

Integrated Outdoor and Indoor Tracking Through GPS, LTE and Wi-Fi Solution

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1. Introduction

Nowadays, the outdoor tracking system that utilizes the GPS signal become a common technology. A GPS Navigator System is a must have gadget to a driver as it helps to navigate driver to any places easily. On the other side, an indoor location is becoming more important to help us navigate especially in a wide building with multi floors spaces. Here, the main challenges is the fact that inside a buildings a GPS signal is not that strong to operate [1]. However, this limitation may be overcome if Wi-fi signal which is commonly available in a closed area and supported by cellular signals can perform similar operation as GPS signal. Cellular signals or to be specific is the Long-Term Evolution (LTE) signal and WI-FI signal can be analyzed to perform estimation for indoor tracking [2]. This chapter explains about the proposed outdoor and indoor tracking system to estimation location of stationary and mobile objects in the open terrain as well as inside a building by utilizing GPS signal, cellular signal and WiFi signal. The accuracy of the system is found within 5 m and 2 m range for outdoor and indoor environment respectively. The estimation of the location is uploaded to cloud based platform, ThingSpeak. In this proposed system, we are utilizing the Motorola board known as M-WiCom platform, act as the key component and able to upload the estimated location in a cloud platform, ThingSpeak. The workability of the system is evaluated by conducting few experiments in UTHM campus area.

2. Development of Outdoor and Indoor Tracking System

This section presents the architecture of proposed system as shown in Figure 1. The M-WiCoM platform consist of Beaglebone Black Module to communicate with two parts, the first part is associate to outdoor tracking and the second part is mean for indoor tracking. For outdoor part, the Beaglebone Black Module have been connected to the Qualcomm LTE-GPS chipset (Sierra Wireless module) with SIM Card slot. For indoor part, The M-WiCom has communicated with the Arduino ESP8266 NodeMCU Lua WIFI Controller Board V3 (with FC Certification) module via the UART pins. To monitor the output of the proposed system in real time, the board is connected to a laptop as shown in Figure 2.

