Performance Of The IEEE 802.15.4 Protocol As The Marker Of Augmented Reality In Museum

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Abstract. Museum is a place to keep the historic objects and historical education center to introduce the nation's culture. Utilizing technology in a museum to become a smart city is a challenge. Internet of thing (IOT) is a technological advance in Information and communication (ICT) that can be applied in the museum. The current ICT development is not only a transmission medium, but Augmented Reality technology is also being developed. Currently, Augmented Reality technology creates virtual objects into the real world using markers or images. In this study, researcher used signals to make virtual objects appear in the real world using the IEEE 802.14.5 protocol replacing the Augmented Reality marker. RSSI and triangulation are used as a substitute microlocation for AR objects. The result is the performance of Wireless Sensor Network could be used for data transmission in the museum. LOS research at a distance of 15 meters with 1000 ms delay found 1.4% error rate and NLOS with 2.3% error rate. So it can be concluded that utilization technology (IOT) using signal wireless sensor network as a replace for marker augmented reality can be used in museum.

1. Introduction

Museum is a place to keep the historic objects and historical education center to introduce the nation's culture. Internet of things is the development of internet technology for human needs in various ways. Utilization of technology in the museum to the city of smart is a challenge. Technology that may be realized is AR. Augmented Reality (AR) combines real and virtual objects in real environments, runs interactively in real time, and there is integration between objects in three dimensions [2]. Combining real and virtual objects is something that might happen with appropriate technology, interactivity is not impossible through good input devices and integration with effective tracking.

The development of AR research is very rapid. The AR object can appear without having to use an image as the point where the virtual object appears. The AR connected to the sensor and the internet can display virtual objects. The virtual object may appear in a location using the Global Positioning System (GPS). The GPS work system is by using a satellite as the signal sender to the GPS receiver and the signal is used by the receiver to determine the location. GPS has been popularly used by Google Maps to determine the user's location. Unfortunately GPS can not be used properly in the room so it can not be implemented in the museum.
Previous research has found that position tracking indoors or known as microlocation has been successful. Some examples of the use of this system are indoor guides, ISAM European ADAMANT project [3], and Wireless Sensor Network application indoors that can replace GPS [4]. There are three wireless positioning algorithms that use ID, triangulation and signal strength [5]. Based on the above descriptions researchers are interested in making research using signals to make virtual objects appear in the real world by using the IEEE 802.14.5 protocol instead of the Augmented Reality marker.

2. Augmented Reality Markers
There are several ways in reading AR. Commonly used AR with images or known as marker AR. Marked AR is rarely encountered because to make AR appear using GPS coordinates as ID or marker [6]. In this research, the author used a marker by utilizing ID and RSSI on WSN. Marker AR reading AR with markers is a way to bring 3D objects to the real world using images. AR implementation in the smartphone there are several processes: Tresholding, Contour detection, Rectangle Fitting, Undistortion, Pattern checking and Pose estimation [7].

Markeles is a method of reading AR without pictures or drawings as its markers but by utilizing the real environment itself as its marker [6] [8]. The markeles concept is not much different from the marker. Markeles reads the mark using GPS coordinates or captured directly from the surrounding environment. So without using paper, 3D objects can appear in accordance with the coordinates or positions we want. This is easier and does not require much time in AR readings. Wireless Sensor Network (WSN) is a wireless network infrastructure composed of a number of sensor nodes scattered in an area. Each sensor node has radio transceivers and antennas, microcontrollers, electronic interfacing circuits and energy sources [9]. WSN technology can be used to monitor, control, and communicate.

3. Designing The Positioning System
At this stage, augmented reality system will be built on smart museum based on wireless sensor network to recognize objects in the museum by using the IEEE 802.14.5 protocol in recognizing markers to show the object AR. The method in this research is by designing a microlocation system to determine the AR object of marker replacement on augmented reality based on wireless sensor network by using RSSI and Triangulation which will be applied in the museum. In addition, testing will be performed to determine the performance of Wireless Sensor Network Figure 1.

