

Performance Evaluation of Android Location Service at the Urban Canyon

M.H. PARK*, H.C. KIM**, S.J. LEE*, K.S. BAE***

*ETRI (Electronics and Telecommunications Research Institute), Korea

**OCube Co., LTD, Korea

*** School of Electronics Engineering, Kyungpook National University, Korea

mano@etri.re.kr, hckim@ocube.com, sjlee@etri.re.kr, ksbae@ee.knu.ac.kr

Today smartphone is expected to play a key role in the fast growing LBS market. Many studies have been carried out to develop the LBS service on the smartphone and to evaluate the service quality of the smartphone based location service. However, most of studies focused on the positioning performance not at the urban canyon that is one of the major service target areas but at the general environment. In this paper, we developed a mobile application to test the performance of Android location service and to collect the positioning results as well. We also carried out some experiments to evaluate the quality of the location service and the reliability of GPS and WPS at a dense urban area.

Keywords— LBS, GPS, WPS, Urban Canyon, Location

I. INTRODUCTION

In recent years, as a smartphone has emerged as the most powerful multimedia, multi-functional mobile personal device, the LBS market is expected to be move from the simple navigation oriented services to the ubiquitous and convergence services using more accurate and reliable location information. According to the technology report of IDC, it is estimated that total sales of smartphone to be about 1.2 billion, and 770 million units among them is expected to be a smartphone capable of providing location service via network connection and integrated GPS receiver. Development in LBS technologies makes it possible to provide user with the comprehensive location service by using multiple positioning resources and information, for example multiple GNSS technologies like GPS, GLONASS, Galileo and the hybrid location algorithm and Network based position service like WPS and the PDR algorithm using built-in inertial sensor. In terms of LBS service, it is expected that compositive service like SNS (Social Network Service), AR (Augmented Reality), mobile game, mobile advertisements, and public safety service based on location information will prosper.

Generally, people can have location information from multiple sources like GPS or WPS at the same time. So it is important to provide user the exact performance indicators to take the best service between them or to calculate the appropriate hybrid output with multiple location information.

In this paper, we have carried out experiments to measure positioning performance and to determine the accuracy reliability at urban canyon. We have developed a PositionLogger, test application on Android smartphone to collect the GPS and WPS positioning results and to analyse the characteristics of the location service of Android. The positioning performance is evaluated in terms of accuracy and reliability and these results will be used as a basis for further research to provide more accurate and more reliable location service in urban canyon.

II. LOCATION SERVICE ON ANDROID

A. GPS and WPS

The GPS (Global Positioning System) is one of the most popular worldwide location services and one of GNSS (Global Navigation Satellite System) services that sends and receives a radio signal containing location related information to determine the user location, velocity, time, etc. While GPS can provide a relatively accurate location service and is able to provide a reliable positioning performance outdoor, positioning performance indoors or at urban canyon shows totally different aspects at all. In dense urban environment, positioning quality of the GPS service is so severely degraded due to the attenuation, fading, and multi-path of the signal that users may have a very low-quality location service or receive no location service in some cases. Therefore, it cannot be guaranteed to provide location service of appropriate quality using the GPS at urban canyon.

WPS (WiFi Positioning System) is a location service that calculates the user's position using the WiFi AP (Access Points) information at the server or the terminal side and regarded as a good alternative location service in the shadow area of the GPS service.

However, in order to provide a location service of good quality, WPS requires WiFi AP measurement operation of the service area and needs a database process in advance. In addition, it is pointed out as the weakness of WPS service that quality of service changes dramatically depending on the density of the AP and the quality of the database.

B. Android Location Provider

Android, one of the leading mobile device operation systems with iOS is a Linux based open source development platform. Recently, there has been a substantial increase in the share of Android OS in the market of mobile phones. This significant increase is based on the fact that, developer could carry out development more efficiently without concerns about development fee or distribution cost and could solve problem easily with the help of the massive developer communities and the help of extensive technical documents.

