Autonomous Simplified Long-Range Web-Based System for Tracking of Movement Using FindXTech

Roderick R. Puvok, Jedol Dayou#

Energy, Vibration and Sound Research Group (e-VIBS), Faculty of Science and Natural Resources, Universiti Malaysia Sabah, Jalan UMS, 88400 Kota Kinabalu, Sabah, MALAYSIA.

Corresponding author. E-Mail: jed@ums.edu.my; Tel: +6-088-320000; Fax: +6-088-435324.

ABSTRACT Generally, long-range movement tracking system requires either complex integration of multiple short-range communication networks such as Zig Bee, Bluetooth, Wi-Fi, Wi-MAX and RFIDs, or through commercial satellite communication system such as Global System for Mobile Communications and General Packet Radio Service. It could be for many purposes such as smart city management, tracking asset, smart agriculture management or reducing traffic accidents. Using multiple short-range communication networks require wide range of electronics components and communication protocol to enabling the function. On the other hand, using Global System for Mobile or General Packet Radio Service could incur additional cost for subscription and depending on the coverage area. This paper discusses a simplified long-range tracking system with unlimited access over the internet. A prototype called FindXTech was built in the paper that uses point-to-point transceivers using Long Range communication device or LoRa in short, without any intermediate third-party communication medium. For location identification, a global positioning satellite module was coupled with a primary LoRa module and integrated using Arduino Nano microcontroller that also channeled the required power to LoRa and global positioning satellite modules, as well as to handle the sending global positioning satellite data via LoRa at the transmitter's end. At the receiver's end, the GPS data received by the secondary LoRA which is also powered by using Arduino Nano microcontroller where at the same time the microcontroller red and process the data. The receiver's Arduino Nano microcontroller is connected to a local server personal computer with local area network connection where the microcontroller fed related information such as latitude and longitude (Lat-Long) data and sending time of the transmitter. The Lat-Long data are integrated into a map to display the transmitter's location. A series of test were conducted to show the workability of the system for tracking a moving car on a road at different conditions where the transmitter is fitted. It was found that FindXTech system is capable of displaying the moving car location on a straight road at different speed. The system also capable of smoothly showing a U-turn movement on a U-turn road, movement in a shopping lots area, residential area, hilly and winding road as well as under flyover road and dense housing area within 5 km radius.

KEYWORDS: Point-to-point communication; Transceiver; Location identification; Global positioning satellite; Autonomous tracking system.

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INTRODUCTION

They are so many things in motion and it is impossible to manually track each of them. However, with location intelligence, live maps and mobile applications can be created for efficient movement tracking as well as for monitoring. By knowing and analyzing the present and the past of the object locality, decision-makers can generally identify opportunities for growth, safety, and efficiency depending on the nature of their interest and purpose. It could be for smart city management (Nellore & Hancke, 2016), tracking asset (Balakrishnan & Nayak, 2012), smart agriculture management (Mahama Chedao et al., 2020), for safety of lives and properties (Bello-Salau et al., 2019) or reducing traffic accidents (Salazar-Cabrera et. al., 2019).

Depending on complexity and cost that involves, movement tracking can be in a short-range radius or long-range distance. Generally, for long-range movement tracking system, it requires either complex integration of multiple short-range communication networks such as Zig Bee, Bluetooth, Wi-Fi, Wi-MAX and RFIDs or using commercial satellite communication system (Nellore & Hancke, 2016). Integration of multiple short-range communication networks may require complex infrastructural setup of multi communication platforms and protocols. This may also involve inter-device connectivity that is a very dominant mechanism that appears to be complex, leading to much complication due to different protocols and design aspect.

Long-range movement tracking implemented through commercial satellite communication such as Global System for Mobile Communications (GSM) and General Packet Radio Service (GPRS) (Behzad et al., 2014) requires a third-party telecommunication system. Such a tracking system has been used by Alli et al. (2015), Dutta et al. (2018) and Kadiri et al. (2019) for anti-thief of vehicle purpose. A system for similar purpose has also been developed by Maurya et al. (2012) that consists of GSM modem and GPS receiver that constantly monitor the vehicle but return the coordinates of vehicle only when requested and therefore, there is no need of a central server in this system (Shibghatullah et al., 2022). GPS-GPRS on web-based vehicle tracking system can also be used to serve enterprises for monitoring of large number of vehicles (Salim & Idrees, 2013). It could consist three main sections: the tracking device mounted to the vehicle, a web-based application (to view the location), and a central server that receives and transmits data. GPS position of the vehicle is retrieved at certain interval, sent to the central server by using General Packet Radio Service (GPRS) and displayed on an integrated Google map (Murallo, 2021). Then, user will be able to view the location on the web application that has a Google map embedded in it. GPS-based movement tracking for personal use can also be implementation on Android device (Sundas & Karim, 2018). It utilizes the GPS service features in smartphone to monitor the location of user. However, long-range movement tracking implemented through commercial satellite communication generally means that the tracking system is not independent because it uses GPRS and SMS gateways. The system may crash if the SMS gateway and GPRS is blocked, so, the system is totally dependent and is not standalone. In addition, coverage is limited to the Base Transceiver Station (BTS) and the sector antenna under whose coverage the tracked object is located and this operation requires the services of the mobile operator whose network is used to carry the tracking information for the location to be accessed.