![Figure 1. System Design WSN Node And Object WSN.](image-url)
Stages of the WSN system starts from the smartphone user connected to the internet in the museum. Then the user will get information from objects that have been placed wireless sensor network. Wireless sensor networks start sending data after sleep mode, then wireless sensor network nodes send a packet of data with hexa letters, where each protocol has a different package structure. Furthermore, the package structure will be sent to the coordinator. Coordinator will be provided with 1 arduino to buffer to get the ID from wireless sensor network. The next step is the data that has been obtained will be continued on the database using ethernet shield. Once the data entered into the database, the data will be taken to be displayed into virtual objects in the Augmented Reality application. The position of AR will use RSSI and triangulation. Where this position is used as the appearance of the AR object.

3.1. Triangulation and RSSI

By measuring the distance using the signal intersection, we get the midpoint of the signal. This method is also used to calibrate the node position with the coordinator. In determining the position with strong signal there are still many obstacles. Therefore we adopt a more sophisticated propagation model [10]. Described in this study with an explanation of our position, shown in 1.

\[\text{RSSI} = - (10 \log_{10} d + A) \]  

(1)

To measure RF parameters (Radio Frequency) with A is defined as absolute energy with dBm units. Where n is the constant for signal transmission. d is the distance from each transmitting node to the coordinator or receiver. The value of RSSI can be measured using several equations. In WSN there is an RSSI value using the XCTU application. To calculate d can use (1). In order to know the third boundary of WSN with the coordinates of the reference nodes A, B, C and determine the distance between the nodes to the WSN coordinator Suppose the WSN coordinates are \((x, y)\), in equation (2) can be set:

\[
\begin{align*}
(x-x1)^2+(y-y1)^2 &= d1^2 \\
(x-x2)^2+(y-y2)^2 &= d2^2 \\
(x-x3)^2+(y-y3)^2 &= d3^2 
\end{align*}
\]

(2)

With the above equation we can determine the coordinates of the user’s WSN and predict the AR object to appear.

4. Designing The Positioning System

From several experiments we got some positions where AR objects appear. With a signal of 15 dBm, the distance was estimated at 5.6 m. This distance corresponded to the system when we did the experiment and was supported from some of the data we had with the three WSN nodes. ID had been set 16 for brahma gods, ID 18 for god ganesh and ID 19 for gods of siwa. The data can be viewed in Table 1.

| ID | x  | Y  | z  | dBm | Distance | AR Object Position |
|----|----|----|----|------|----------|-------------------|
| 16 | 3  | 1  | 2  | 15   | 5.6m     | Right             |
| 18 | 1  | 2  | 1  | 13   | 4.4m     | Right             |
| 19 | 2  | 1  | 3  | 17   | 7m       | Left              |

From the analysis and experiments we did for many times, the position of the object more often appeared in the position of the object in Table 1 with the position of x, y and z in accordance with the condition of data collection in the museum. We used three WSNs for this experiment. With three WSN we estimated where the AR object appeared. The appearance of the AR object can be seen in Figure 2. Furthermore, from this experiment conducted a third performance analysis WSN.
4.1 Performance of Wireless Sensor Network
By tested and observed the performance maximum on the wireless sensor network on LOS and NLOS conditions, the researcher will get the results to get the maximum distance on the data transmission. The purpose of distance measurement testing is to determine the quality of data delivery process in Xbee S1 for the system to work optimally and can be used indoors or outdoors museum’s Mpu Tantular.

This test was used to determine the level of system success made to get the error value for the evaluation in the processed of sending data. In LOS testing, the node of the coordinator was further away, the data received by the coordinator got better with 1000ms delay. It can be seen on graphic Figure 3 and Figure 4. However, still need to be tested and delay analysis to know the delay of data because this affect the appearance of AR object. Next will be analyzed the delay to error on WSN performance.

4.2 Analysis of delay to error
The delay test was performed to observe the data transmission time from the node to the coordinator. In this test some delay experiments were conducted to observe the effect of AR objects. This time the test was done to start sending data packets with the time from 50ms to 1000ms.

| No | ID WSN | 50 ms | 100 ms | 500 ms | 1000 ms |
|----|--------|-------|--------|--------|---------|

Figure 2. AR Object 3D Position in Museum.

Figure 3. Graph Error in LOS condition.

