Radio Signal Failure Notifying System – LOST TRANSMISSION

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***Abstract*-**Radio transmission (RT) is a commonly used process inside radio stations, which enables broadcasting a radio signal from the radio station to radio channel listeners all over the world depending on the radio signal's strength. Sometimes, radio signal failures can happen due to various reasons and listeners would not be able to listen to the radio channels properly. 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. In this paper, a troubleshooting mobile application to get instant notifications of radio signal failures happening at radio outstations and predict future radio signal failures based on the weather components is presented. A cloud platform, IoT technology, and machine learning technique are combined with the aforementioned system to provide fast service to the radio station end-users. 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 about sudden radio signal failures along with the future radio signal failure-predicting feature using Machine Learning.

Keywords - radio signal failure, IoT, machine learning, logistic regression, nodeMCU esp32, mobile app

1. Introduction

Radio stations broadcast radio channels' signals from their base stations to the outstations using wireless communication with the help of Internet Service Providers (ISP). Later, the signals will be transmitted to the listeners from those outstations in the form of a radio wave. Eventually, listeners receive the radio signals into their radio device and enjoy listening to their favorite radio channel. Sometimes, listeners will not be able to listen to the radio channel properly because a signal failure happens in the RT process. Therefore, maintaining a radio signal failure detecting system and notifying the radio station end-users immediately is a much-needed requirement at the organizational level. The deficiency of notifying immediately about a radio signal failure of a radio channel to the radio station's staff, and predicting future radio signal failures based on the weather variables are considered in this system.

With the present use of RT process, radio signal failures notifying part is being done using wireless-communication method and a device placed in the radio stations, which indicates an indicator on it when a signal failure happens in any radio outstation [1]. Also, the staff members in the base stations will have to undergo a manual process in order to record and get notified about a signal failure. Therefore, sometimes, 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 logging the radio signal failures will be far away from the system at some moment, some radio signal failures can be missed from their records. Plus, providing the feature to predict future radio signal failures is a lack of the systems at the radio stations that are currently being using.

The main objectives of this research are to identify suitable IoT technological approaches for detecting radio signal failures, radio signal failure patterns with the change of the weather conditions, existing systems, which use weather forecast for prediction, and evaluate existing radio signal failure notifying techniques. And, the research team has developed a mobile application using IoT technology to notify about sudden (live) and future radio signal failures that may happen, and it predicts future signal failures based on weather patterns using the Machine Learning technique. The prediction model is created using Logistics Regression Algorithm.

The rest of the paper will expand on the research background/related work, the methodology used, results & discussions, conclusion, and scope for future works.

2. Related Works

In this section, the literature review part presents the current knowledge including substantive findings as well as theoretical and methodological contributions relevant to the system that is developed. It mainly focuses on existing systems to report radio signal failures, the technology that has been used in the system, weather influence over radio signals, and the systems that use weather forecasting & machine learning techniques.

A. Existing Systems

Reporting about a radio signal drop is a needed factor inside the radio stations in order to make things done with the RT procedure. 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 [1]. In some radio stations, the staff members will have to keep a record of the failures by looking at the indicators on the device as they use very old devices for their RT process. Because it can be very costly for them to shift into the newer technological devices. Some of the physical devices at radio stations have been able to report RLC retransmission 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.

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 retransmission failure as seen in Fig.1. In this system, 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].

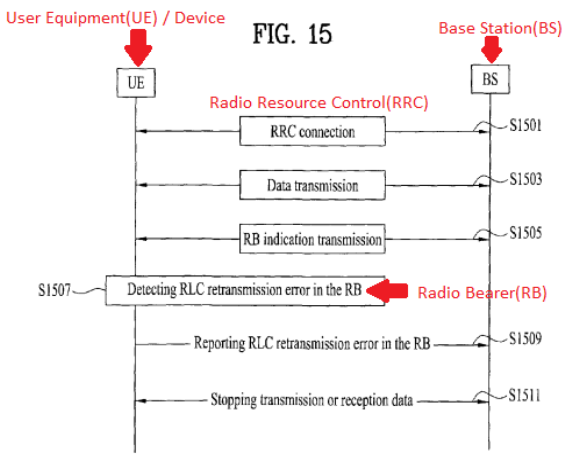

Figure 1-a diagram for reporting a Radio Link Control(RLC) error in the general wireless communication system

B. Technology using

When developing a system, the input data could be provided to the system using different kinds of technologies depending on the requirements of it. 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 [2] [3]. 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 [6]. 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 facility [2] [3] [4] [5]. The input data will be transmitted from the NodeMCU unit to the cloud-based database via Web API request [6].

