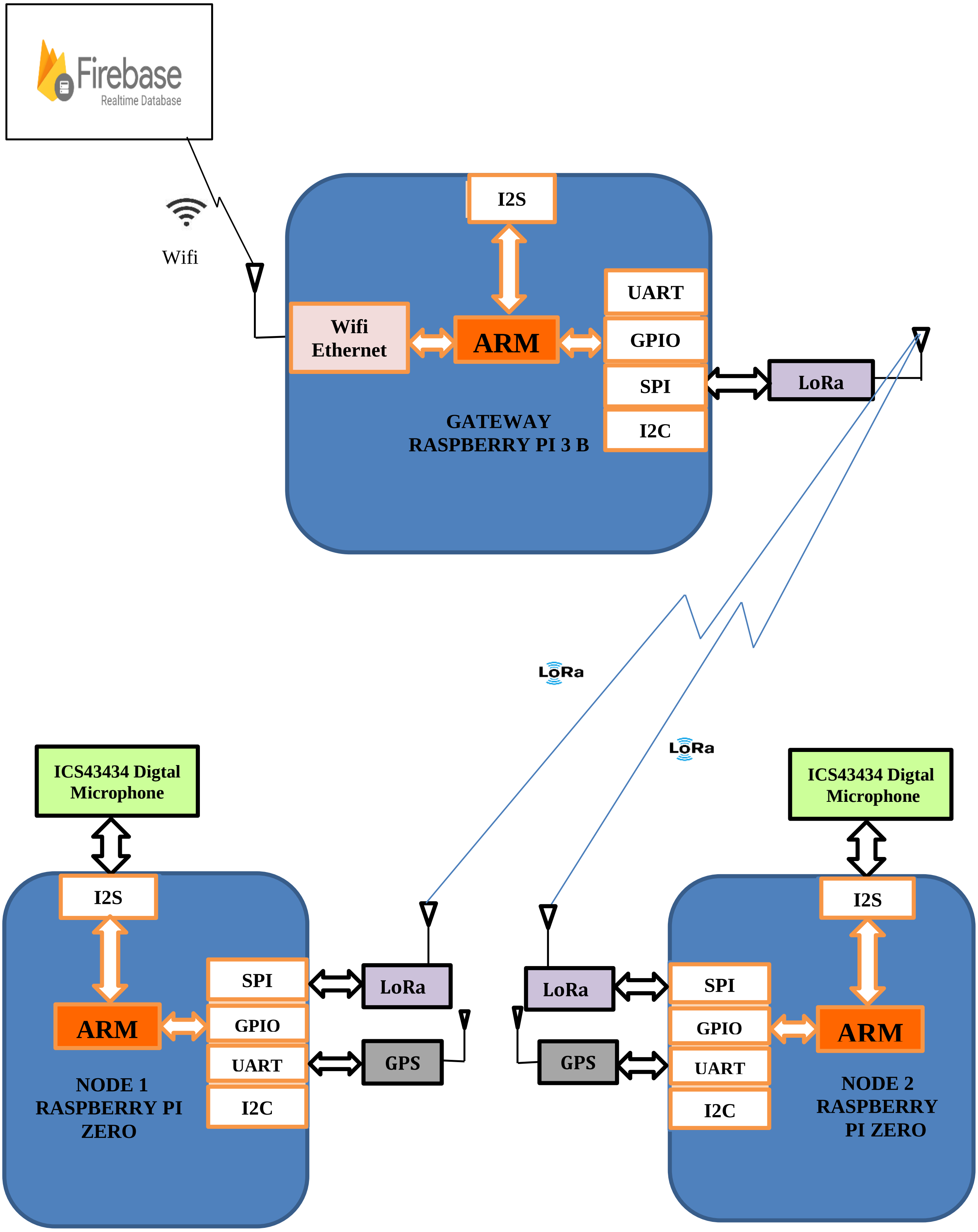

Figure 6. Block diagram of the proposed system

2. RESEARCH METHOD

The human ear responds more to frequencies between 500 Hz and 8 kHz and is less sensitive to very low-pitch or high-pitch noises. The frequency weightings used in sound level meters are often related to the response of the human ear, to ensure that the meter is measuring pretty much what you actually hear.

It is extremely important that sound level measurements are made using the correct frequency weighting - usually A-weighting. For example, measuring a tonal noise of around 31 Hz could result in a 40 dB error if using C-weighting instead of A-weighting.

The most common weighting that is used in noise measurement is A-Weighting. Like the human ear, this effectively cuts off the lower and higher frequencies that the average person cannot hear. Defined in the sound level meter standards (IEC 60651, IEC 60804, IEC 61672, ANSI S1.4), a graph of the frequency response can be seen to the right. A-weighted measurements are expressed as dBA or dB(A).

The main purpose of this project are measuring and monitoring sound amplitude over internet connection so we have to dive into sound measuring knowledges to ensure the high quality of the research.

