

Develop 3D Map Signal Strength Surveying System for Cellular Mobile Phone

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Abstract— The purpose of this research is to develop a 3D map signal strength surveying system for cellular mobile phone. Currently, the traditional cellular signal surveying is generally done by walking or driving while carrying the measurement device which greatly limited the surveying area. The survey in this research uses new method, by using a 250mm quadcopter with an application-installed mobile phone, so it can easily measure the signal strength. The application on the mobile phone is used to measure the signal strength, latitude/longitude coordinate and timestamp, send it to the server via cellular network in real-time, and also store it into local database. The quadcopter also has a barometer and GPS (global positioning system) installed. This information can be accessed by GCS (ground control station) via radio link. This system uses information from both mobile phone and GCS, display it in form of 3D signal strength map that will benefit for quality of service of cellular mobile networks.

Keywords— signal strength, 3D survey, cellular, urban cellular, signal strength surveying

I. INTRODUCTION

It is an undeniable fact that communication is essential for human. The cellular network is one of the primary methods of communication. The quality of cellular network service is determined by the cellular signal strength. So the cellular service providers need to gather the data about signal strength constantly to maintain the quality of service. One of the methods to gather the data about signal strength is the 3D signal propagation simulation. To make the signal propagation data more reliable, site surveying is also important. Because site surveying can also detect the weak signal area in the actual environment.

There is a demonstration of the traditional site surveying in the research named “Mobile Real-Time Information System for Snow Fighter Supervisors - System Design & Test” [5]. This research clearly shows the limitation of site surveying. The surveying is done by carrying a measurement device and driving or walking to the designated position [1], which means measurement by human cannot measure the signal strength in the aerial space between the buildings. If there is a way to carrying a measurement device more freely. The surveying between buildings is going to be easier than traditional way.

Aerial surveying is going to make the planning for signal coverage area more practical, and also enhance the service quality and enable new services such as using drone via cellular network and provide more reliable network to support IoT (internet of things) technology. Some IoT devices and drones usually stay in the air and need a reliable network to maintain the connection. Which means live streaming or video broadcasting from drone is more reliable and also fundamental for many more technologies in the future.

The research named “Aerial Sensing and Characterization of Three-Dimensional RF Fields” [6] proposed the method of aerial surveying by drone. The limitation of this research is the surveying which can measure one radio frequency at the time which can be selected. But the new model of mobile phone enables the usage of different radio frequency simultaneously so our research used the signal strength measured by mobile phone instead.

From the mentioned problems and limitations above, this research presents a problem-solving method by using a 250mm quadcopter, mounted with an application-installed mobile phone, to survey the signal strength in the air, and send a set of data in a specific interval back to the server. A set of data consists of signal strength in dBm and bars, signal technology type, latitude, longitude, altitude and GPS variance rate. This information can be processed into a three dimensional (3D) signal strength map, and use this map for signal quality improvement planning.

II. AERIAL CELLULAR SIGNAL SURVEYING BY QUADCOPTER

The aerial surveying is done by attaching the smartphone with the quadcopter and fly in the specific route and altitude and send a set of data to the server with a specific interval. The smartphone which is attached with quadcopter must installed with an application for sending data to the server. The smartphone also need to contain 3 following features, the first one is the cellular signal strength measurement, the second is the fine positioning such as GPS, and the third is the Internet access. Next is the server, which is used to collect the sets of data from the smartphone and also has a webpage for input data

monitoring. The last is the quadcopter used to carry the smartphone.



Fig. 1 Measuring signal strength at 10 meters above the ground and controlling with LOS and FPV at Thai-Nichi Institute of Technology, Bangkok, Thailand



Fig. 2 The quadcopter with the smartphone



Fig. 3 The quadcopter controlling by using FPV

In this aerial surveying prototype, we used LOS (line of sight) and FPV (first person view) to control the quadcopter for safety purpose. The aerial surveying prototype controlling by using LOS and FPV is showed in Fig. 1.