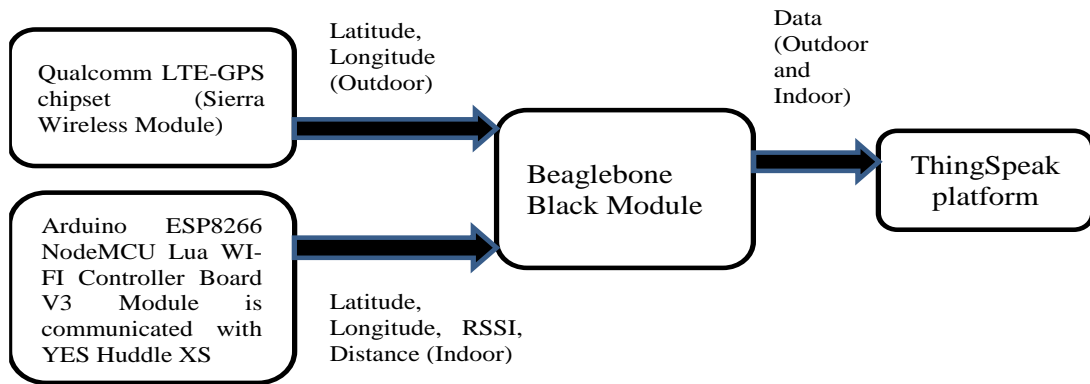


Fig. 1 - System block diagram

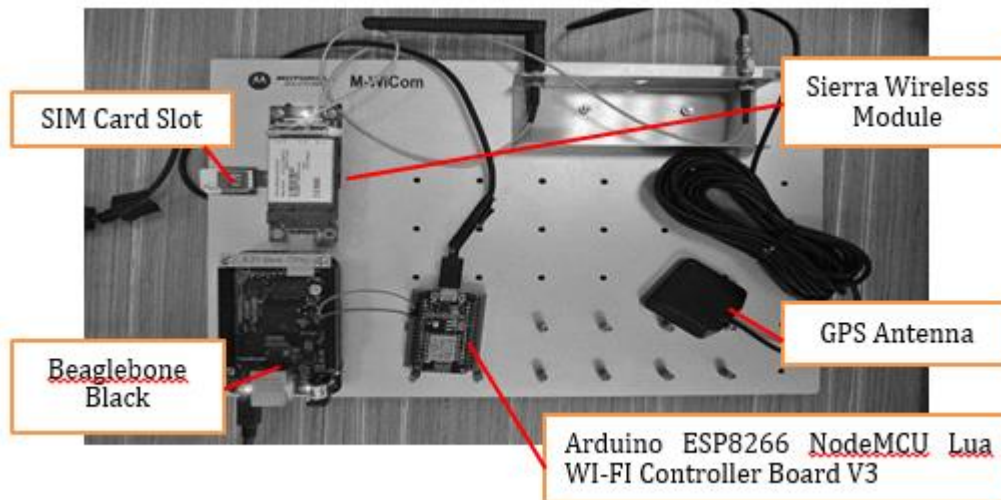


Fig. 2 - Development of board

3. Operation in Outdoor Tracking

The GPS receiver identifies the prototype location and sends the data to the BeagleBone Black module. The raw GPS data is then uploaded to the cloud platform, ThingSpeak, through an LTE connection in real time. The outdoor latitude and longitude of the prototype are displayed on the ThingSpeak Platform. The experiment is conducted by taking measurements at three fixed checkpoints around UTHM's area: 1) Checkpoint 1: Faculty of Electronic and Electric Engineering, Block Q; 2) Checkpoint 2: Faculty of Civil and Environmental Engineering (FKAAS); Checkpoint 3: Faculty of Technical and Vocational Education (FPTV). The locations of all three checkpoints along the route are marked in red dotted lines in Figure 3 (a). The readings from the stopwatch for the time taken to read the serial monitor (Linux Software) and upload the data to the ThingSpeak Platform are recorded to demonstrate system functionality and accuracy.

The prototype is placed on the dashboard in a car during the testing, as shown in Figure 3 (b). Real-time data on latitude and longitude is collected as soon as the car starts to move. The stopwatch is started to calculate the processing time taken by the prototype to upload the GPS data into the ThingSpeak Platform.

