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# A System to Notify Real-Time Radio Signal Failures and Predict the Possibility of Failures – LOST TRANSMISSION

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**Abstract:** The focal point of this work was to build a troubleshooting mobile application, which provides an alert notification when RT (Radio Transmission) failures happen at radio outstations and enables predicting the possibilities of radio signal failures based on weather components. The current radio signal failure notifying process is being done half-manual at most of the radio stations while not providing immediate notifications to the radio station staff. A cloud platform, IoT (Internet of Things) technology, and machine learning technique are combined with the aforementioned system to provide fast service to the radio station end-users. The IoT-based Wi-Fi module distinguishes RT failures of each outstation. When weather data is detected, the predictive model displays the possibilities of radio signal failures. The cloud-based functionalities push instant notifications which make the system highly reliable. A key benefit of this system is that even though the users are out of the radio station, the system will be one notification away from the users to notify sudden RT failures.

**Keywords:** Radio Signal Failure, Iot, Machine Learning, Logistic Regression, Nodemcu Esp32, Mobile App

## 1. Introduction

Radio stations broadcast radio signals from their base stations to outstations using wireless communication with the help of Internet Service Providers (ISPs). Later, the signals will be transmitted to listeners in the form of a radio wave [1]. Eventually, listeners receive the radio signals and enjoy listening to their favorite radio channel. The actions of the atmosphere show a direct influence on radio signals, and the signal strengths vary according to weather components [2] [3]. This impact of weather variables on radio signals may lead to RT failures [2]. Therefore, maintaining an RT failure notification system is a much-needed requirement at the organizational level especially for radio station end-users. The deficiency of immediate failure notifications, and predicting the possibilities of radio signal failures based on weather variables are considered in this system.

With the present use of RT process, radio signal failures notifying part is being done using a wireless-communication method and a physical device placed in the radio stations, which indicates an indicator on it when a radio re-transmission failure happens in any radio outstation [1]. Therefore, the staff members of base stations will have to undergo a manual process to record and get notified about a signal failure. As the local radio stations broadcast critical information among the communities, it is important for radio station staff to be aware of emergency news [4]. In case, if RT failures occur, it would interrupt the organizational duties of a radio station as well. Hence, notifying the radio station's staff about a radio signal failure can be difficult, when it comes to the manual part. If the employees who are in charge of detecting the variance in indicators of the physical device will be far away from the base station, some RT failures might go unnoticed [1]. Plus, providing the feature to predict future radio signal failures is a lack of the systems that are currently being using at radio stations [1].

The main objectives of this research are to identify suitable IoT technological approaches for detecting radio signal failures, failure patterns with the change of the weather conditions, existing systems which use weather forecast for prediction, and evaluate existing RT failure notifying techniques. The research team has developed a mobile application using IoT technology and Machine Learning (ML) techniques to notify sudden RT failures and predict radio signal failures that may happen. The prediction model is created using Logistics Regression Algorithm in ML [5] [6].

The rest of the paper will expand on the research background/related work (section 2), development of the system (section 3), results and discussions (section 4), conclusion, and scope for future works in section 5.

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## 2. Related Works

In this section, the literature review part presents the current studies which contributes to the system that is developed. It mainly focuses on existing systems to report RT failures, the technology that has been used in the system, weather influence over radio signals, and the systems that use weather forecasting and machine learning techniques.

### A. Existing Systems

Reporting about a radio signal loss is a needed requirement inside the radio stations to make things done with the RT procedure. Said reporting comprises indicating an indicator on the existing system when a radio re-transmission occurs [1]. When the radio station staff gets notified about signal failures at right time without any latency, it makes it easier for radio stations to broadcast emergency information through their radio channels [4].