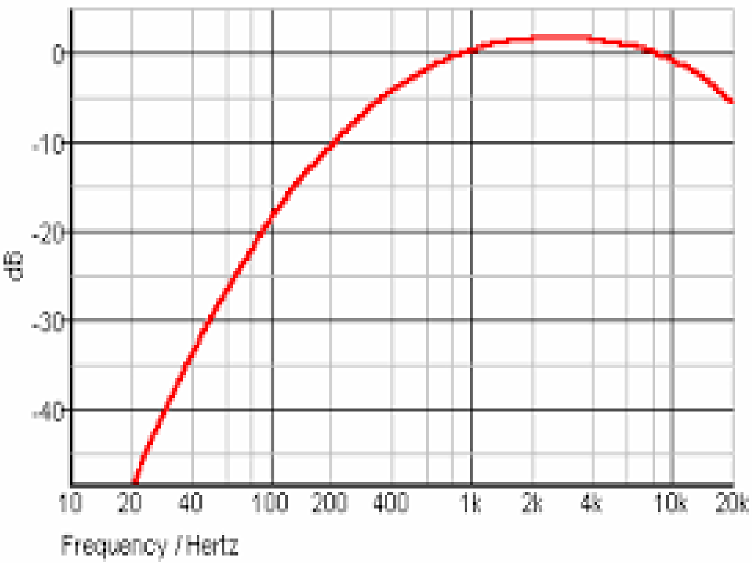

Figure 7. A-weighting

High quality audio and fast processing are the keys of I2S standard so the first thing to do is choosing a decent microphone which has a reasonable price for later expansion. After months of testing and eliminating, we finally choose ICS43434 microphone MEMS from Pesky manufactor as our rear input devices, It has a solid build and amazing performance so that we can have it for long-term usage.

Bring collected data to cloud storage is now a tendancy of recent IoT projects, the data now can be accessed from any devices that accquired internet connection so a Web application is suit for this case. Firebase is our selected platform for this study due to its services consist of hosting, authentication, real-time database, storage, etc and those are what we need for this project. Morever, Firebase is a part of Google so the security is credible.

Raspberry Pi Zero is node processor and Raspberry Pi 3B is selected for gateway device. The Pi Zero is small and have I2S communication built-in while 3B one comes with a powerful performance as that what a gateway processor need to process and upload data to database. Raspberry devices used in this project have a various connection standard and 40 GPIO pins which can be easily upgrade others things in the future base on your objective. Community is also a big advantage of Raspberry, we can ask and share our knowledges with others and download avaible library for each sensors.