Android provides a Location Provider component for determining the available location provider and for selecting an appropriate location output. Android platform basically supports two types of standard location provider, i.e., GPS, Network provider and provides information related to the estimated position using the location API [1].

- **Timestamp:** Time information of estimation in milliseconds since January 1, 1970.
- **Location:** Position information with estimated latitude, longitude, and altitude in degrees.
- **Accuracy:** Estimated accuracy of the provided location, in meters.
- **Auxiliary Information:** Other information of the estimated location like bearing, speed and etc.

Location Provider of Android defines accuracy as the 68% confidence area, that is to say, Android assumes user location as the circular statistical region. Coordinates of location represent the center of statistical region and accuracy means the radius equal to one standard deviation of the probability estimation.

Therefore, in the concept of the location service provider of Android, the probability that the target user is located inside the prediction area whose center is the predicted position and whose radius is the estimated accuracy becomes 68%.

III. EXPERIMENTS

A. Performance Evaluation Factor

As described in the previous section, GPS service is not able to provide high quality of service due to the influence of high ambient building at the urban area where most of the service targets are concentrated. Meanwhile, WPS is serviceable at the GPS shadow area and shows a relatively stable performance at the urban canyon if AP density is qualifying the certain requirements.

Therefore, in order to provide the location service with high accuracy and reliability, many studies have been performed to analyse the effects of urban canyon model on GPS performance, to evaluate the WPS service accurately.[2] [3] [4]

However, in most of the previous researches, assessment about service quality was performed by measuring the difference between the actual and estimated position which is the center of circular region, to be exact [5] [6] [7].

If user could have only one service or would like to use only one service among the multiple location services than conventional evaluation method would be effective regardless of the accuracy. However, if user wants to use a most accurate, reliable service among them or wants to calculate a fused location using the multiple services, then evaluation of accuracy will be essential and inevitable.

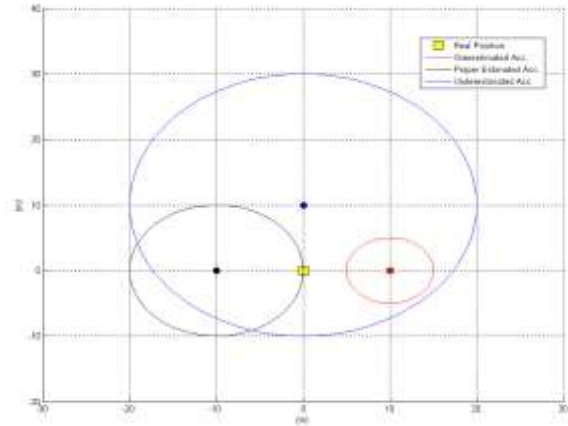


Figure 1. Examples of Position Accuracy

Figure 1 shows three examples of different accuracy with the same positional error. In conventional scheme of performance evaluation, these three location examples have same performance because they all have same distance between the reference and estimated position regardless their accuracies.

Meanwhile, two examples in black and blue could be classified as a successful estimation according to the definition of Android location service provider because the actual position locates inside the circular prediction region but last example in red should be regarded as a failure because the actual position locates outside the region.

We propose the novel performance evaluation scheme based on the reliability of accuracy to identify the best positional prediction among the multiple location results. In an aspect of reliability of accuracy, two examples in red and blue should be classified as failure. The example in red shows a positioning failure based on the concept of service and should be regarded as a failure in terms of reliability of accuracy, an overestimated prediction because location provider assumed that expectation is more accurate than the actual value so accuracy radius must be extended than the original estimation to reduce the accuracy gap.

On the other hand, the example in blue shows a conceptual positioning success but should be regarded as a failure in terms of reliability of accuracy, an underestimated prediction because location provide assumed that expectation is less accurate than the actual value so radius must be reduced to reflect the actual accuracy in this case.

$$\text{Reliability Accuracy} = \frac{\text{Position Error}}{\text{Estimated Accuracy}} \quad (1)$$

We measured the reliability of accuracy by calculating the ratio of actual positional error and estimated accuracy as in equation 1.