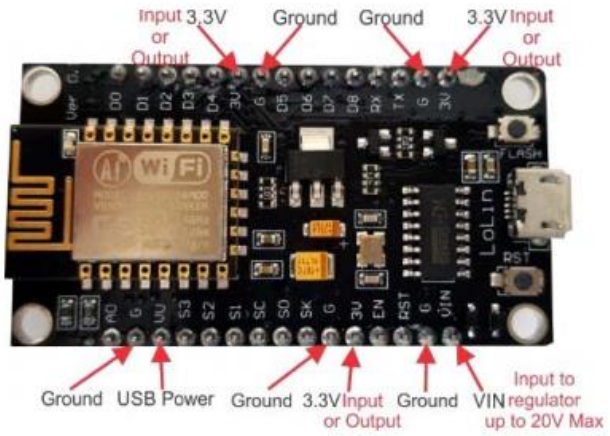

Figure 2-NodeMCU Wi-Fi module

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. 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 as seen in Table 1. 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 [7].

Month	Mean Signal Strength from EBS (dBm)	Mean Signal Strength from NTA (dBm)	Temperature (0 C)	Relative Humidity (%)	Mean Sea Level Pressure) (mbar)
Jan	17.10	19.10	29.10	49.70	1010.60

Feb	17.70	19.80	30.50	47.40	1009.70
March	15.60	17.90	28.70	66.90	1008.90
April	14.70	17.20	27.50	78.50	1009.00
May	14.10	16.70	26.80	83.60	1010.50
June	13.50	16.10	26.30	94.30	1012.20
July	13.30	15.80	25.40	96.70	0 1012.80
Aug	13.10	15.20	24.90	91.50	1012.60
Sep	14.00	16.40	27.10	89.40	1011.90
Oct	16.80	18.90	28.60	80.70	1011.00
Nov	16.50	18.30	28.20	73.30	1010.40
Dec	16.90	18.60	26.90	55.50	1010.80
Average	15.30	17.50	27.50	75.60	1010.90

Table 1- The Monthly Mean Measurements of the Signal Strength and Weather Variables for 2018 in Edo State, Nigeria

The researches about the impact of weather components on radio signals state that the atmosphere has enormous control over radio signal propagation. 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 2) within the standard conditions, the below-mentioned relationship between radio signals and weather components has been found [8].

S α1/PTH S=K/PTH

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

Signal Strength	Temperature(F)	Pressure(inHg)	Humidity (%)	Wind(Mph)	Time(hrs)
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

Table 2-Half-hourly measurement of Signal strength and Weather components in the residential area in Calabar metropolis (Ettaabgor)

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 [9].

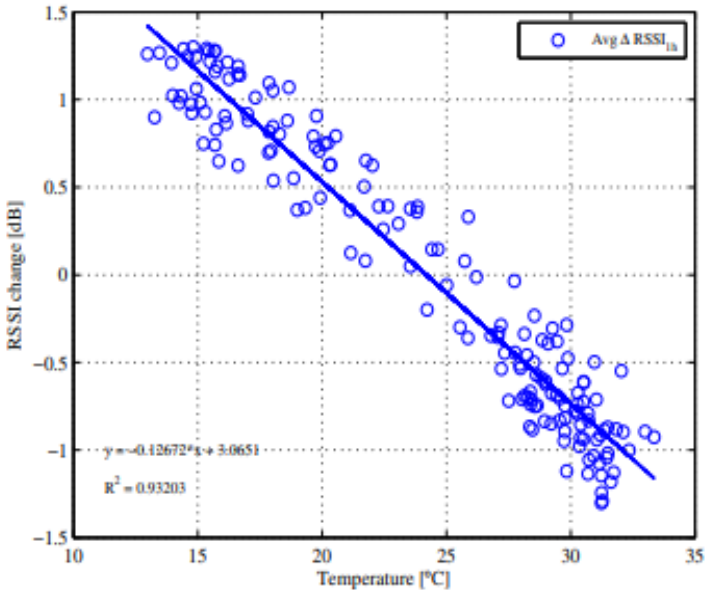

Figure 3– Radio signal strength vs Temperature

D. Weather Forecasting & 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 [10]. 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 [11] [12].

