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Study of DOA-based indoor location positioning utilizing MIMO WLAN system in a typical room environment

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1. Introduction

Interest in Wireless Local Area Network (WLAN) indoor location positioning systems has continuously increased in this last decade. In particular, with the dysfunctional state of Global Positioning Systems (GPS) in indoor area, the possibility of utilizing of widely deployed WLAN systems in buildings makes for a good prospective research topic. The challenge faced is the multipath fading environment presented in the indoor environment. There are many techniques[1] that have been used to build WLAN indoor location positioning systems but DOA estimation utilizing MIMO technique was focused because it allows us to use multiple antennas and receivers and enable the use of OFDM advantageous to counter multipath fading defect. Furthermore, location of a mobile terminal can be estimated by measuring DOAs of the direct propagation path which theoretically has the strongest power among all the multipath components and synchronization is not needed.

2. System and experimental setup

In this paper, a DOA-based indoor location positioning method utilizing MIMO wireless LAN system model performances in a typical room environment has been studied and analyzed. Recently, 2x3 MIMO type is a typically used configuration. Array antennas at the base station are the main focused to be exploiting in DOA estimation.1x3 SIMO was chosen to be applied in our research.

In IEEE 802.11a system model, orthogonal frequency division multiplexing (OFDM) is among the main part in its system. OFDM allows 52 frequencies subcarriers. Out of the 52 OFDM subcarriers, 48 are for data while the other 4 are pilot subcarriers with a carrier separation of 0.3125 MHz (20MHz/64). These unique and advantageous criteria are applied in our DOA estimation research.

Our experimental testbed is 8x8(m) area, located in Innovation room; a typical class room at Ibaraki University. The layout of the floor is shown in figure 4. Unfortunately, this experimental area has a draw back which is the ground is covered with metallic plate that has high reflection coefficient. This issue will be address in latter chapters. We set 16 point location coordinates and 4 point coordinates for arrays of 3 antennas receiver. We name each 4 point coordinates for arrays of 3 antennas receiver as A, B, C and D. The experimental location point and arrays of 3 antennas receiver location are shown in Figure 1. The basis setup is as follow:

Table 1: Basis setup

Frequency	2.4GHz band
Frequency bandwidth	20 MHz
Antenna element spacing	6.25 cm
Number of subcarrier	19

A network analyzer and 4 antennas were used. The transmitter antenna at the location point for estimation was connected at port 1 of the network analyzer. In the case of the array of antennas at the receiver end, in order to be able to measure one receiver antenna at a time, one antenna was

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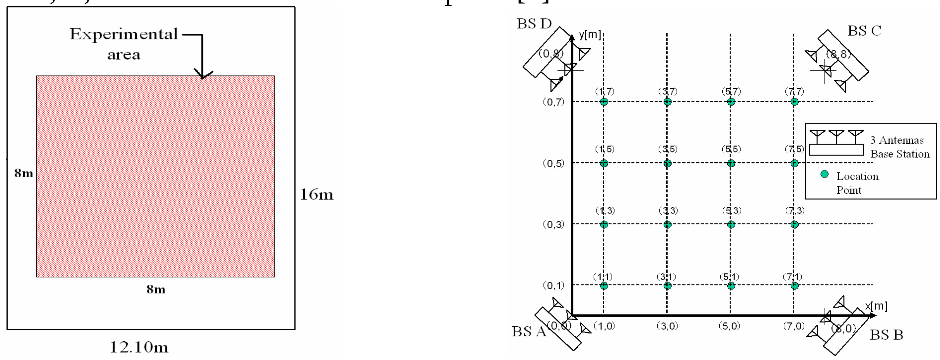
connected to port 2 whereas the other two were terminated with 50 ohm load resistance. To measure the receiver antennas alternately, the connection to port 2 and load resistance was alternated respectively[1]. Data of 19 frequency subcarriers between 2.39GHz and 2.41GHz are collected at base station A, B, C and D for each 16 location points[2].