Several attempts have been reported in the literatures in developing an independent tracking system such as by (Salazar-Cabrera et. al., 2019; Selvaperumal et al. 2019; Mahama Chedaod et al. 2020), to name a few. However, in principle these systems are limited within a relatively small radius of coverage. Therefore, if the end goal is for long-range movement tracking, integration of these independent systems is needed and this might contribute to additional complexity and cost. Although some literatures reported a communication range as far as 15 km on land and 30 km on water (Petajajarvi et al., 2017), and 766 km (TheThings Network, 2020) for such independent tracking system, these are merely a performance tests, and not an actual system for movement tracking application as presented in this paper.

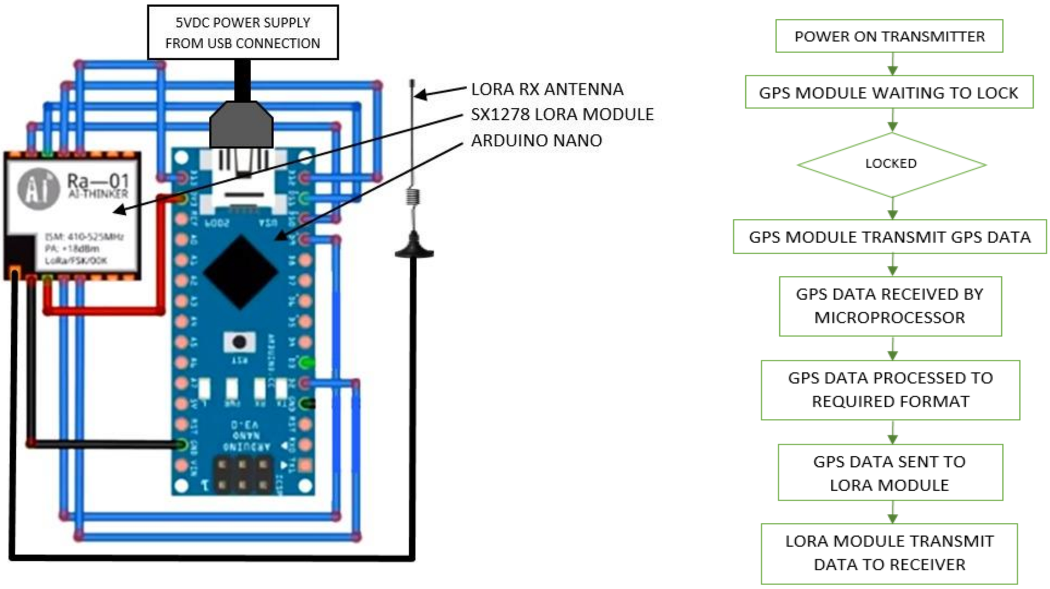
In this paper, a simplified autonomous point-to-point long-range movement tracking system is developed and tested to verify its workability. A complete system for this prototype called FindXTech utilizes two units of low power long range transceiver chips or LoRa in short where one of them was used as a transmitter and the second acts as receiver. To manage the communication between the two transceivers, independent Arduino Nano microcontroller board was used at both ends that also act for power supply management. A global positioning satellite (GPS) module was attached to the transmitter to get the geographical coordinates of the transmitter. Various test conditions for real time monitoring of a moving vehicle were carried out in Kota Kinabalu, the capitol city of Sabah, Malaysia and is reported in this paper.

HARDWARE AND SOFTWARE REQUIREMENTS, AND TEST METHODOLOGY

The prototype called FindXTech was built in this paper for long range movement tracking system that uses point-to-point autonomous transceivers communication using LoRa, without any intermediate third-party communication medium. The raw design and early connectivity test result of the system can be found in Puvok & Dayou (2019). The system was further improved and additional feature was introduced which is the internet access capability of the system where monitoring of object movement is made possible over internet as well as over smart mobile communication system when required.

The Transmitter

The main task of the transmitter module is to identify its geospatial location and then to send this location coordinates to a paired receiver. For location identification, a global positioning satellite (GPS) module was used and coupled with a primary LoRa module and integrated using Arduino Nano microcontroller, that also manage the required power to LoRa and GPS modules, as well as to handle the sending of GPS data via the LoRa module antenna. Upon activation of the FindXTech transmitter module, the GPS unit will lock its geospatial real time location. This location in terms of latitude and longitude (Lat-Long) coordinates are captured by the Arduino Nano microcontroller. The Lat-Long coordinates are coded into a suitable format by the written code in the microcontroller. These coordinates are then sent to the paired receiver together with the sending time and identification number (ID) for further processing. Fig. 1(a) shows the schematic diagram of the transmitter of the FindXTech system whereas Fig. 1(b) summarizes the computer algorithm inside the FindXTech transmitter module.