3. RESULTS AND DISCUSSION (10 PT)

3.1 RESULTS

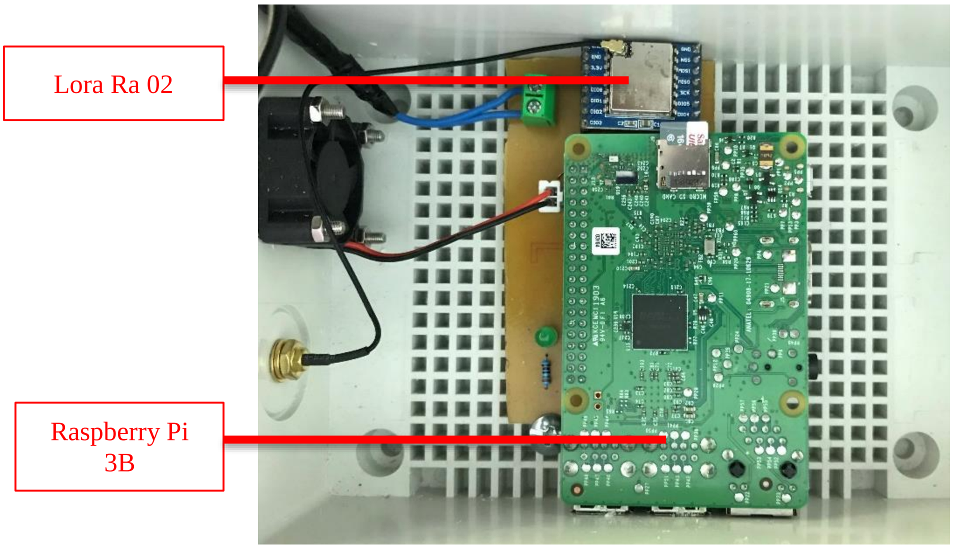

Figure 8. The Gateway

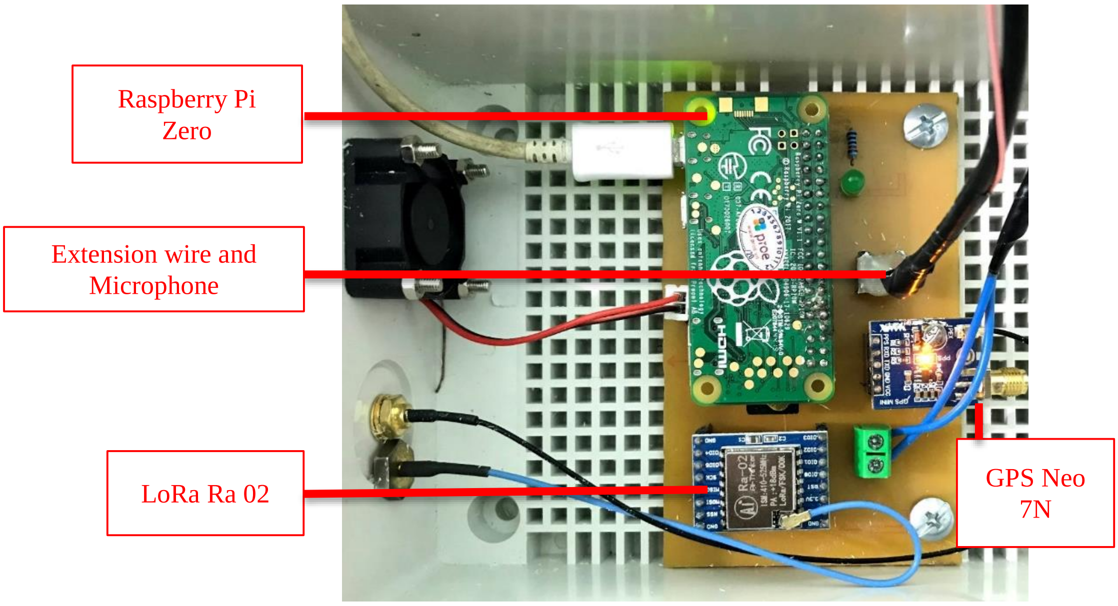

Figure 9. The Node

These above figure 8 and figure 9 respectively are the photo of Gateway and Nodes when fully finished. In figure 7 is an image of the gateway, using Raspberry 3B as the central processor with the main task of receiving data from 2 nodes through LoRa communication network and transmitting that data to the Firebase cloud database and Figure 9 is a node with raspberry pi zero as central processor and ICS43434 microphone to record audio data and send it to gateway via LoRa communication network. They are all stored in boxes that have fans to prevent overheat issue. The Nodes is quite similar to the gateway but they have 2 more module which are GPS and MEMs microphone to receive data send them to Gateway via LoRa standard. After being get by the gateway, data then is processed and store in Firebase database, we use this to display them as chart thanks to Plotly library (as can be seen in Figure 10)

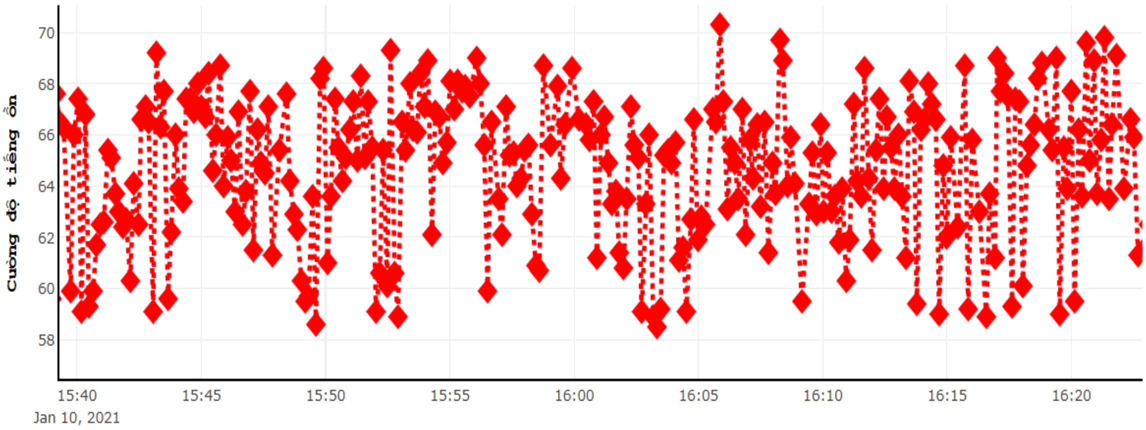

Figure 10. Noise data in 10/01 at College of Enginering Technology

The figure 10 give us imformation about noise data which were collected in a short time from 15h40 to 16h20, as we can see, the data is quite unstable because the noise source is in the lobby of the building, there are time people walk around and there are moments when there is no one. The peak of the graph is approximately 72 decibel meanwhile the lowest point is about 59 decibel. Each value is about 5 seconds from the previous value. A short demo video can be accessed with this link: https://shorturl.at/cdot1

CONCLUSION

In this article, we use all common components to conduct the sound intensity monitoring using I2S standard. The data is displayed as dot graph with line to show the tendancy of the sound intensity and they are all store in Firebase realtime database that can be easy to access. The results of this project could be are reference for later studies and have big potential such as measuring noise in school libray, a mobile devices that record noise in its way, home security,etc. The range of the devices could be extended to give a better performance per price with coding optimisation and using better LoRa. There are a lot of things to do or improve in the future about this field. We hope our works can be an important part for advanced studies later.