(a) Innovation room geometry (b) Base station array antennas and location points

Fig. 1: Experimental environment

3. Research methodology

3.1 DOA estimation and location estimation method

Generally, this experiment consists of several processes like data collection and processing, DOA estimation using MUSIC algorithm[4], maximum directivity algorithm and MUSIC with spatial smoothing algorithm[5] and then location estimation process[2][3]. First, incoming signals data was collected and averaged. Then DOAs are estimated in each array of antennas receiver; A, B, C and D. Location coordinates is estimated from DOAs result in each combinations; A-B, B-C, C-D and D-A. The resulting 4 estimation coordinates are averaged to get the final estimated location coordinate. Although MUSIC, spatial smoothing processing, maximum directivity and others algorithms in DOA estimation is nothing new research and almost matured research, but evaluation of these algorithms on a MIMO environment is something new, interesting and needed.

3.2 Estimation at multiple frequency points

In the office environment, severe fading will be estimated and cause degradation of DOA estimation. Estimation at multiple frequency points and average all of them for each algorithm is proposed to overcome this problem[2]. Theoretically this technique should improve the performance and decrease the effect of multipath fading and noise on the result.

$$\theta_s = \sum_{i=1}^{N} \frac{\theta_i}{N} \qquad (1)$$

θ_i is DOA estimation in each subcarrier and N means the number of frequency point.

3.3 2 approach techniques to increase accuracy performance

Two methods were proposed, 2 step process technique and majority vote technique, in order to improve the performance of DOA estimation result[2].These methods are referred to as (a) and (b), here.

In 2 step process technique, the experimental testbed and location coordinates were divided into four areas according to each area was near to arrays of antennas location receivers. Each divided area was name number 1, 2, 3 and 4. Second step, location estimation of each coordinate point is based on the nearest base station. The reason to our approach is because receivers close to transmitter will receive high power of line of sight (LOS) rays and it helps to give good DOA estimation.

In majority vote technique, measured data result is divided to two part; positive and negative value. Then, majority values assumed to be near true DOA are selected and averaged. This is because DOA estimation is strongly affected by multipath component and causing opposite estimation of true DOA. This is our second approach method.

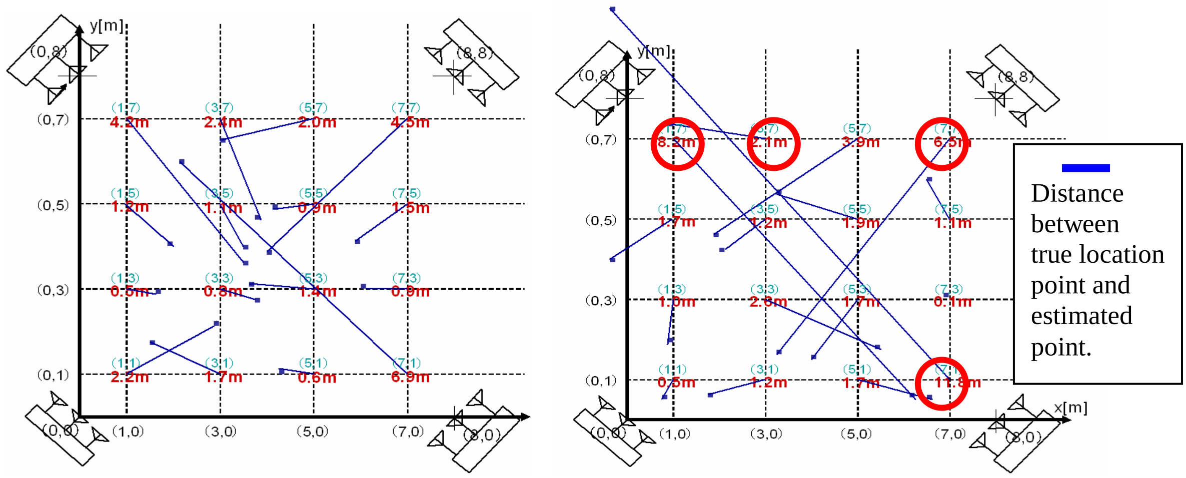
4. Experimental result

Experimental processes are well explained in chapter 3 and in our previous research paper [2]. From the result of table 2, clearly it stated that maximum directivity algorithm and MUSIC with spatial smoothing algorithm perform well than MUSIC algorithm. MUSIC algorithm was heavily affected by indirect coherence signals in a multipath fading environment. The important fact is the result clearly shows that by using more than one data frequency, we can improve the location estimation accuracy performance. Mean accuracy performances of 19 subcarriers model system outperform 1 subcarrier model system. However as shown in Figure 3(a), there is a drawback that estimated location likely to gazer for the center. This is caused by opposite side DOA estimation.