If reliability factor shows much larger value than 1.0 then it means expectation of accuracy is overestimated. On the other hand, if reliability factor has much smaller value than 1.0 then it means expectation of accuracy is underestimated.

B. Experiment Method

For the experiments, we have developed and implemented an application for Android, PositionLogger to collect results and to analyse the performance of Android location service with the Samsung Galaxy Note 1(GT-N7000). Note 1 is an Android based smartphone with built-in Broadcom BCM4330 WiFi/Bluetooth/FM chip and Broadcom BCM4752 GPS receiver.

We have developed the PositionLogger on the Android 4.0 platform (Ice Cream Sandwich) to evaluate the actual service quality and reliability of Android location service at urban canyon. It consists of a front-end GUI and a background service which collects the positioning results continuously and then logs them according to user configuration.

The user can use the PositionLogger to collect the results of GPS or WPS location service separately, can select the operating mode of the predefined period or predefined count. The user can also adjust the time interval of the execution of each positioning through the User Interface shown in Figure 2. The coordinates and accuracy of the estimated location are displayed on the user screen and marked on the map. So user can confirm the measurement results simultaneously during the measurement.

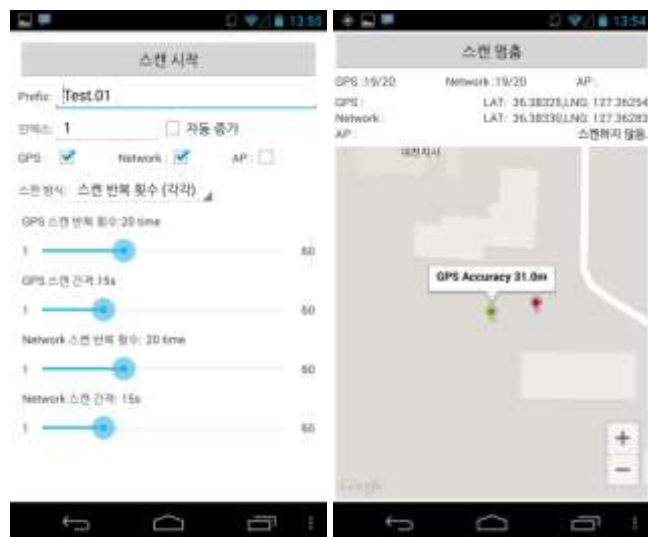


Figure 2. GUI and Location Example of PositionLogger

We have classified the environmental model in two categories, a Low-profile and a High-profile, referred to the urban canyon model of previous studies [4], [8]. If the elevation of the building is high than 60 degrees at the test spot 15 m away from the building and if the distance between

the buildings across the street is shorter than the average building height then we classified the spot as a High-profile satisfying the urban canyon scenario.

9 reference test spots in the test site qualifying the High-profile scenario was chosen along the 1.4 km streets of the central business district area of Seoul, Korea. Figure 3 shows where the test spots are located at test site. At each test spot, 44 estimation results of GPS and WPS service were collected using two Galaxy Note 1 smartphone. The time interval was set to 15 seconds to prevent abnormal estimation caused by the network delay and to ensure independence between estimations. The average number of GPS satellite on the test site was 14, the average fix number was 13. We were able to scan the WiFi AP four or more at all reference spots of the test site except the mobile WiFi dongle or cellular hotspot.



Figure 3. Location of The Reference Spots (Yellow) in The Test Site .