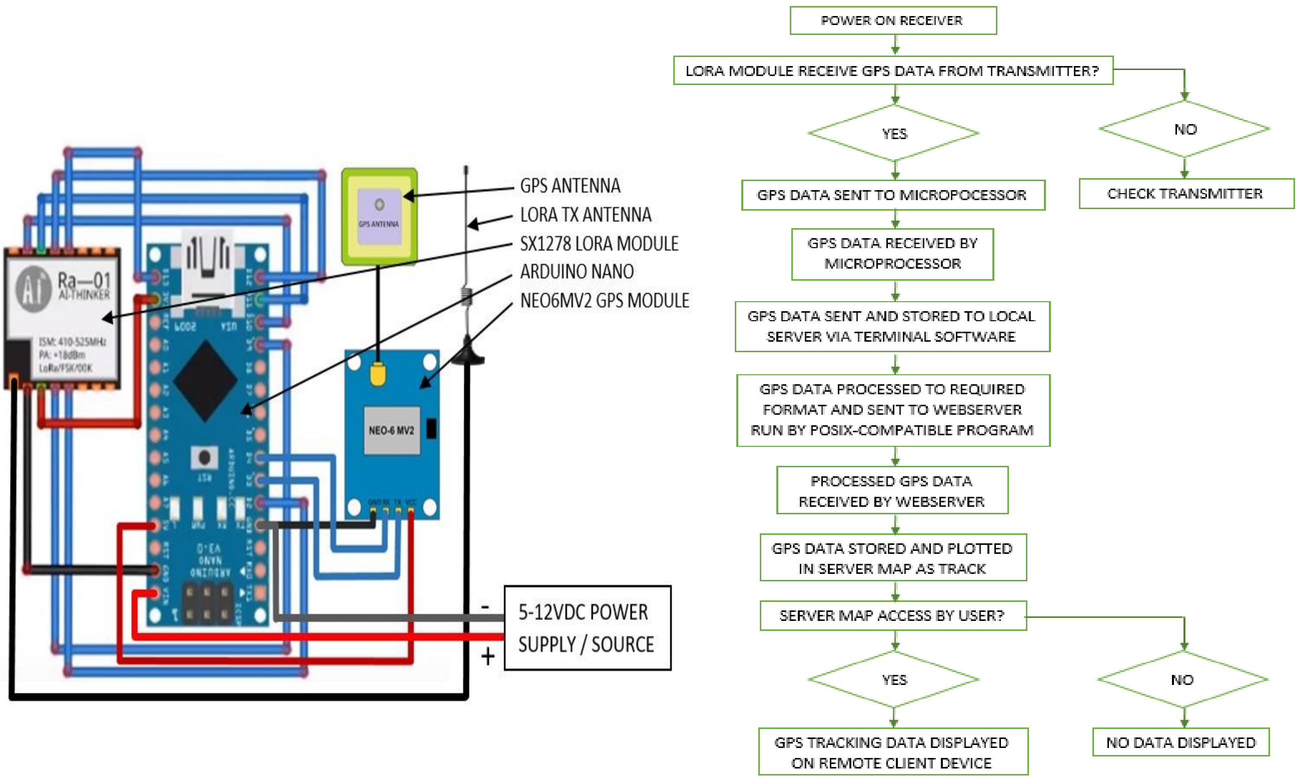


(a). Circuitry connection. (b). Flow chart of the coded computer in the Arduino

Figure 1. FindXTech transmitter module.

The Receiver

At the receiver's end, the Lat-Long coordinates, time stamp and transmitter ID are received by the secondary LoRa via receiving antenna which are captured by the Arduino Nano microcontroller where at the same time channeled the required power to LoRa chip. The Arduino Nano microcontroller is connected to a local server personal computer with local area network access where the microcontroller fed Lat-Long coordinates, time stamp and transmitter ID of the primary LoRa. The microcontroller runs a program that consists of custom coding which allows it to integrate with the receiver LoRa module and configure the output data to the local server. The Lat-Long data are integrated into a map to display the transmitter's location whereas the sending time and RSSI are stored for analysis purpose when required. Fig. 2(a) shows the schematic diagram of the transmitter of the FindXTech system, and the algorithm that takes place in the receiver is shown in Fig. 2(b).



(a). Circuitry connection. (b). Flow chart of the coded computer program.

Figure 2. FindXTech receiver module. (a) (b).

Enabling Tracking of Movement Over Internet

The data from the transmitter acquired by the local server from FindXTech receiver via USB port using a Terminal Emulation Software. These data are first stored in a specific folder on the local server. These data are then retrieved and prepared to be sent to cloud web server using a script written in a C++ programming language and executed under POSIX environment. The data was made into HTTP message format and uploaded to the web-server over internet connection with the assistance of the HTTP file retrieve software. The software authentication retrieval was performed in the form of HTTP feedback or response from the FindXTech tracking system web server, before able to transmit or upload the time stamps, GPS data and transmitter ID with HTTP format to the web server. If the HTTP files retrieval fail, means no response received from the web server, and the processed data will not be uploaded.