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

The main finding, which lays the foundation for the concept of the LOST TRANSMISSION system, is the existing system that is occupied at radio (base) stations. But, it cannot notify the radio station's end users immediately about a radio re-transmission error. Further, existing systems are not able to provide information about possible future signal failures. Therefore, the need for a troubleshooting system, which notifies the user

immediately when an RT failure happens at any outstation of a radio station, is shown as a gap. As a suitable solution, the aforementioned troubleshooting system is successfully developed. In this section, the development process of the system will be explained in two sections.

A. Implementation of Hardware Components

Fig.4 shows the block diagram of the system along with the hardware architecture. 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 in order to receive voltage. 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.

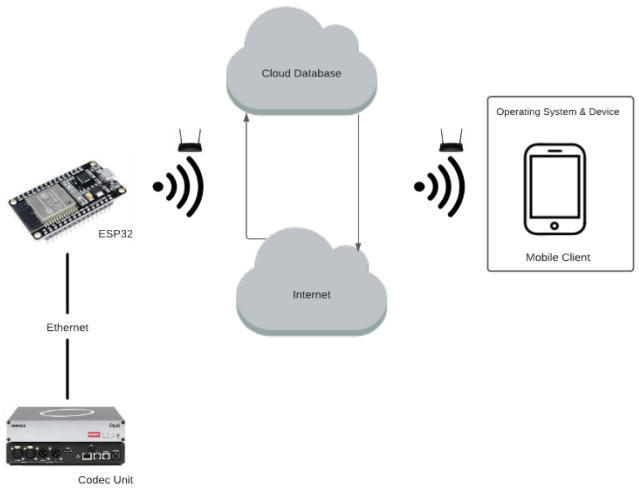

Figure 4: Hardware Architecture of the LOST TRANSMISSION System

B. Implementation of Software Component

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 server-side components are real-time database, cloud services & Restful APIs.

I. 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 & 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 & 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.

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.

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

The Axios request contains the weather variable values obtained via weather API.

II. 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.

III. 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. A pickle file (prediction model) is obtained by training the dataset using a logistics regression algorithm.

IV. Cloud Services & 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 & Discussion

Notifying the radio station end-users about sudden & 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.

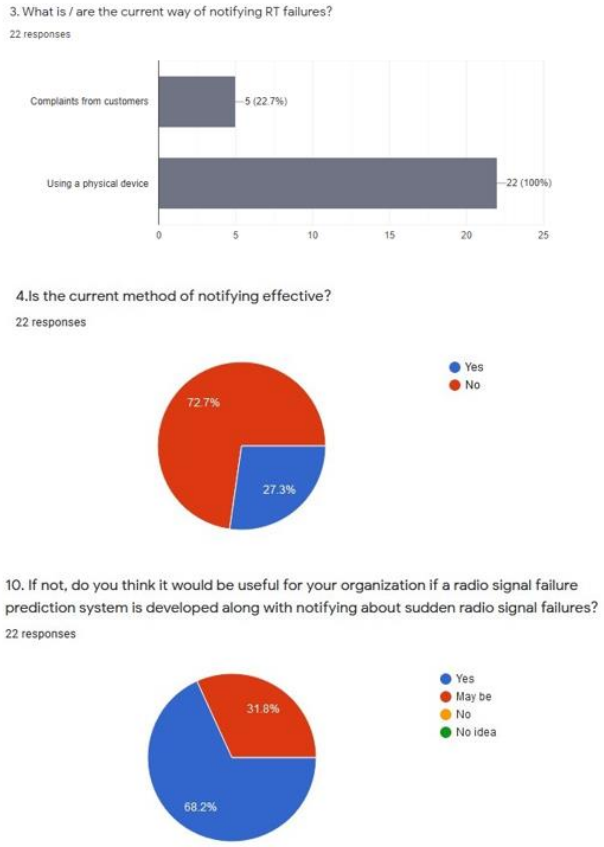

Figure 5- Survey Questions

As shown in Fig.5 above, 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.5 revealed that there is a need among users for a troubleshooting system in the RT process, which notifies both sudden (live) and future radio signal failures. The solution was made by paying more attention to the user's needs.

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.6.