Currently, in many radio stations worldwide, if there is a radio signal loss, the base station will get notified about the failure using a physical device with the help of wireless communication [1]. As per comments received while collecting data via interviews, a respondent (user) stated that “We have to keep a record of failures by looking at the indicators on the device as we use very old devices for our RT process, Because, it is very costly for us to shift into the newer technological devices”. Some of the physical devices at radio stations have been able to report radio re-transmission error back using an indicator indicating a radio bearer (RB), but lack of feature to notify the user immediately when a radio signal failure happens even when the user is out of the base station has been an issue that is not yet solved [1].

When a radio signal/transmission failure happens in a radio station, the object of the present invention, which is a User Equipment (UE)/device-detect about a radio link re-transmission failure and notify the Base Station (BS) while indicating a Radio Bearer (RB) as seen in Fig.1 [1]. In existing systems, if the user will be far away from the radio station, they do not provide immediate notification to the user about a signal failure [1].

### B. Technology

When developing a system, the input data could be provided to the system using different kinds of technologies depending on its requirements. IoT technology can create information based on the inputs of the objects connected, analyze those, and make suitable decisions. NodeMCU unit is a great example for this scenario and it makes it easy to detect data, which are difficult to find otherwise. Most of the systems use the ESP32 NodeMCU Wi-Fi module to collect the sensed data from various sensors connected and detect the variance of data [7] [8]. Fig.2 shows an ESP32 NodeMCU, which is a microcontroller with an integrated Wi-Fi, which means that there is no need for an additional Wi-Fi chipset [9]. These kinds of systems, which use IoT technology to go along with the system requirements, can be remotely accessed by web or mobile applications as the systems are based on cloud storing facilities [7] [8] [10] [11]. The input data will be transmitted from the NodeMCU unit to the cloud-based database via Web API request [9].

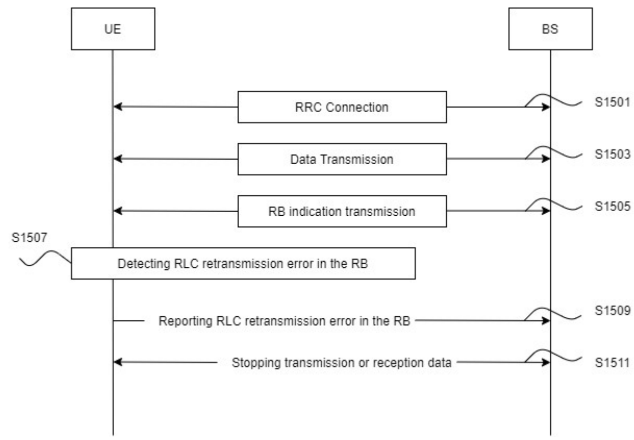


Figure 1. A diagram for reporting a Radio Link Control error in the general wireless communication system

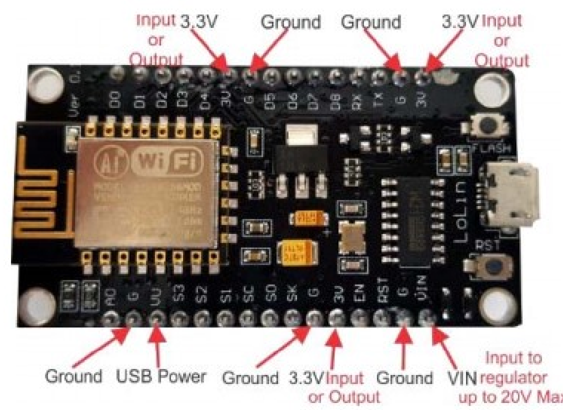


Figure 2. NodeMCU Wi-Fi module

In the technological aspect, the LOST TRANSMISSION troubleshooting system has included an ESP32 NodeMCU Wi-Fi module to receive voltage from the physical device (Codec unit) placed at base stations when a failure occurs. In addition, a cloud storage (real-time) feature is used to store gathered input data.

### C. Weather Influence over Radio Signals

Radio signals drop from time to time due to various reasons, among them, the weather components play a major role as it is continuously changing [2] [3] [12]. Therefore, finding out how each weather variables affect radio signals is worth considering. A study has shown that the radio signals from both the UHF and VHF television stations were directly proportional to the temperature, inversely proportional to the relative humidity, and no defined pattern of proportionality with the mean sea level pressure [12]].