A third-party web server used in this project allows quick access for remote users or clients with internet access for monitoring the movement of their subject. In this web server, the HTTP format data received from the local server is stored in the MySQL database. This includes FindXTech transmitter identification number (ID), lat-long coordinates, sending date and time, and also the IP address of the local server. Using the data stored in MySQL database, FindXTech tracking system website is used to display the location, time and ID data of the transmitter in the in the form of plotting on a map. The map display linked to the system was developed using OpenStreetMap that is free and open-source, and accessible to any authorized personnel or can be made with open access option suits to the tracking purpose.

There are three main script segments that are written in the web server, each with its own function. The first script segment is for the data input that enables the data received to be stored in the MySQL database. The second script segment is function to arrange the map layout, to display the map and map functions, and to display symbols or character on the map. In order to display the tracking object information on the map, the third script segment was written and its function is to read the transmitter's Lat-Long coordinates, time stamp and ID, and print it on the map at the right point. The third segment is basically to plot out the location of the transmitter with ID and time information on the linked OpenStreetMap's map. With the execution of the three main script segments, it enables the data sent from the local server to the web server to be received, stored and displayed on the FindXTech tracking system web. Fig. 3 shows the integrated web display of the FindXTech tracking system. Clients and remote users of the FindXTech tracking system can access the location information of their transmitter from anywhere as long there is internet connection. Any device with web browsing platform should be able to connect to the FindXTech tracking system web, via computers or smart mobile phones. For clarity, the overview of the FindXTech movement tracking system is summarized in Fig. 4.

Figure 3. Web display of the FindXTech tracking system (Map data © OpenStreetMap contributors, CC BY-SA).

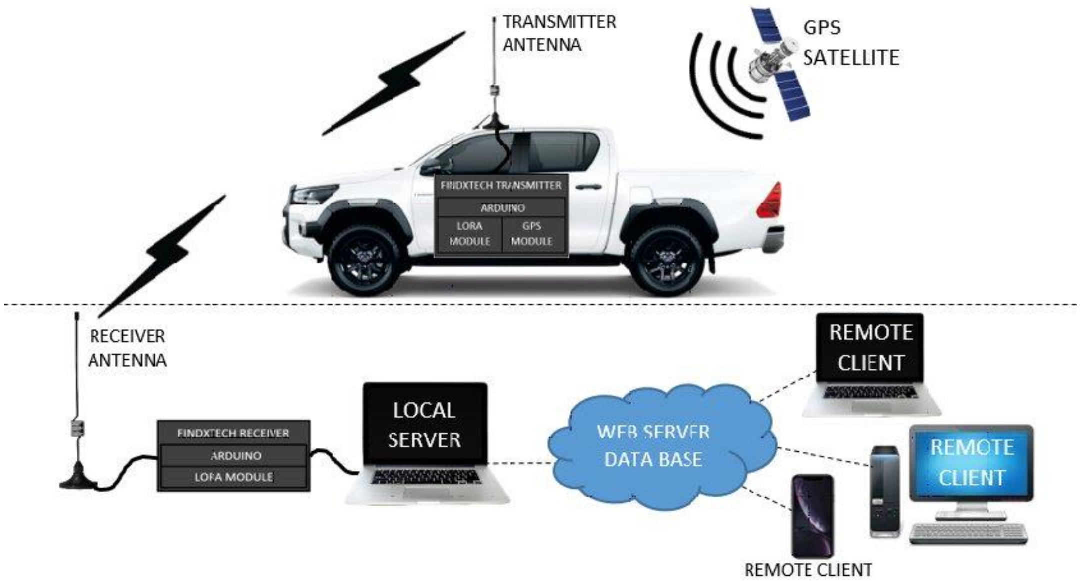


Figure 4. Overview of the FindXTech movement tracking system.

FindXTech Tracking System Testing

The current FindXTech movement tracking system was meant to be used in a particular city. For this reason, a series of test was carried out within the area of Kota Kinabalu City. Kota Kinabalu is the capital city of the State of Sabah, one of the founding States of the Federation of Malaysia located on the northern part of Borneo Island.

A Toyota Hilux was used as an object for this movement tracking that is driven in a different driving conditions and speeds. The FindXTech transmitter module was placed inside the vehicle whereas the antenna was placed outside to ensure no direct obstacle by the vehicle to the radio frequency signal transmission. On the other hand, the FindXTech receiver was placed strategically on a hill within 5 kilometers from the furthest test sites and is approximately 100 meters higher than the surrounding lowlands and the test sites. This is to provide as much as possible line of sight between the test sites and the receiver. Fig. 5 shows the transmitter and antenna placement on the moving Toyota Hilux whereas Fig. 6 shows the test sites in reference to the point location of the receiver. The receiver is connected to the local server that is connected to internet all the time during the tests, and the movement of the Toyota Hilux was monitored on a smart mobile phone connected to the FindXTech tracking website.