Figure 4. Error Chart under NLOS Conditions.
Table 3. Delay against database.

| No | ID | WSN | Delay Error (Node - Database) |
|----|----|-----|------------------------------|
|    |    |     | 50 ms | 100 ms | 500 ms | 1000 ms |
| 1  | 16 |     | 54,92% | 45,07% | 39,43% | 1,40%    |
| 2  | 18 |     | 66,19% | 47,88% | 36,61% | 1,40%    |
| 3  | 19 |     | 59,15% | 46,47% | 38,02% | 1,40%    |

Table 4. Loss on The Data Base.

| No | ID | WSN | LOSS (Node - Database) |
|----|----|-----|-------------------------|
|    |    |     | 50 ms | 100 ms | 500 ms | 1000 ms |
| 1  | 16 |     | 4,22% | 2,81%  | 1,40%  | 0%     |
| 2  | 18 |     | 2,81% | 2,81%  | 1,40%  | 0%     |
| 3  | 19 |     | 4,22% | 2,81%  | 1,40%  | 0%     |

Table 5. Loss on Data Coordinator.

| No | ID | WSN | LOSS (Node - Coordinator) |
|----|----|-----|---------------------------|
|    |    |     | 50 ms | 100 ms | 500 ms | 1000 ms |
| 1  | 16 |     | 4,22% | 2,81%  | 1,40%  | 0%     |
| 2  | 18 |     | 2,81% | 2,81%  | 1,40%  | 0%     |
| 3  | 19 |     | 4,22% | 2,81%  | 1,40%  | 0%     |

4.3 Loss analysis

In this test was done Data loss analysis when sent data packets. From the data obtained in Table 4 and Table 5, loss occurs very much at 500ms. The greater the delay, the smaller the data loss and reduced the rate of data transmission failed. The caution was the data accumulation in the coordinator and database. And too soon the data sent by xbee to the coordinator. When the process of sorting ID occurs data accumulation resulting in loss. The effect of loss will be seen when the data transmission process takes place and result in the AR object does not appear.

5. Conclusion

The use of wireless sensor network in Augmented Reality as ID and position using triangulation method and RSSI run well and can be used in place of AR marker and AR markeles using GPS position. However, there are some advantages and disadvantages with this method. The advantages of this system no longer require images in presenting AR and can be used to determine the position of the user. Besides maximum distance that can be applied to the Augmented Reality Real time Monitoring system is as far as 15 meters with the condition of LOS (Line of Sight) found 1.4% error rate and NLOS (Non Line of Sight) with 2.3% error rate. Because at this distance maximum data can be sent well. In addition it can reduce the loss rate with set delay standarts 1000ms. So that the data sent is not lost and accumulated by new data.
References
[1] I. E. Sutherland, “A head-mounted three dimensional display,” Proceedings of the AFIPS ’68 (Fall, part I), pp. 757–764, 1968
[2] R. Azuma, R. Behringer, S. Feiner, S. Julier, and B. Macintyre, “Recent Advances in Augmented Reality,” IEEE Computer Graphics and Applications, vol. 2011, no. December, pp. 1–27, 2001
[3] Y. Wang and A. Ma, “An Agent-based Passenger Support System over Heterogeneous Wireless Infrastructures in an Airport Environment,” IASTED International Conference on Networks and Communication Systems (NCS 2006), pp. 240–244, 2006
[4] F. Darakeh, “An Accurate distributed rage free localization algorithm for WSN I,” pp. 2014–2019, 2014
[5] Y. Wang, X. Yang, Y. Zhao, Y. Liu, and L. Cuthbert, “Bluetooth positioning using RSSI and triangulation methods,” 2013 IEEE 10th Consumer Communications and Networking Conference, CCNC 2013, pp. 837–842, 2013
[6] Grasset, “Image-Driven View Management for Augmented Reality Browsers,” pp. 177–186, 2012
[7] J. Kim and H. Jun, “Implementation of image processing and augmented reality programs for smart mobile device,” Proceedings of the 6th International Forum on Strategic Technology, IFOST 2011, vol. 2, pp. 1070–1073, 2011
[8] N. Navab, T. Blum, L. Wang, A. Okur, and T. Wendler, “First deployments of augmented reality in operating rooms,” Computer, vol. 45, no. 7, pp. 48–55, 2012
[9] M. Patel and A. Shah, “Energy Efficient Target Tracking in Wireless,” International Journal of Distributed and Parallel Systems (IJDPS), vol. 3, no. 2, pp. 542–549, 2012
[10] J. Albowicz, A. Chen, and L. Zhang, “Recursive position estimation in sensor networks,” Network Protocols Ninth International Conference on ICNP 2001, pp. 35–41, 2001