Also, it has used a self implemented weather-monitoring device to measure the weather variables simultaneously at an equidistant position within the Benin City in Nigeria [12].

The researches about the impact of weather components on radio signals state that the atmosphere has enormous control over radio signal propagation [2]. The atmosphere can refract and turn back the radio signals to earth. The study further shows that the components of weather, which are temperature, pressure, humidity, and wind, refract the radio signals corresponding to the refractivity index of each element. According to the collected data (Table 1) within the standard conditions, the below-mentioned relationship between radio signals and weather components has been found [2].

$$S \propto 1/PTH \tag{1}$$

$$S = K/PTH \tag{2}$$

S-signal strength, P-pressure, T-temperature, H-humidity

TABLE I. Evolution of test-bed clusters

| | | | | | |
|---|---|---|---|---|---|
| 9.5 | 77.0 | 29.91 | 94 | 0NA | 5.30 |
| 8.1 | 78.0 | 29.94 | 94 | 0NA | 9.30 |
| 8.5 | 77.0 | 29.91 | 100 | 0NA | 13:00 |
| 9.1 | 77.0 | 29.85 | 85 | 6SSW | 16:00 |
| 9.4 | 79.5 | 29.85 | 80 | 0NA | 20:00 |

The experimental results of another research point out that temperature and humidity seem to have a significant negative influence on radio signal strength as shown in Fig.3 [3].

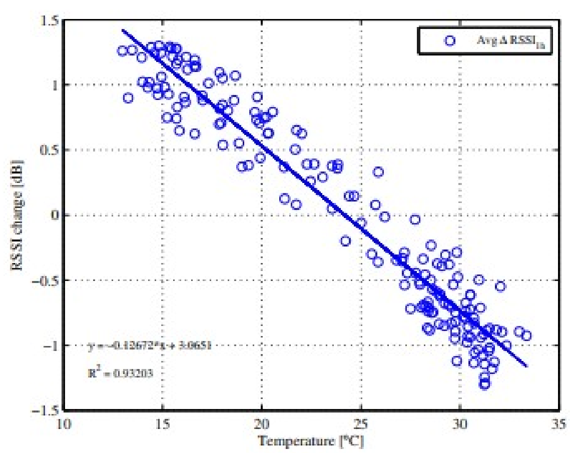


Figure 3. Radio signal strength vs Temperature

## D. Weather Forecasting and Machine Learning

To create the features of a prediction system, the machine learning-based approach is more accurate than the other prediction models and a convenient way to programmatically pull and analyze data [13]. Most of the systems do provide real-time information insights based on the analysis of sensor data and weather forecast data and those are wirelessly collected over the cloud using web services [14]]. Some expert systems are built using data-driven methods such as linear regression. In addition, historical data and machine learning techniques are used to get the forecasting outputs [15] [16].

As elaborated above, the features that would be valuable for the users as a whole are the ones that were intended to provide as a product of this research.

# 3. DEVELOPMENT OF LOST TRANSMISSION

In this section, the development process of the system will be explained in two sections.

## A. Implementation of Hardware Components

Fig.4 shows the circuit diagram of the system and how the hardware components are connected to gather input data. Fig.5 displays how gathered data are processed to notify RT failures. The physical device, which outputs an electrical voltage when radio signal failure occurs at base stations, consists of a hardware component called Codec Unit. That Codec Unit is connected to a NodeMCU(ESP32) Wi-Fi module to receive voltage.

