Performance Evaluation of Positioning Techniques Based on UWB Radio

Jinwon Choi, Jun-Sung Kang, Yu-Suk Sung and Seong-Cheol Kim
School of Electrical Engineering and Computer Sciences
Seoul National University
San 56-1, Sillim-Dong, Gwanak-Gu, Seoul 151-742, Korea
E-Mail : caesar@maxwell.snu.ac.kr, sckim@maxwell.snu.ac.kr

Abstract: In this paper, performances of positioning techniques based on UWB radio are evaluated. The positioning techniques for UWB systems, SS, and time based algorithms, TOA and TDOA, are the target ones to be analyzed. Using the reported CRLB of each algorithm, the location estimation error is obtained. The estimation error variation to the number of base stations is reported also.

1. INTRODUCTION

Wireless network based on Ultra Wide Band (UWB) system has been proposed for many applications recently for its advantages, such as low complexity, low power, resistance to multi-path and very good time domain resolution. For location based applications, there are positioning techniques based on UWB communications as well. The algorithms are defined to the channel parameters used for estimation. For example, if the network uses the received signal strength for location estimation, the positioning algorithms of that network is SS algorithm. In this paper, fair performance comparison of positioning algorithms based on UWB radio is reported. Using the demonstrated CRLB of SS and time based algorithm, the distribution of ranging estimation error is obtained. Then, using this distribution, the location estimation error in wireless network is calculated and compared to the number of base stations.

2. POSITIONING TECHNIQUES BASED ON UWB

In [1], positioning techniques based on the UWB radio is introduced. The angle of arrival (AOA), the signal strength (SS), and time delay information, time of arrival (TOA) and time difference of arrival (TDOA) are those. For each estimation algorithm, Cramer-Rao lower bound (CRLB) is provided. In case of SS algorithm, CRLB of the distance estimation is given by

$$\sqrt{\mathrm{var}(\hat{d})} \geq \frac{\ln 10}{10} \frac{\sigma_{sh}}{n_p} d, \quad (1)$$

where d is the distance between BS and MS, n_p is the path loss factor, and σ_{sh} is the standard deviation of the zero mean Gaussian random variable representing the log-normal channel shadowing effect. For time based algorithms, it is suggested as

$$\sqrt{\mathrm{var}(\hat{d})} \geq \frac{c}{2\sqrt{2}\pi\sqrt{SNR}\beta} \quad (2)$$

where c is the speed of light, β is the effective signal bandwidth of transmitted signal and *SNR* is the signal-to-noise ratio.

This work is supported in part by ITRC and Seoul R&BD Program (10544)

3. PERFORMANCE ANALYSIS

3.1 CRLB using channel model

The demonstrated values of CRLB in previous section are calculated using the channel parameters. The IEEE 802.15.4a channel model for standard [2] and empirical channel model [3] is used for the practical CRLB values. The first one is based on the time domain channel properties and the other one is from the frequency domain channel properties.

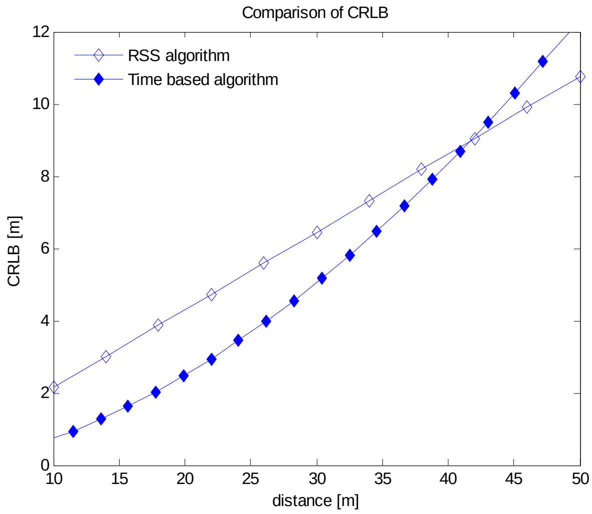

Figure 1. CRLB values of SS algorithm and time based algorithm to separation between BS and MS based on IEEE model when NLOS environment

In Figure 1, CRLB values of SS algorithm and time based algorithm is illustrated. These values are obtained using IEEE channel model in non-line-of-sight (NLOS) environment and drawn to the separation between MS and BS. Similar results are obtained from various channel condition of IEEE model and empirical model.