(a). Transmitter's antenna (b) The transmitter module

Figure 5. FindXTech transmitter system placed on a moving Toyota Hilux during test.

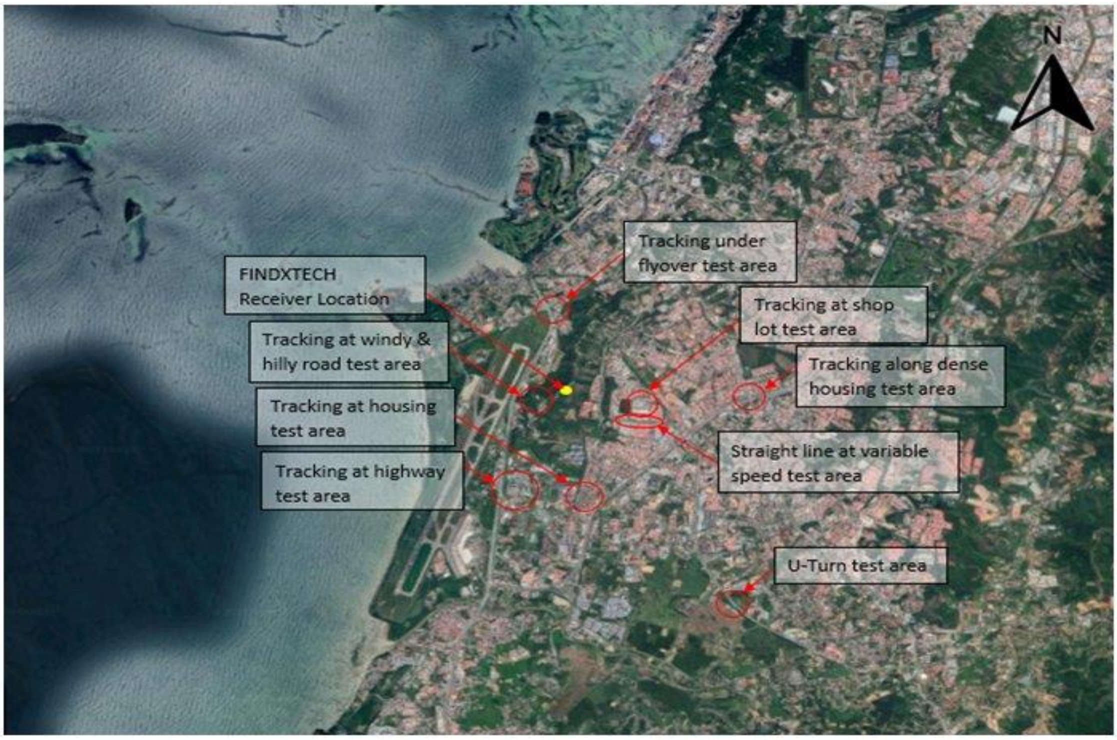


Figure 6. Geographical impression of the FindXTech tracking system test sites in Kota Kinabalu City area. (Map data © OpenStreetMap contributors, CC BY-SA).

RESULTS AND DISCUSSION

As previously mentioned, a series of test was conducted with a Toyota Hilux as an object for this movement tracking that is driven on a different road condition and driving speeds. The test conditions and the results are discussed in this section.

Movement on a Straight Line at Different Speeds

The vehicle was driven at about 1 kilometer away from the receiver at different speed of 50 km/h, 60 km/h and 70km/h and the FindXTech transmitter was set to send GPS location to the receiver every second. This test was carried out to investigate if there is any abnormality in the point location shown on the map at a different speed on a straight road. Fig. 7 shows the location of the vehicle on the map at the selected speed. It can be seen that the interval between locations is quite irregular. However, this is mainly due to difficulties in maintaining the exact speed selected for the test. In addition, irregular pattern of obstacles by buildings and vegetations between the transmitter and the receiver may also contribute to this.

From the data shown in Fig. 7, the average distance between locations of point detection were calculated for each speed. It was found that when the vehicle was driven at the speed of 50 km/h, the average distance between detection points is around 54.20 meters as shown in Fig. 7(a). At the speed of 60 km/h (Fig. 7(b)), the average distance was around 75.53 meters and at 70 km/h, the average distance was 107.52 meters apart (Fig. 7(c)). This shows that although the distance between points of detection were not uniform, the overall detection capability was acceptable as the average distance between detection points is proportional to the speed of the object as expected.

Figure 7. Location of point detection on straight road test for object that moving at different speed. (a) At 50 km/h. (b). At 60 km/h. (c). At 70 km/h. (Map data © OpenStreetMap contributors, CC BY-SA).