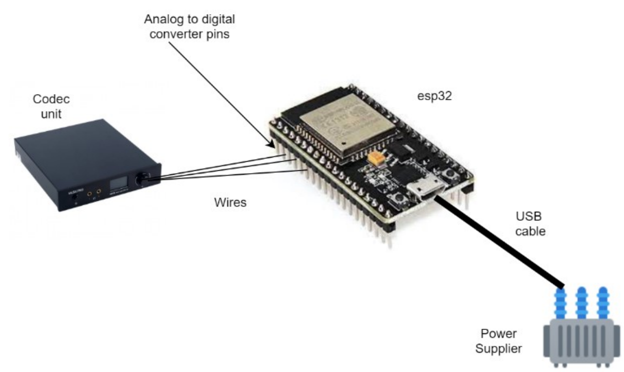


Figure 4. Circuit Diagram of the LOST TRANSMISSION System

The cross-platform application, Arduino IDE is used to write and upload the code into the esp32 module to connect with the cloud database (Cloud Firestore), and then by turning on the Wi-Fi router, the hardware components will be connected to the cloud platform. On the client-side, staff members of the radio station can use the mobile application just by connecting to Wi-Fi on their mobile devices.

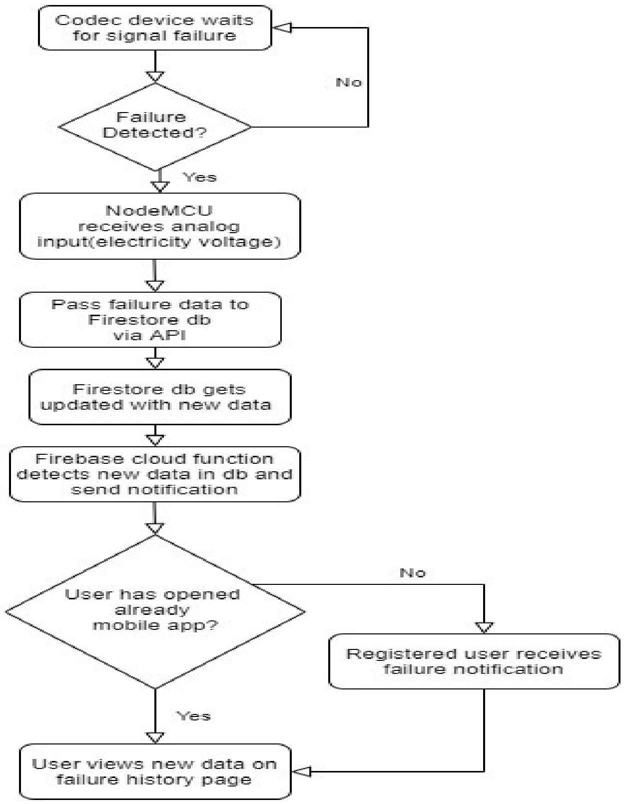


Figure 5. Failure Notifying - Process Flowchart

## B. Implementation of Software Components

In this section, how the LOST TRANSMISSION software has been developed will be explained along with the features in it. On the client side, users can utilize the functionalities developed in the LOST TRANSMISSION mobile app. And, the serverside components are real-time database, cloud services and Restful APIs. Fig.6 shows how all the below-mentioned software components are connected.

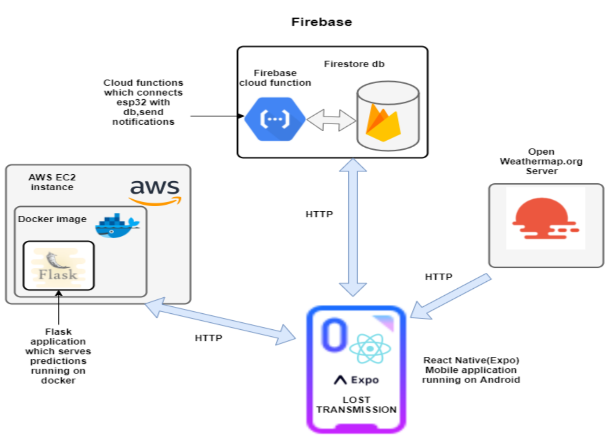


Figure 6. Software Architecture Diagram of LOST TRANSMISSION

### 1) Mobile Application

The LOST TRANSMISSION is an Android mobile application, which is deployed on the client-side to receive radio signal failure notifications, view failure history and future failure possibilities. The popular hybrid mobile application framework, React Native(Expo) is used to develop the application. The user can receive signal failure notifications, and view failure history and failure possibilities by radio outstation's location and date. The app is connected to the database via Firebase SDK. As soon as radio signal failure happens, push notifications are sent to the users via a Firebase cloud function. Based on input data gathered through the Esp32 module, the failure-notifying algorithm works as per Fig.7.