C. Experiment Results

Figure 4 shows the location results of GPS and WPS on the reference spot No. 7. From the Figure 4, we can see that WPS positioning results are more concentrated and have higher positional performance than GPS in urban area. We can also confirm that the reliability of WPS accuracy estimation is higher than that of GPS in conventional evaluation method and in novel concept based on the fact that the reference point was located inside the accuracy circle and positioned around the border of the circular region in most WPS cases. However, in most GPS cases, the reference point was located outside the circle and positioned far away from the border.

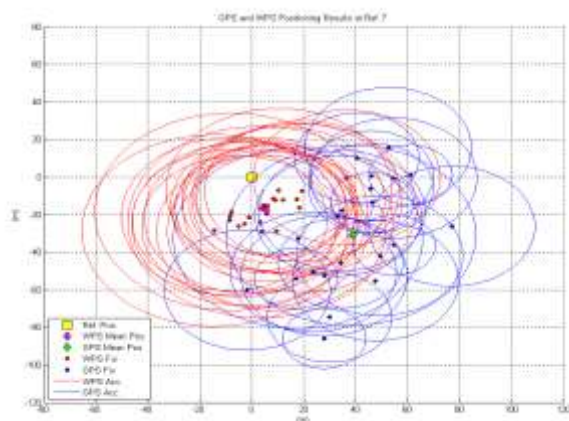


Figure 4. WPS and GPS Positioning Results at Reference Spot No. 7.

Table 1 summarizes the results at the test site and Figure 6 shows the cumulative distribution function (CDF) of positioning error and accuracy difference between the position error and accuracy estimation.

At the test site, WPS has a median horizontal position error of 21.8 m and is clearly much more accurate than GPS with a median error of 48.4 m. WPS has a median accuracy of 34.3 m and is slightly higher than GPS with a median value of 31.6 m. Meanwhile, median reliability factor of WPS is 1.01 and is considerably more credible value than GPS with 2.27.

From the results, we can assure that GPS is much less accurate, considerably overestimated, and not reliable than its prediction, but WPS is relatively accurate, a little bit underestimated, and reliable as its prediction at the urban canyon.

Table 1. Summarized Results of Test Site

Position Error		Reference Spot									Site
		2	3	4	5	6	7	8	10	12	
GPS	Min	3.5	5.9	14.8	9.3	17.9	25.4	6.3	6.8	0.3	10.0
	Max	177.8	177.7	136.9	130.8	211.3	112.8	94.5	79.6	61.5	131.4
	Mean	51.2	72.9	42.9	58.1	92.1	57.2	45.1	36.4	25.2	53.5
	Median	36.7	69.9	37.2	53.3	79.2	56.7	45.1	35.1	22.5	48.4
WPS	Min	9.8	23.6	5.2	11.2	9.7	11.4	7.9	17.1	4.5	11.2
	Max	74.7	44.6	19.5	39.3	24.4	69.7	17.2	40.1	36.8	40.7
	Mean	20.9	38.5	14.9	29.7	16.7	24.8	11.6	26.9	14.2	22.0
	Median	18.2	39.2	16.5	33.5	17.0	21.2	11.4	27.3	11.7	21.8

Estimated Accuracy		Reference Spot									Site
		2	3	4	5	6	7	8	10	12	
GPS	Min	16.0	16.0	12.0	12.0	12.0	12.0	12.0	8.0	12.0	12.4
	Max	128.0	48.0	96.0	192.0	64.0	48.0	48.0	48.0	48.0	80.0
	Mean	36.9	40.9	31.6	55.2	34.6	27.5	28.0	21.0	20.8	33.0
	Median	32.0	48.0	32.0	48.0	32.0	28.0	32.0	16.0	16.0	31.6
WPS	Min	30.0	30.0	21.4	30.0	30.0	30.0	30.0	20.4	30.0	28.0
	Max	108.0	42.0	42.0	52.0	57.1	67.5	67.5	68.3	58.5	62.5
	Mean	45.2	31.5	32.6	31.9	43.4	43.6	44.9	40.3	36.3	38.9
	Median	40.5	30.0	30.8	30.0	42.3	40.5	30.0	31.5	33.0	34.3