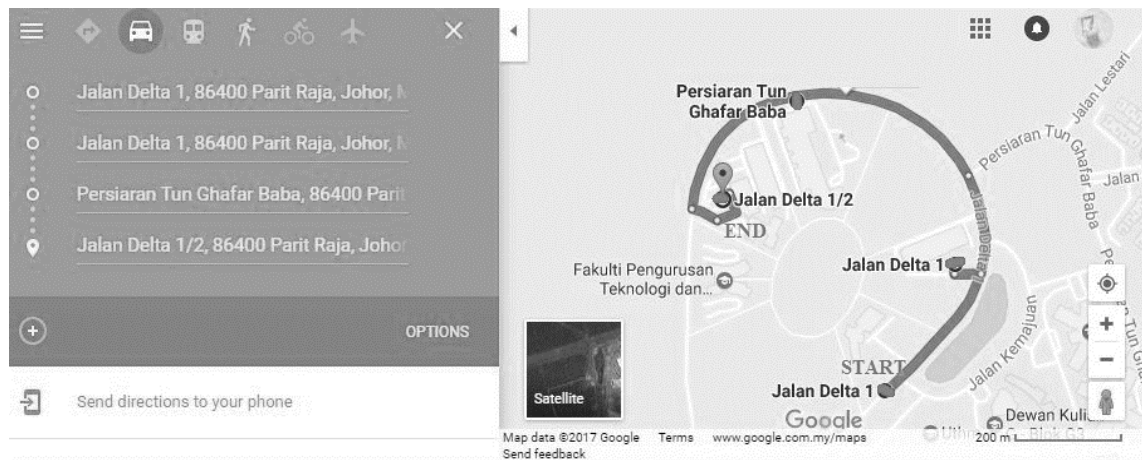


Fig. 3 - (a) Site testing areas for outdoor

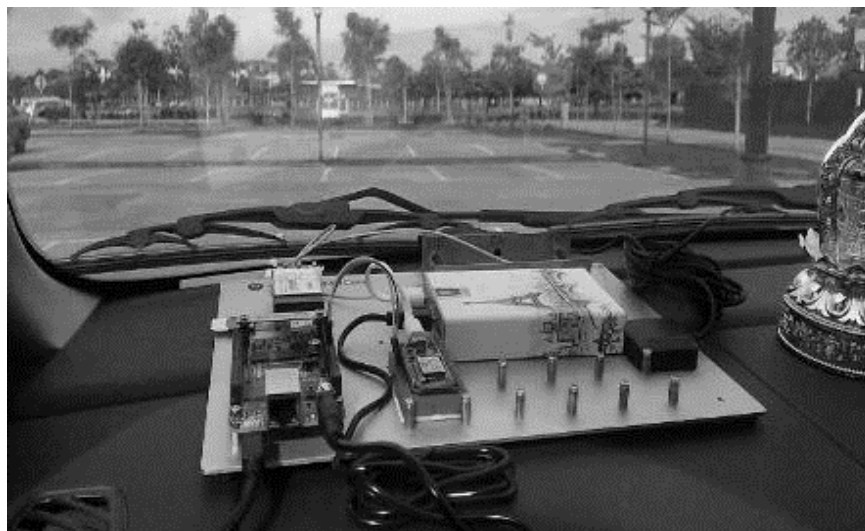


Fig. 3 - (b) Prototype placed on bus dashboard

Figure 4 show the current latitude and longitude as the car move from Checkpoint 1 to Checkpoint 2 and Checkpoint 3. The black dotted point are representing to position of each checkpoint.

Table 1 - Comparison between the latitude and longitude of the real location and the latitude and longitude of ThingSpeak Platform

Checkpoint	ThingSpeak Platform		Actual location (latitude, longitude)	Difference Distance, km
	Latitude	Longitude		
1	1.86147	103.0860	1.861502,103.085973	0.004655
2	1.86421	103.08328	1.864219,103.083287	0.001268
3	1.8626	103.082	1.862608,103.081979	0.002498

4. Operation in Indoor Tracking

Arduino IDE and Python code is mainly utilized for indoor tracking system. Arduino ESP8266 NodeMCU Lua WI-FI Controller Board V3 module is connected with Yes Huddle XS and supported by Google Map Geolocation API to detect the indoor latitude and longitude. In initial setup, the average signal propagation exponent, n need to be calibrated by referring to the equation (1) [3]:

$$RSSI = - (10n \log_{10} d + A) \quad (1)$$

Where n is the signal propagation constant or exponent, d is the distance from sender and A is received signal strength at 1 meter distance. In initial experiments, the RSSI for each distance is measured to calculate the average n . The prototype is tested in the G3 classroom and Level 3 of Tunku Tun Aminah Library, UTHM as shown in the Figure 5. The average n is recorded for this two locations before taking the results of the estimated distance between Yes Huddle XS and prototype. At the same time Beaglebone Black reads the data from the Arduino IDE and send the data to ThingSpeak via Python code.



Fig. 5 - (a) G3 classroom UTHM; (b) level 3 of Tunku Tun Aminah Library, UTHM

The prototype is tested to gather estimated distance between the Yes Huddle XS and prototype. The data is measured at position 2 m, 3 m, 4 m and 5 m. The latitude and longitude for G3 classroom and Level 3 of Tunku Tun Aminah Library, UTHM and RSSI is recorded for every sample distance. The reading is taken for five times at each distance to get the accurate data. If it found that the average latitude for the G3 classroom is between 1.858690 until 1.858725 whereas the average longitude is between 103.086800 until 103.086806. Besides, the average latitude of Level 3 of Tunku Tun Aminah Library, UTHM is within 1.857300 to 1.857330, whereas the longitude is within 103.081890 until 103.081905.