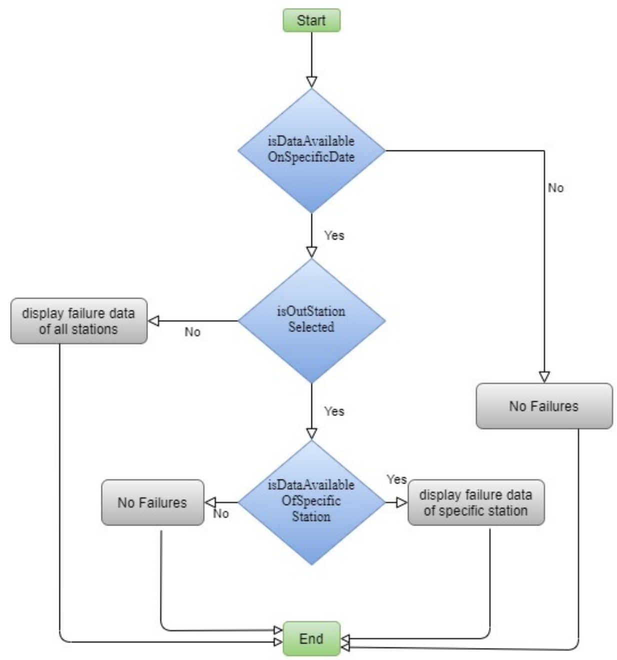


Figure 7. Failure-Notifying Algorithm

Axios, which is a third-party library is used to send asynchronous HTTP requests to Amazon Web Services(AWS) – Elastic Compute Cloud (EC2) instance and receive back predicted failure possibility values as a response. The function to predict future failure possibilities is based on the status of Axios' request and the data received from the weather API as per the pseudo-code explained below in Fig.8.

```
if(isWeatherDataReceivedFromApi){
    if(isAxiosRequestSuccess){
      if(isStationLocationSelected && date){
        display data
      }
    }else{
        display message "Network error"
    }
}else{
    display message "Network error"
}
```

Figure 8. Failure Prediction Algorithm

The Axios request contains the weather variable values obtained via weather API. Fig.9 explains how the failure prediction process is being done in the application.