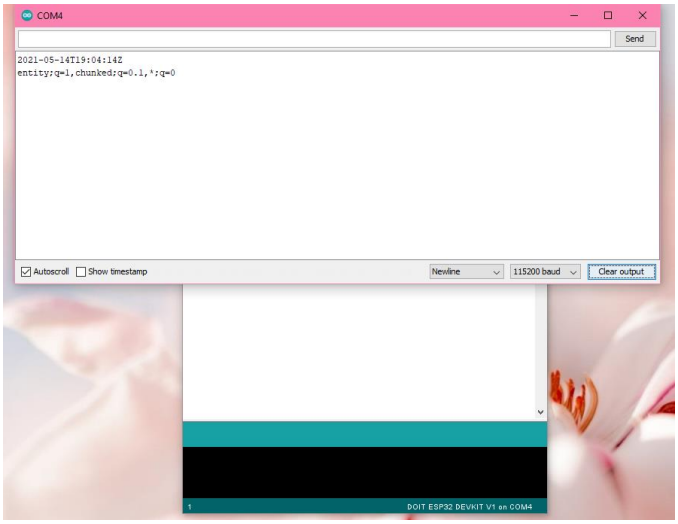

Figure 6-Serial Monitor

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 too related to the outstation where the failure happened as seen in Fig.7.

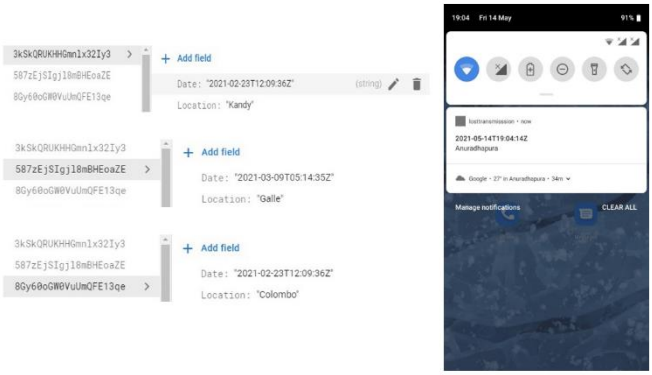

Figure 7- Push Notification Feature

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

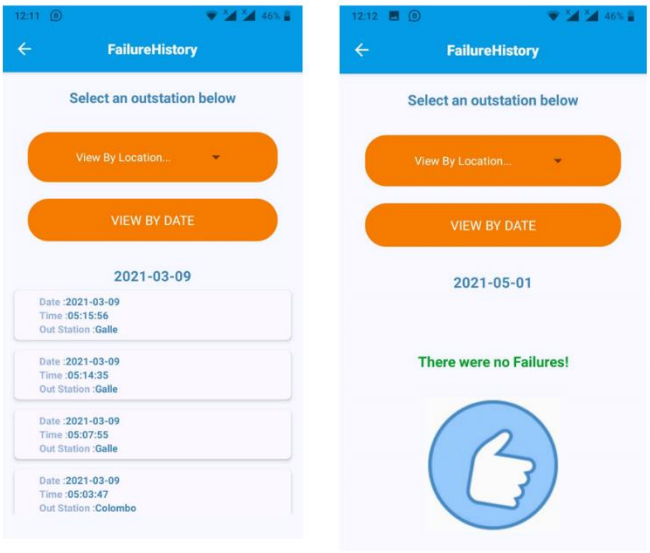

Figure 8- Failure History Interfaces

The testing accuracy of trained logistic regression model is checked as below, 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)

In the mobile app, the predicted failure possibility values are displayed along with respective weather variable values. The prediction values were served successfully when it was filtered by specific location and date as Fig.9 shows.

Figure 9-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 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')

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.

5. Conclusion and future works

At present, most radio broadcasting organizations use a half-manual attempt to get notified when an RT failure occurs at any radio signal transmission outstation. Therefore, the need for an automated system with the combination of RT failure prediction models is crucial at the organizational level. As a solution, the LOST TRANSMISSION troubleshooting system is developed with functionalities such as notifying radio station end-user immediately when an RT failure happens at any of their outstations, predicting the future signal failure possibility by using IoT technology, and machine learning technique respectively. Additionally, mobile frameworks, web services, and cloud technologies have been used in this system to make the processes more effective and efficient. Predicting the possibility of upcoming RT failures is done by measuring and contrasting the influence of weather variables over radio signal strengths.

Currently, this system is developed only as an Android standalone mobile application. To make this solution more sustainable and reliable, some future enhancement tasks have been planned to be achieved. 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 are some of them. 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) too with the advancement of this system.

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