U-Turn Tracking Test

A good tracking system must not only be able to track an object on a straight line, but also on corners and turns. For this reason, a set of tests were conducted on the FindXTech tracking system on a U-turn road. The hardware set up for this test similar with the previous but at approximately 3.7 km from the FindXTech receiver. The speed of the car upon entering the turn is depending to the traffic conditions during the test, and ranging from 30 km/h to 50 km/h.

Fig. 8 shows the point of detection on the map for the U-Turn test. Similar to the previous test on a straight road, the distance between points of detection was also inconsistence. This is due to the traffic condition where the test car required to queue up for the turn causing the test car to decelerate and accelerate randomly. However, as it can be seen on Fig. 8 that all test shows a continuous detection before and after the U-Turns.

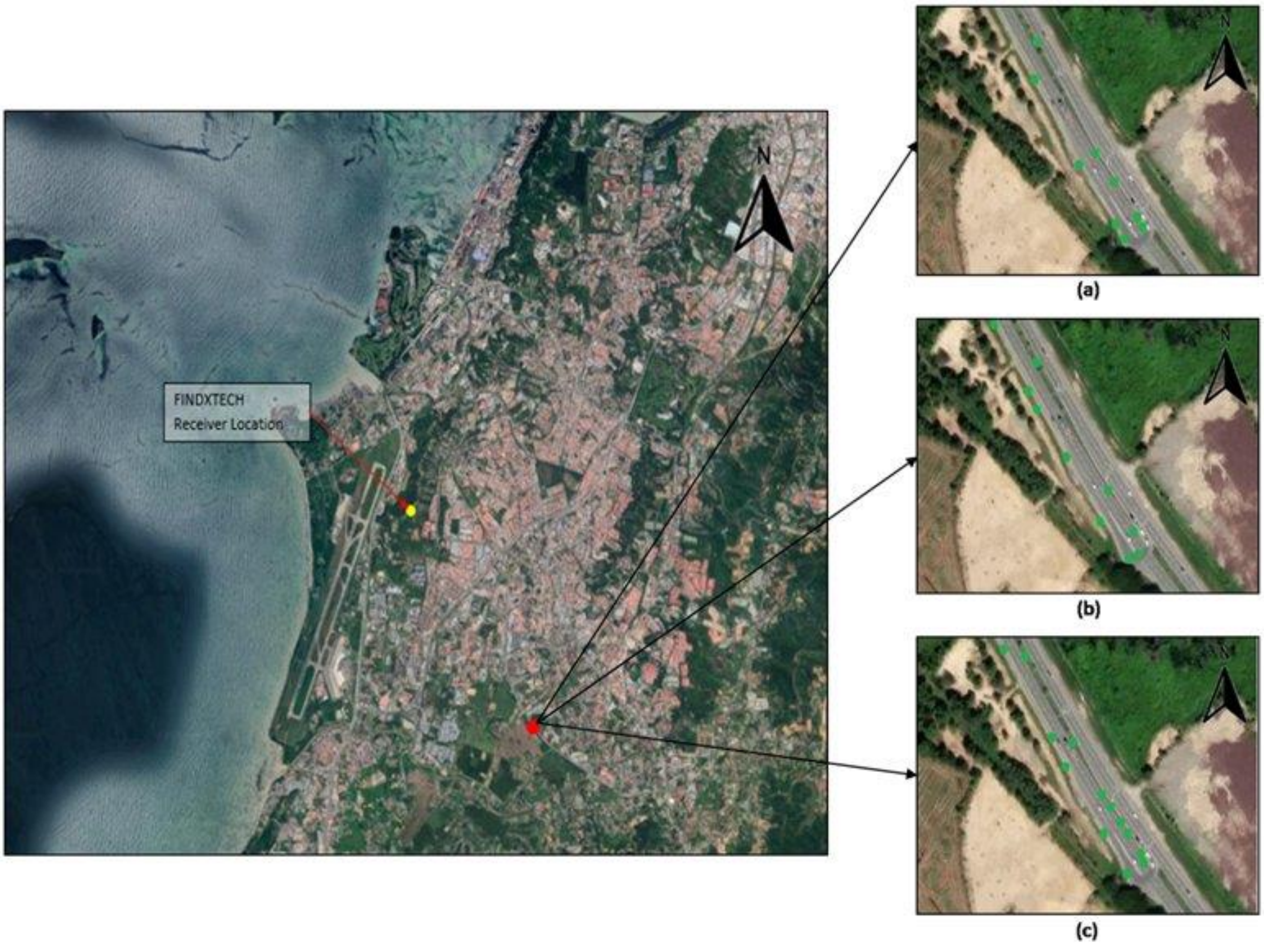


Figure 8. U-Turn drive test. (a) Test 1. (b). Test 2. (c). Test 3. (Map data © OpenStreetMap contributors, CC BY-SA).