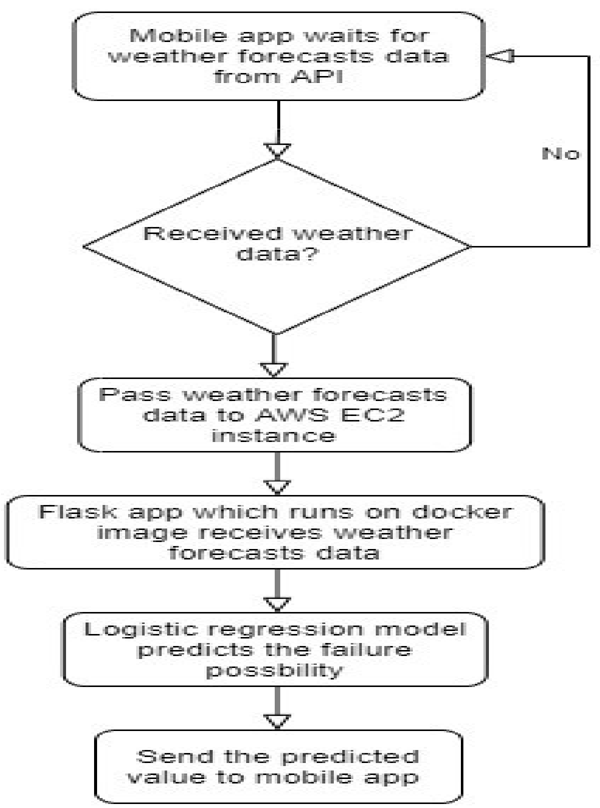


Figure 9. Failure Prediction Process Flowchart

*2) Real-time Database*

Since input signal data needs to be stored somewhere for processing tasks such as historical analyses, a database is required in the system. When the development team needed to work with some streamed data and a mobile application that requires synced states across users in real-time, the cloud Firestore database was an efficient and low-latency solution. It can scale better than even so-called other real-time databases. For real-time processing of the data taken from the NodeMCU module, this No-SQL Firestore database that any mobile or web platform can directly access via native SDKs was used to persist all data in the form of JSON-like documents.

*3) Machine Learning Approaches*

The system uses the influence of weather variables over radio signal failures to predict the possibility of upcoming signal failures. For this, the logistics regression algorithm in machine learning is used. The dependent and independent variables of the dataset are signal failure status (Boolean), temperature, pressure, humidity, and visibility respectively. The visibility of the weather is a categorical variable. Therefore, the One-Hot-Encoding method is used. Here, categorical values of the visibility column are mapped to integers and encoded in binary format. This binary scheme allowed for representing categorical values of the visibility column. A pickle file (prediction model) is obtained by training the dataset using a logistics regression algorithm.

*4) Cloud Services and Restful APIs*

Two separate firebase cloud functions are created. The purpose of the first cloud function is to obtain the signal failure status from the Esp32 module and update the failure data in the Cloud Firestore database. The purpose of the second cloud function is to send the notification to registered users when the failure data is updated in Firestore via the first cloud function. A Flask application is developed to serve the predicted failure possibility values from the prediction model. The flask application is deployed in an Amazon Web Services (AWS) EC2 instance virtual machine. Before deploying the flask application to the EC2 instance, it is containerized using docker. That is for a smooth deployment of the flask application in a cloud virtual machine without any environment compatibility issues.

## 4. Results and Discussion

Notifying the radio station end-users about sudden and future radio signal failures throughout the RT process is the main goal of this research. High accuracy should be achieved to ensure correct failure details and receiving them at right time. Therefore, a user survey was conducted to identify the issues of the staff at Radio stations. The survey collected data from 22 individuals who are currently working at major Radio Channels in Sri Lanka. Mainly, the radio transmission engineers, technicians, and channel heads were among the population. Apart from the survey, a few employees were interviewed in order to gather primary data. As shown in Fig.10 below, it indicates that most users get notified about RT failures using a physical device at radio stations and they are not satisfied with that current method. Fig.10 further revealed that there is a need among users for a troubleshooting system in the RT process, which notifies sudden (live) RT failures and predicts the possibilities of failures. The solution was made by paying more attention to the user's needs.