A. Tools Specifications

- 250mm quadcopter with CC3D revolution flight controller. The quadcopter also includes ESC (electronic speed controller), RC (radio controller) receiver, FPV video transmitter and a camera. The quadcopter also need to have the capability to carry a smartphone. The quadcopter and the smartphone are showed in Fig. 2 and the FPV in action is showed in Fig. 3.
- Android smartphone with the ability to locate the fine position. The smartphone also needs to install the application and has the internet access.

| Signal Level | Bars | Type | Latitude | Longitude | Altitude | Log Time |
|--------------|------|------|------------|-------------|----------|------------|
| -97 | 3 | LTE | 13.7377083 | 100.6287516 | 7.7 | 1458794808 |
| -97 | 3 | LTE | 13.7377083 | 100.6287516 | 7.7 | 1458794810 |
| -97 | 3 | LTE | 13.7377083 | 100.6287516 | 7.7 | 1458794812 |
| -97 | 3 | LTE | 13.7377083 | 100.6287516 | 7.7 | 1458794814 |
| -97 | 3 | LTE | 13.7377083 | 100.6287516 | 7.7 | 1458794816 |
| -97 | 3 | LTE | 13.7377083 | 100.6287516 | 7.7 | 1458794818 |
| -97 | 3 | LTE | 13.7377083 | 100.6287516 | 7.7 | 1458794820 |
| -97 | 3 | LTE | 13.7377083 | 100.6287516 | 7.7 | 1458794822 |
| -97 | 3 | LTE | 13.7377083 | 100.6287516 | 7.7 | 1458794824 |
| -97 | 3 | LTE | 13.7377083 | 100.6287516 | 7.7 | 1458794826 |

Fig. 4 Web-based server data monitor page

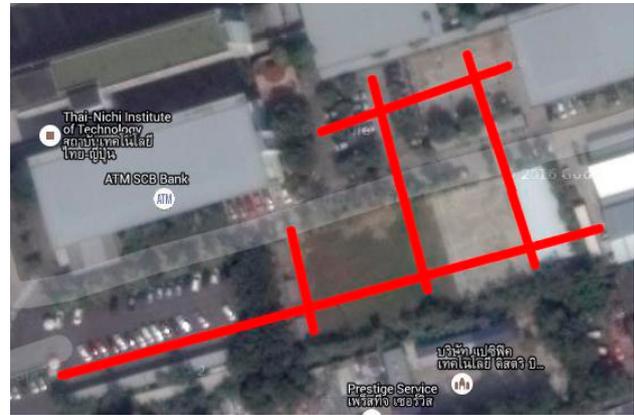


Fig. 5 The aerial surveying route

- The server with the data-receiver software installed.
- Monitoring tool, a device that has an internet access and supports the interactive website to monitor the data on the server. The data monitoring page is showed in Fig. 4.

B. Planning

The aerial surveying route is selected by the population and potential obstacles in the area on the period of surveying. We avoid to fly the quadcopter over the crowd and we also avoid to go near the building or personal asset for safety purpose. The distance between each route should have at least 10 meters to make the waypoint distinguishable. The aerial surveying prototype fly at 2.5 meters, 3.5 meters, 5 meters, 10 meters and 15 meters altitude in each route. The aerial surveying route is showed in Fig. 5.

C. Preparation

For the prototype system there are 7 steps.

- Specify the area, route and altitude.
- Prepare the quadcopter, a controller and a measurement smartphone.
- Check the status of the server. Attach a measurement smartphone to the quadcopter.
- Control the quadcopter to fly along the planed route and record the altitude according to flight controller. The altitude also used to refer to the record number or the record timestamp.
- Filter the data get from the previous step for plotting graphs. We filtered the data because the smartphone starts collecting data before the quadcopter starts the flight.