Continuous Driving Location-tracking Test

The previous tests have shown that FindXTech tracking system is capable of smoothly showing the vehicle location on a straight and U-Turn road driven at different speed. The vehicle with FindXTech tracking system was then driven continuously around town including residential areas, shop lots, hilly and winding roads for an hour up to 5 km away from the receiver. This is to simulate actual tracking situation for a vehicle as the tracking subject. Fig. 9 shows that the FindXTech tracking system could clearly indicate the location of the vehicle hilly and winding road (Fig. 9(a)), when the vehicle is driven under flyover road (Fig. 9(b)), in a housing area (Fig. 9(c) and 9(e)), in a shop lots area (Fig. 9(d)), and also on a highway road (Fig. 9(f)). Detail examination on each road condition shows that FindXTech tracking system continuously showing the location of the vehicle and the pattern of the point detection matched the speed of the car that depending on the traffic conditions and turns.

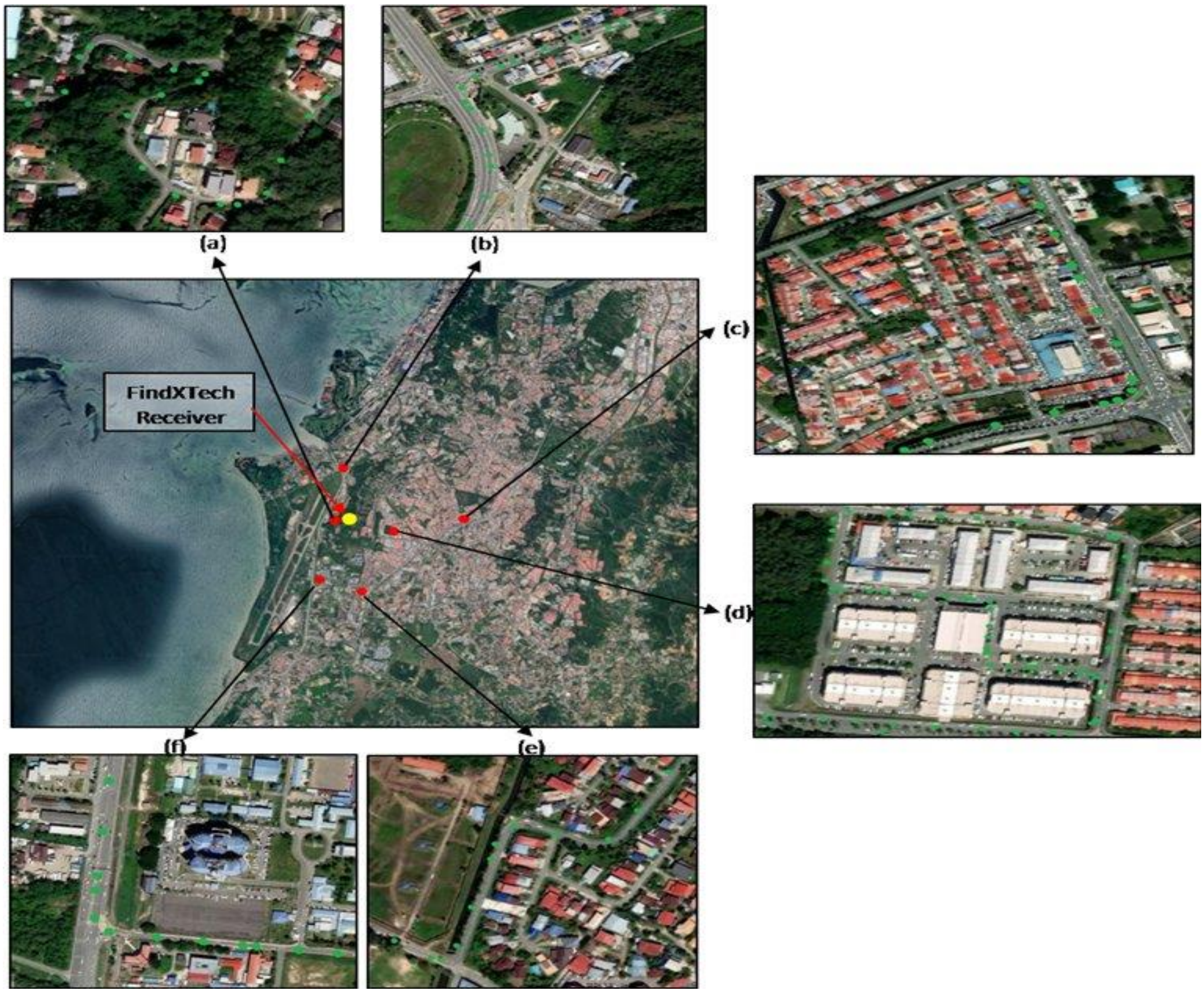


Figure 9. Location detection at selected area for continuous driving test. (a). At hilly and winding road area. (b). Under flyover. (c). In a dense housing area. (d). In shop lots area. (e). In a normal housing area. (f). On a highway road. (Map data © OpenStreetMap contributors, CC BY-SA).