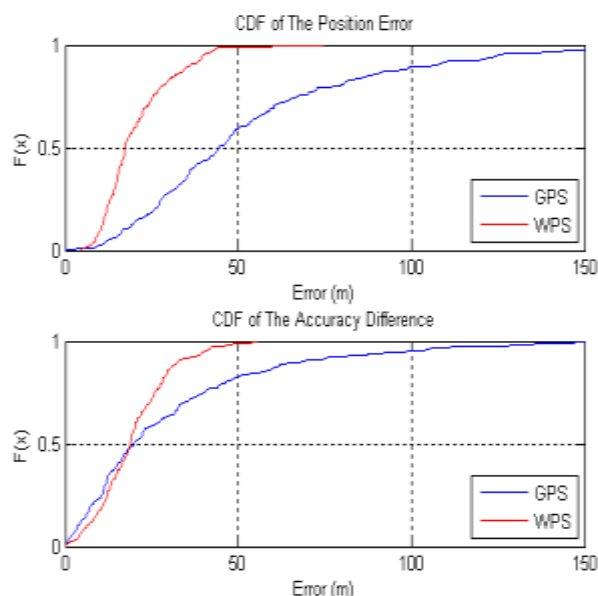


Figure 5. The CDF of The Position Error and Accuracy Difference

IV. CONCLUSIONS

In this paper, we evaluated the performance of positioning and accuracy estimation of Android location service at the urban canyon environments. We have developed the PositionLogger to measure and log the results of Android location service and carried out the experiment at the appropriate target area selected by the urban canyon model definition.

Experimental results show that the positioning performance of the WPS is superior to GPS in dense urban area. It can be also confirmed that the WPS accuracy estimation is stable, reliable, and mildly underestimated but the GPS accuracy estimation is unstable, unreliable, and quite overestimated than the optimal value. From these results, we could know that we should consider the utilization of WPS first than GPS at the urban canyon.

Our next study will be focused on how to take advantage of the reliability of Android accuracy estimation when there are multiple location services available at the same region.

ACKNOWLEDGMENT

This research was supported by the KCC (Korea Communications Commission), Korea, Under the IT R&D program supervised by the KCA (Korea Communications Agency) (11913-04003, Development of 5m accuracy LBS Platform supporting AR service)

REFERENCES

- [1] "developer.android.com." [Online]. developer.android.com.
- [2] T. Gallagher, "Wi-Fi + GPS for urban canyon positioning," IGNS 2009 Symp. GPSGNSS, 2009.
- [3] B. Ben-Moshe, E. Elkin, H. Levi, and A. Weissman, "Improving Accuracy of GNSS Devices in Urban Canyons," CCCG, 2011.
- [4] M. Modsching, R. Kramer, and K. ten Hagen, "Field trial on GPS Accuracy in a medium size city: The influence of built-up," 3rd Workshop Position. Navig. Commun., pp. 209–218, 2006.
- [5] P. A. Zandbergen, "Comparison of WiFi positioning on two mobile devices," J. Locat. Based Serv., vol. 6, no. 1, pp. 35–50, Mar. 2012.
- [6] H. Yoshida, S. Ito, and N. Kawaguchi, "Evaluation of pre-acquisition methods for position estimation system using wireless LAN," Third Int. Conf. Mob. Comput. Ubiquitous Netw. ICMU 2006, pp. 148–155, 2006.
- [7] U. Bareth and A. Kupper, "Energy-Efficient Position Tracking in Proactive Location-Based Services for Smartphone Environments," Comput. Softw. Appl. Conf. COMPSAC 2011 IEEE 35th Annu., pp. 516–521, 2011.
- [8] R. Raulefs and S. Plass, "Combining Wireless Communications and Navigation -The WHERE Project," Veh. Technol. Conf. 2008 VTC 2008-Fall IEEE 68th, pp. 1–5, 2008.