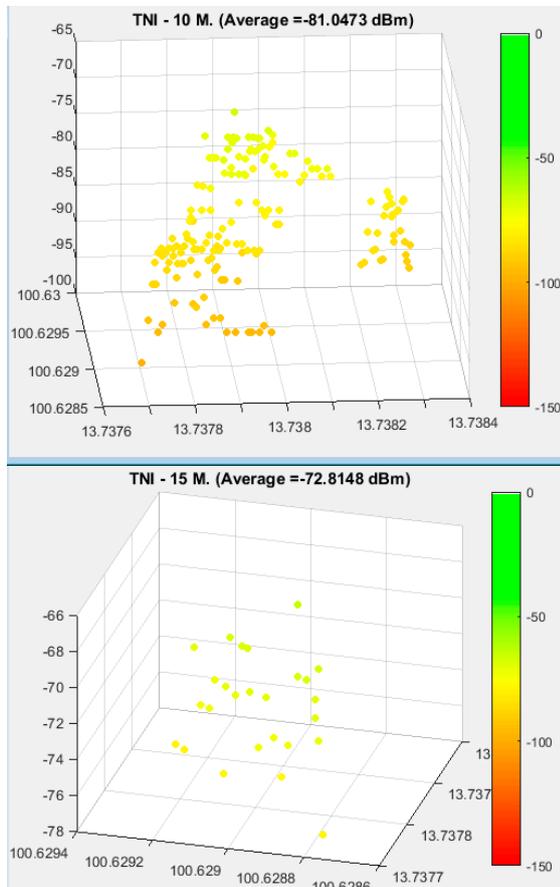


Fig. 6 Single Altitude Scatter Graphs with average signal strength in dBm at the 10 meters altitude and 15 meters altitude.

We also replace the altitude values from GPS with the altitude values from GCS.

- After filtered data in previous step. This step use that data to create the 3D colored scatter graph and 3D surface graph by using MATLAB.

After the aerial surveying, we produce the 3D graph. Start by fetching the data from the server and filter them. Because we need to start the application on smartphone before the quadcopter start the flight. Even after took off, the quadcopter still needs some time to reach the planned altitude. Sometimes the quadcopter is stray from the route because of the gust. There is another problem about mobile GPS measurement [2] which has less precision compared to the altitude measurement from the barometer which is included with the flight controller [3]. The flight controller we used is the CC3D revolution model which has the built-in altitude measurement equipment. We got the altitude value from the flight controller through the ground control station. So we replace altitude value from GPS with the altitude value from the flight controller.

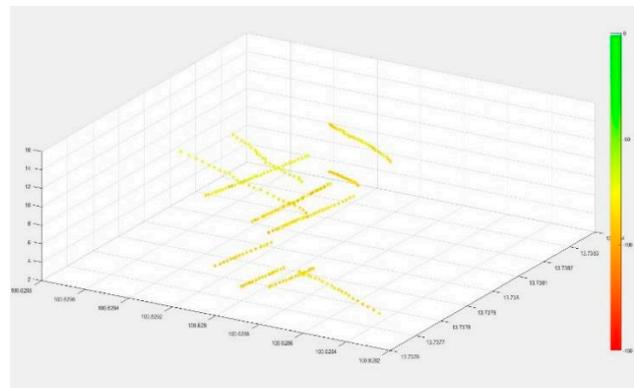


Fig. 7 Multi Altitude Scatter Graph of the Aerial Surveying

III. CELLULAR SIGNAL MEASUREMENT RESULT

In the last step, we split the filtered data into 2 sets. The first one is the original set of data. The another one is the set of data which is calculated by average the value with the nearby cell. The original data is used to plot the 3D scatter graph. And the calculated data is used to plot the 3D surface graph. Both of the graph use the same color scale which contains 152 colors.

The scatter graph is divided by the display into 2 types

- Single altitude scatter graph showed the positions of the collected data by using latitude, longitude to plot the points on the graph. This graph preset with a specific altitude. The signal strength is showed by using z-axis and colors, the color range is showed on the right side of the graph. Single altitude scatter graphs with average signal strength divided by altitude is showed in Fig. 6.
- Multi altitude scatter graph showed the positions of the collected data by using latitude, longitude and altitude to plot the points on the graph. The signal strength is showed by using colors, the color range is showed on the right side of the graph. From the color range, green color represent high signal strength and red color represent weak signal strength as shown is Fig. 7.

The surface graph is also divided by the display into 2 types

- Single altitude surface graph showed the positions of the collected data by using latitude, longitude to plot the points on the graph. This graph preset with a specific altitude. The signal strength is showed by using z-axis and colors, the color range is showed on the right side of the graph. The graphs are showed in Fig. 8.
- Multi altitude surface graph showed the positions of the collected data by using latitude, longitude and altitude to plot the points on the graph. The signal strength is showed by using colors, the color range is showed on the right side of the graph. The graph is showed in Fig. 9.