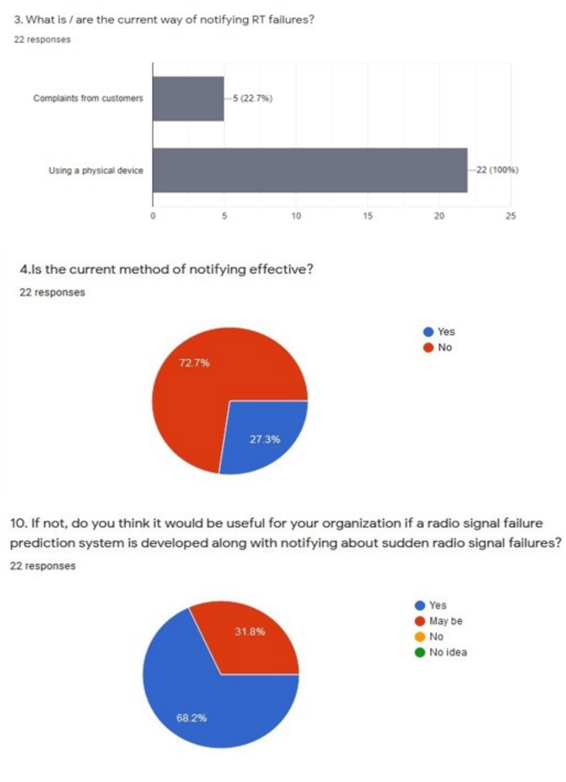


Figure 10. Survey Questions

The Esp32 Wi-Fi module, which was powered using a power supply, was given a small voltage to a few of its ADC (Analog to digital converter) pins. The output was monitored using a serial monitor built-in Arduino IDE, and it displayed the expected output (in the serial monitor) successfully as seen in Fig.11.

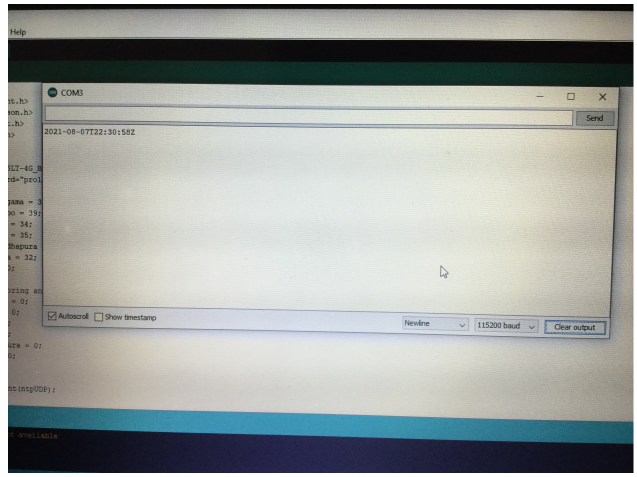


Figure 11. Serial Monitor

Each ADC pin of the Esp32 module is assigned to the location of each radio outstation. Each pin was given a small voltage to test and see whether the database is being updated correctly and to represent a signal failure happening at each outstation. The database was updated instantly as expected without any latency issue. In the software developed by the team, the user instantly receives a push notification related to the outstation where the failure happened as seen in Fig.12.

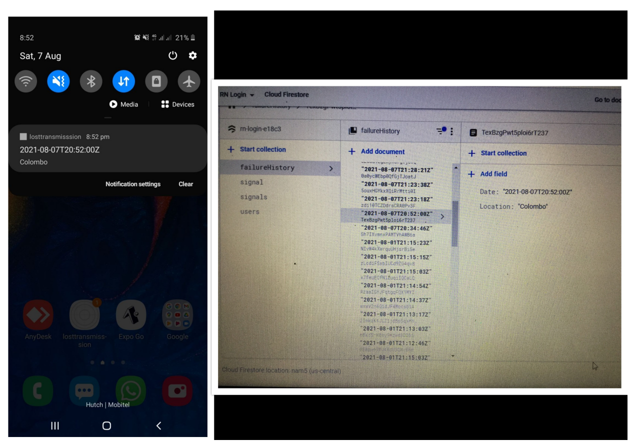


Figure 12. Push Notification Feature

The application could be installed in Android devices with low hardware specifications, and it functioned well as expected without any crashes to ensure reliability under identical conditions. Also, the mobile application was installed on multiple Android devices to ensure all the users receive the notifications at the same time without any latency when the failure data was updated in Cloud Firestore.

Fig.13 below displays the history of signal failures, which can be viewed by each location for each date in the software developed.