3.2 Location Estimation Error

Once the standard deviation of ranging estimation error is obtained, the distribution of estimation can be acquired as well. We assumed that the distribution of ranging error is to Gaussian one. From this assumption, the location estimation error is defined as figure 2. The location estimation error means the distance difference between original position of MS and the furthest position of MS probable area. Figure 3 illustrates an example scenario with a MS and three BSs. In this scenario, the original location of MS is center of BS and separation between MS and BS is set to 40m. The location estimation error is reported in Table 1. With same procedure, the location estimation error of 4 BSs-network is also obtained.

4. Conclusions

For the deployment of location positioning system based on UWB radios, the estimation errors of location algorithms are obtained. Using the CRLB of each positioning algorithm and measured channel characteristics, practical ranging error boundary is calculated. Assuming the ranging error model to Gaussian distributions, the location estimation error of each algorithm is evaluated. In most scenario of three BSs-network, time based algorithm has better performance than SS algorithm. However, if the IEEE model of NLOS environment is applied, the SS algorithm has more accurate estimation than time based algorithm as the separation between MS and BS increases over 40m.

References

[1] S.Gezici et al. "Localization via Ultra-Wideband Radios: a look at positioning aspects for future sensor networks," *IEEE Signal Processing magazine*, vol. 22, pp. 70-84, July, 2005

[2] A. F. Molisch, K. Balakrishnan, D. Cassioli, C. C. Chong, S. Emami, A. Fort, J. Karedal, J. Kunisch, H. Schantz, U. Schuster, and K. Siwiak, "IEEE 802.15.4a Channel Model – Final Report," 2005, tech. rep. doc: IEEE 802.15-04-0662-02-004a. [Online]. Available: http://www.ieee802.org/15/pub/TG4a.html

[3] J.Choi, N.G. Kang, Y.S. Sung and S.C.Kim "Empirical Ultra Wide Band Channel Model for Short Range Outdoor Environments," in *proc. IEEE VTC 2007 spring*, to be published.

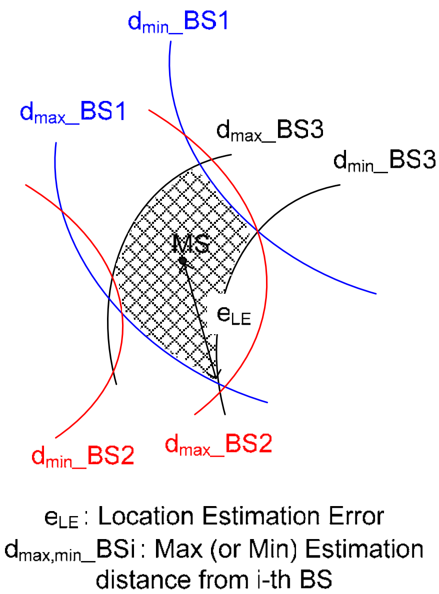

Figure 2. Geometry of MS probable area and its location estimation error

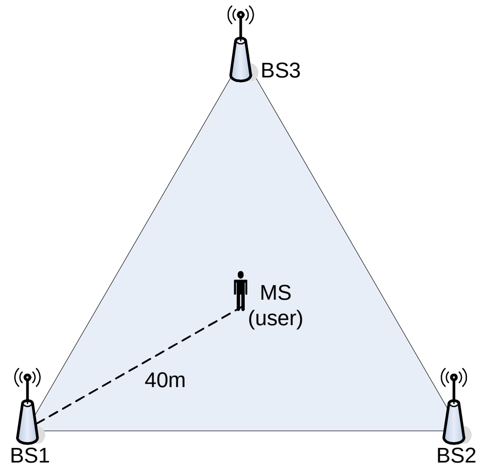

Figure 3. An example of location estimation scenario with a MS and three Mobile Stations (MSs)

Table 1. Location estimation error of each channel model in scenario of Figure 3.

Channel model		e_{LE} [m]
SS algorithm		
IEEE model	LOS	6.1
	NLOS	9.8
Empirical model	LOS	8.24
	NLOS	8.96
Time based algorithm		
IEEE model	LOS	0.32
	NLOS	9.6
Empirical model	LOS	0.36
	NLOS	3.68