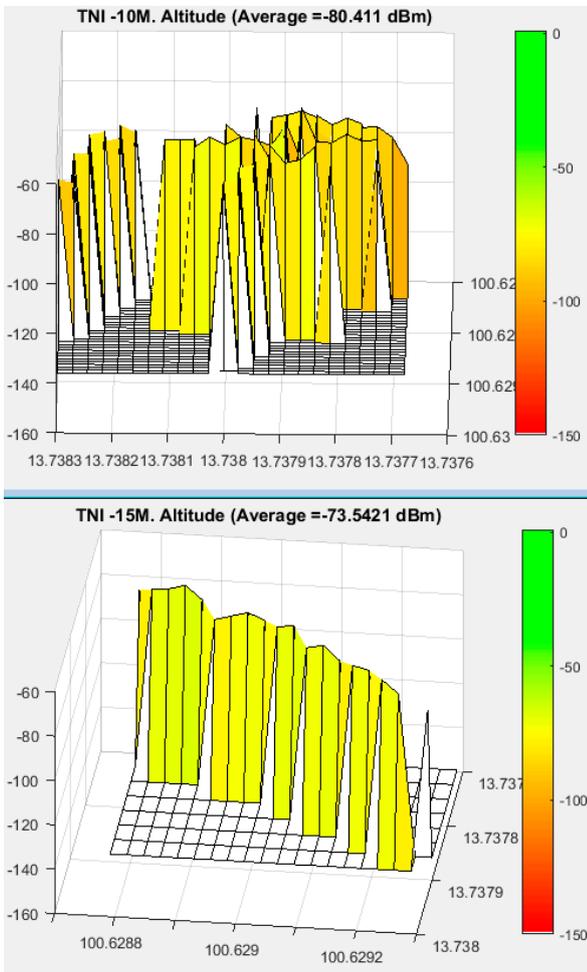


Fig. 8 Single Altitude Surface Graphs with average signal strength in dBm divided by altitude

Fig. 6 shows signal strength at the 10 meters altitude. At the same altitude the measured signal strength changed constantly because of fading channel in the urban area.

Fig. 7 shows the signal strength at multi altitude for analyzing the signal strength in the area. This graph also shows the scattering of the ununiformed signal strength.

The result of the aerial surveying shows that the higher altitude has better average signal strength which is showed in Fig. 8. At the 15 meters altitude has the signal strength of -72.8148 dBm and the 2.5 meters altitude has the signal strength of -86.2941 dBm.

From the prototype of aerial surveying system, there is a flaw which is about maintaining the drone course. It's an inevitable problem because we manually control the quadcopter for safety purpose. And there is an another problem with the altitude which we need to replace its value manually. The drone with greater safety measure such as DJI Phantom 4 [4] is going to make the aerial surveying much more convenient because it has an auto-pilot feature that can fly to the waypoint with steady speed and also avoid obstacles automatically.

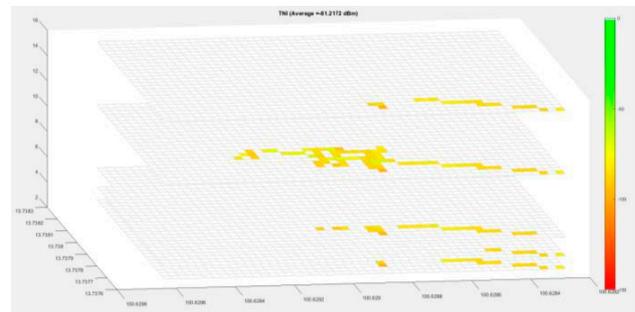


Fig. 9 Multi Altitude Surface Graph of the Aerial Surveying

IV. CONCLUSIONS

This paper developed a 3D map signal strength surveying system for cellular mobile phone in urban area by using the quadcopter. This paper proposes the aerial surveying system. The result of the surveying is satisfying. We got the 3D graphs as we planned, and this aerial surveying can be used to verify and adjust the cellular network to improve the network performance. The improvement of cellular network also increases the capability to support the smartphone and the IoT.

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