Table 2 depicts the comparison between the actual location and average location gathered by prototype for all distance. It is shown that accuracy of the average indoor location is within 2 m. For the G3 Classroom, the average n is obtained as 1.63, 2.02, 2.36 and 1.76 whereas the average n in Level 3 of Tunku Tun Aminah Library, are 1.57, 1.68, 1.89 and 1.55. Table 3 and Table 4 depict the estimated distance and actual distance calculated according to the different values of average n .

Table 2 - Difference distance between real location and average location

Actual distance, m	G3 classroom			Level 3 Tunku Tun Aminah Library		
	<i>Real location</i>	<i>Average location</i>	<i> Real - Average </i>	<i>Real location</i>	<i>Average location</i>	<i> Real - Average </i>
2	1.8587009, 103.0868090	1.858694, 103.086806	0.0008366	1.8573040, 103.0819050	1.857304, 103.081898	0.0007780
3	1.8587100, 103.0868100	1.858710, 103.086804	0.0006668	1.8573140, 103.0819060	1.857310, 103.081918	0.001406
4	1.8587200, 103.0868100	1.858720, 103.086806	0.0004445	1.8573239, 103.0819065	1.857324, 103.081922	0.001723
5	1.8587279, 103.0868100	1.858724, 103.086804	0.0007954	1.8573310, 103.0819065	1.857326, 103.081904	0.0006215

Table 3 - Record results of G3 Classroom UTHM (estimate distance)

Actual Distance, m	Estimated Distance, m					Average Distance, m
	1 st (average n= 1.63)	2 nd (average n= 2.02)	3 rd (average n= 2.36)	4 th (average n= 2.02)	5 th (average n= 1.76)	
2	1.76	1.96	1.96	1.98	2.19	1.92
3	2.71	3.06	3.16	3.12	2.84	3.01
4	3.47	3.83	3.83	3.92	3.69	3.76
5	5.05	4.93	4.75	4.93	4.8	4.92

Table 4 - Record results of the Level 3 of Tunku Tun Aminah Library, UTHM (estimate distance)

Actual Distance, m	Estimated Distance, m					Average Distance, m
	1 st (average n= 1.57)	2 nd (average n= 1.68)	3 rd (average n=1.68)	4 th (average n= 1.89)	5 th (average n= 1.55)	
2	1.87	1.99	1.99	2.08	2.10	1.98
3	3.00	3.00	3.00	2.99	2.83	3.00
4	4.11	3.94	3.94	3.82	3.81	3.95
5	5.63	5.19	5.19	4.87	5.13	5.22

From the results, the average n for the library is below 2 whereas the average n for the G3 classroom is in the range of 1.6 to 2.4. These values are expected because in indoor environment, the signal propagation exponent, n is within 1.6 to 1.8. It is observed that the average n for the library is much lower than the G3 classroom, so does the RSSI. Note that the environment influences the RSSI value and the average n which may be due to signal propagation such as reflection, diffraction and scattering in none or line of sight path. The size area of the G3 classroom is also smaller than the area of the library UTHM and the propagation due to partition may influence the RSSI results. For indoor, the processing time taken to display the indoor data in Linux Software is depending on the speed of the internet connection which is within 30 seconds. Time taken to upload the gathered data to ThingSpeak Platform is within 25 seconds.

5. Conclusion

Here, the development of integrated outdoor and indoor tracking system is presented. The system able to track the location of stationary and mobile objects both in the open terrain and inside a building. The tracking mechanism is build by manipulating signal strength from GPS, LTE and WI-FI signals. For outdoor tracking system, the Motorola Solutions WiCom platform is deployed while for indoor tracking system, Arduino ESP8266 NodeMCU Lua WI-FI Controller Board V3 Module and YES Huddle XS is exploited. The localization in indoor and outdoor environment is uploaded into ThingSpeak Platform through LTE connection. The accuracy of the outdoor tracking and indoor tracking is below 5 m and 2 m respectively. The accuracy of the developed system may be improved by using trilateration method where the average n can be calculated by using combination of three or more routers. The operation also may be extended to cater indoor tracking in multi-level indoor environment.

References

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