Table 2: Experiment result at typical room environment

	MUSIC			Max. Directivity			MUSIC+SSP		
Coordinate	1 sub-carrier (2.4GHz)	19 sub-carrier	a+b	1 sub-carrier (2.4GHz)	19 sub-carrier	a+b	1 sub-carrier (2.4GHz)	19 sub-carrier	a+b
Mean Accuracy(m)	11.73	2.78	4.02	3.08	2.08	2.65	5.20	2.05	2.95

On the other hand, as regards to applying (a) and (b) techniques to the measurement data, interesting and intriguing results clearly can be seen. However, location coordinate (1,7),(3,7),(7,1) and (7,7) have still large error. The distant estimation error of each point is 8.2 meter, 2.1 meter, 6.5 meter, and 11.80 meter, respectively.



(a) MUSIC+SSP based 19 subcarriers result (b) MUSIC+SSP based 19 subcarriers with (a) and (b)

Figure 3: Experimental results

5. Study of indirect signal interference effect

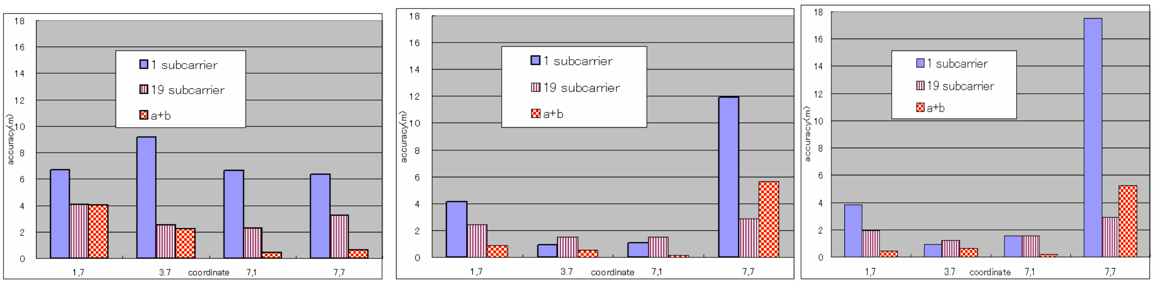
In multipath environment, DOA estimation usually has large error as interference effect from indirect signals. Because of the experimental area floor consists of metallic plate, high possibility is fading mainly caused by reflection from the ground. An additional experiment was setup to address this issue. 4 location points that have high location estimation error were selected to be used in this experiment. An electromagnetic absorbent was placed in the ground along the direct path from signal source to base station array antenna to prevent indirect signal coming from the floor.

6. Experiment on indirect signal effect

Table 3: Experimental result with electromagnetic absorbent

	MUSIC			Max. Directivity			MUSIC+SSP		
coordinate	1 sub-carrier (2.4GHz)	19 sub-carrier	a+b	1 sub-carrier (2.4GHz)	19 sub-carrier	a+b	1 sub-carrier (2.4GHz)	19 sub-carrier	a+b
1,7	6.69	4.08	4.04	4.12	2.45	0.89	3.82	1.92	0.46
3.7	9.16	2.52	2.23	0.94	1.50	0.53	0.90	1.19	0.62
7,1	6.65	2.30	0.45	1.08	1.49	0.17	1.53	1.56	0.17
7,7	6.37	3.26	0.62	11.92	2.88	5.65	17.51	2.91	5.23

In table 3, it shows that higher accuracy performances can be achieved if the environment floor is less reflection coefficient and prove validity of assumption about indirect signals from floor as the main contributor to DOA estimation error.



(a)MUSIC (b)Maximum Directivity (c)MUSIC+SSP

Fig 4: Accuracy performances result

7. Conclusion

In this paper, a DOA-based indoor location positioning method utilizing a MIMO Wireless LAN system was proposed, studied and analyzed. It was shown that by considering and adding more data subcarriers to estimate the DOA and location positioning, better results could be obtained and that the proposed method proved advantageous to IEEE 802.11a WLAN and IEEE 802.11g WLAN. Alternative 2 techniques approaches also have shown an acceptable result. Furthermore, this paper shown that it is important to mitigate indirect signal from the floor in case the room has high reflection coefficient floor as metallic plate. The main aims are to show MIMO advantages in indoor location positioning and provide better approaches, techniques and environment condition setup for applying this system in the future.

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