Fig. 10 shows the whole location detection for the whole continuous driving test. It can be seen that the vehicle could be detected by the FindXTech tracking system on over 90% of the route taken. However, there are two blind spots area experienced by the tracking system during the test shown as spot A and B in Fig. 10(a). Detail examination of their blind spots indicate that the signal transmission from the FindXTech transmitter was completely blocked by obstacles between the transmitter and the receiver. This is clearly shown by the line-of-sight analysis between the two points in Fig. 10(b) for blind spot A and Fig. 10(b) for blind spot B. Both areas were separated from the receiver by elevated land, and thus signals from the FindXTech transmitter could not be registered by the receiver of the system.

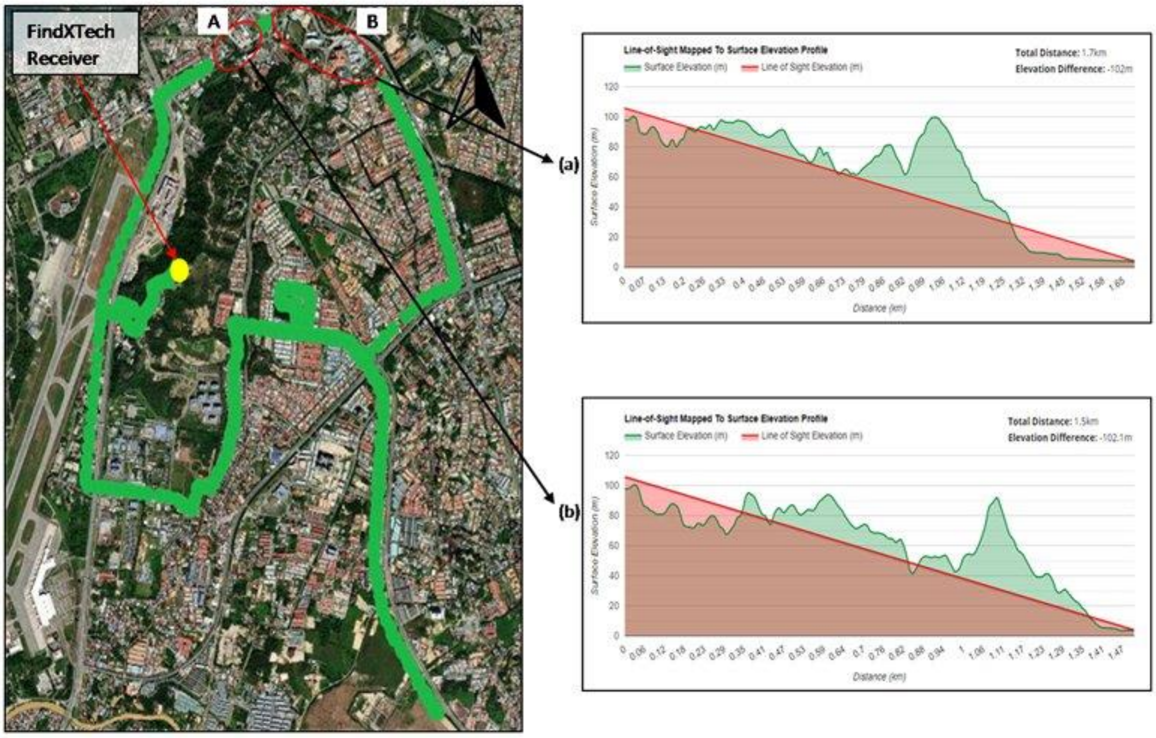


Figure 10. Detection and blind spot for continuous driving test. Two blind spots shown A and B in the figure were experienced during the continuous driving test. (a). Line of sight analysis for blind spot B. (b). Line of sight analysis for blind spot A. (Map data © OpenStreetMap contributors, CC BY-SA).

CONCLUSION

In this paper, a long-range tracking system known as FindXTech was designed, fabricated and tested. The system uses a simplified and autonomous system which is based on point-to-point long range or LoRa communication module between object of interest and the base station where the receiver was placed. The base station was connected to a web server that enables users or clients to monitor the movement of their object where the transmitter was attached. To the authors' knowledge, the actual tracking system reported in this paper was with the longest distance between the moving object and the receiver which is up to 5 km apart. It was shown that the FindXTech tracking system was capable of detecting the movement of a vehicle as an object in most road conditions. This paper has shown that an autonomous tracking system that is independent from third-party telecommunication company, such as this FindXTech, is capable of monitoring of an object locality over a long distance, yet the system is much simpler compared to other tracking systems in the market. This is made possible with the help of the low power long range transmitter that enable a simple point-to-point communication between the transmitter and the receiver. However, some difficulties in object tracking have occurred in areas with heavy obstructions especially by elevated land. In such situation, relay transceivers could be needed to ensure continuous detection in the known blind spot areas that adds relay nodes, which effectively improves the coverage of the FindXTech tracking system.

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