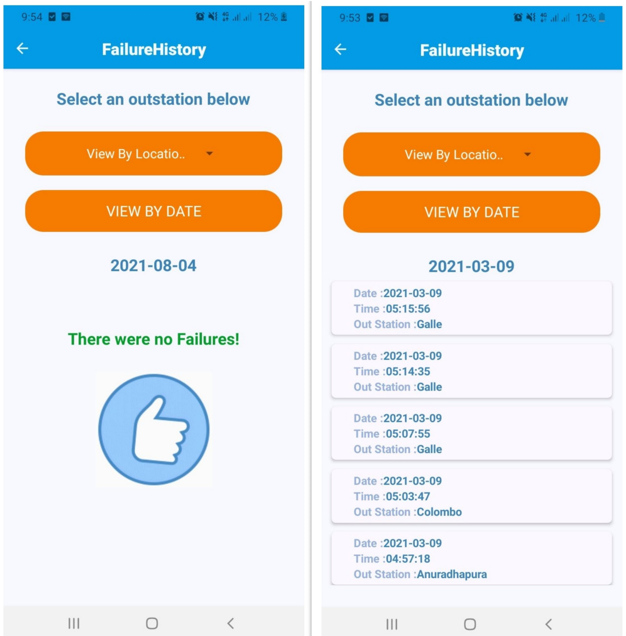


Figure 13. Failure History Interfaces

The testing accuracy of trained logistic regression model is checked as in Fig.14, and its score was 0.9468, which is nearly 95% of accuracy rate. Hence, the accuracy of this model is very high.

```
logistic_model=LogisticRegression()
logistic_model.fit(X_train,y_train)
logistic_model.score(X_test,y_test)
```

Figure 14. The testing accuracy of trained logistic regression model

In the mobile app, the predicted failure possibility values are displayed along with respective weather variable values. The prediction values were served successfully as Fig.15 shows. The weather API provides weather forecasts values for every three hours up to five days.


Figure 15. Failure Prediction Interface

When predicting the signal failure possibility, categorical variable values needed to be converted into numeric values. To overcome this issue, the One-Hot-Encoding method was used as below in Fig.16 for the "visibility" column in the dataset.

```
Import pandas as pd

dummies=pd.get_dummies(df.visibility)
df2=pd.concat([df,dummies.drop('scattered
clouds',axis='columns')],axis='columns')
```

Figure 16. One-Hot-Encoding method

The ESP32 Wifi module should be continuously connected to the Codec unit at the radio station to receive the inputs, which indicates radio signal failures along with a power supply to maintain the overall accuracy of the system.

The present invention is claimed an IoT-based solution functioning push notifications when RT failures happen, unlike the existing system which reports radio re-transmission errors to base stations by indicating an indicator on it. As a new function, the LOST TRANSMISSION system allows users to predict the possibilities of RT failures that might happen in the future. While the existing system needs more human interaction to be notified immediately about a failure, the present invention pops up a message on the user's mobile device as soon as an RT failure occurs.

## 5. CONCLUSION AND FUTURE WORKS

### A. Conclusion

At present, most radio broadcasting organizations use a half-manual attempt to get notified when an RT failure occurs at any radio outstation.

Based on the survey results, it has been erected that there is a crucial need for an automated system with the combination of RT failure prediction models at the organizational level. As a solution, the LOST TRANSMISSION troubleshooting system is developed with the functionalities as follows.

According to the RT failure data gathered using IoT technology, the system notifies end-users immediately as soon as a failure took place at any of the radio outstations.

Predicting the possibility of upcoming RT failures is done by measuring and contrasting the influence of weather variables over radio signal strengths. Logistic Regression Algorithm is used here to develop the prediction model.

### B. Future Works

To make this solution more sustainable and reliable, a function to indicate the radio signal strength (in real-time), and enhancing the platform capability by developing the same app using IOS along with push notification service can be anticipated.

As the aforementioned system is a troubleshooting system related to the RT process, there is a scope to solve RT issues happening due to Internet Service Providers (ISPs), transmitter breakdowns, and power failures too with the advancement of this system.

## 6. ACKNOWLEDGMENT

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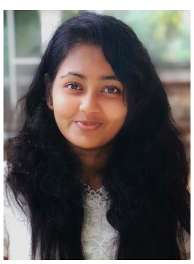

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