EXPERIMENTAL STUDY FOR EFFICIENT USE OF RFID IN CONSTRUCTION

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ABSTRACT

This paper presents an experimental study conducted to facilitate the use of RFID on construction job sites. The study focuses on deployment settings to provide data acquisition with higher accuracy for indoor location sensing. It provides extension to the state-of-the-art in this field as it addresses the impact of metal media proximity to RFID tags, the reasonable duration for data capturing, number of RFID tags employed and the distance between them. Low cost passive RFID tags were used in the experiments where each tag is used as a reference point with a known location. Five hundred and forty (514) experiments were conducted in lab environment using a 3m by 3m test bed that is dynamically rearranged to generate 15 test beds and a total of 67713 data sets were collected and analyzed. The collected data were captured from nine locations for each test bed at four time intervals. Received Signal Strength Indicator (RSSI) was used as the main attribute for signal measurement to process the captured data. Results of the data analysis performed are studied under four main categories: duration, number of tags, locations of tags and metal interference. The best duration was found to be the 15 second in the test bed with the least number of tags; as the short amount of time to capture data did not allow creation of a lot of interference among the emitted signals. Within each test bed, errors occurred most at points where the received signals were not well distributed in a 360 degree vicinity of the data capturing point. It means that the center point of each test bed resulted in lowest errors and the points located on the extremities led to the highest errors. Finally, metal objects were found to have major impact on the accuracy of the captured data; to the level where reliable values for errors could not be calculated in the test beds attached to metal objects. In summary, the results of the experimental study and related findings are expected to provide guidelines to the users of RFID technology for localization in building construction.

KEYWORDS

RFID, Indoor location sensing, Experimental study, Deployment settings, RSSI, Proximity method

INTRODUCTION

Location sensing is used to determine the absolute and/or relative location information of objects with given observations and spatial relationships (Tzeng et al, 2008). Global Positioning Systems (GPS) with centimeters accuracy proves to be fit for the purpose of outdoor location sensing, (Navon and Goldschmidt, 2002 and Montaser et al, 2011). However, to identify indoor areas, GPS cannot be used because of its poor reception of satellite signals. Signal measurements that are used in indoor location sensing technologies include Received Signal Strength Indicator (RSSI), Angle of Arrival (AOA) and Time of Arrival (TOA) (Hightower and Borriello, 2001). RSSI is a measurement of the power of the received radio signal. Signal strength has close relationship with the distance between the sender and receiver. Localization system can estimate spatial information using the degree of signal attenuation. There are two principle advantages in signal strength measurement based on localization systems; cost effectiveness and straightforward implementation (Choi, 2011). RFID technology is used in this respect. RFID data can be stored in tags and retrieved with readers that can communicate with these tags, using radio frequency waves (Jaselskis and El-Misalami, 2003, Chae and Yoshida, 2010 and Montaser and Moselhi, 2012). Li and Becerik-Gerber (2011) did a comparative study of eight indoor location sensing technologies taking into consideration accuracy, affordability, line of sight, wireless communication, context independence, on-board data storage, power supply, and wide application in the building industry. They concluded that RFID technology is the most suitable technology for indoor location sensing. Time and angle of arrival signal measurement methods are not used for RFID location identification in light of the fact that signals are affected by their respective multipath effects (Razavi et al, 2012).

Three main methods have been developed to locate an object using RFID: Triangulation, Proximity and Scene Analysis. Scene analysis technique estimates the location of signal source using pre-observed data set about the monitoring scene. However, it requires extra information and data storage to maintain pre-observation and is not practical for dynamically changing environments such as construction jobsites (Fu and Retscher, 2009 and Woo et al, 2011). Triangulation is a technique of determining the location of an object, based on geometric properties. Triangulation determines the position of an object by measuring its distance from several reference positions. Triangulation method requires a path loss model to convert RSSI to distance (Gonçalo and Helena, 2009). However, the triangulation method suffers from drawbacks such as the dependency on path loss models (location-environment dependent models), which is not robust enough to represent the characteristics of radio waves and its interference in a dynamically changing construction environment. Proximity method requires the measurement of the nearness of a set of neighboring reference points, which have fixed and known locations, and are close to the target. Proximity method uses RSSI as a weighting method to express how near the reader is to the reference tags (Li and Becerik-Gerber, 2011). Therefore, the higher the RSSI number (or the less negative in some devices) is, the stronger the signal; indicating that the reader is closer to that tag. The computational time required for identifying location using triangulation method is much more than that of the proximity method due to the mathematical complexity of triangulation method, which gives advantage to proximity method in near-real-time localization. Thus, the proximity algorithm guarantees the most simple and easy implementation for object localization (Montaser and Moselhi, 2012).

Most RFID literature focuses on deployment of active RFID tags for tracking (Jaselskis et al, 1995 and Goodrum et al, 2006) and outdoor localization supported by Global Positioning System (GPS) (Ergen et al, 2007). However, active tags are expensive and have limited battery life time (5-10) years (Dziadak et al, 2009). In addition, the use of active tags may result in undesirable interference, in view of their relatively wide range and likely obstruction objects onsite during construction. Therefore, a short read range passive RFID tags could reduce the impact of obstructions in case of using it at zone level. Although, the deployment of passive RFIDs entails the deployment of larger numbers of tags than active RFIDs, its lower cost makes it even more economically feasible than active RFIDs. Further work is needed to address the impact of metal media proximity to RFID tags, optimum duration for data capturing, number of RFID tags employed and the distance between them to provide guidelines to the users of RFID technology for localization in building construction.

EXPERIMENTAL STUDY

This paper presents a study recently conducted to address the effective use of Ultra High Frequency (UHF) passive RFID technology in location sensing. The study focuses on deployment settings to provide data acquisition with higher accuracy for indoor location sensing. A total number of five hundred and forty experiments were conducted. Figure 1 depicts an area of 3m by 3m (referred to later as test bed) that was setup for the experiments. There are a number of low cost reference tags fixed on the perimeter of the test bed. The Distance between reference tags is X. Three different number of RFID reference tags are deployed in the experiment that are 16, 8 and 4 with distance between tags equals to 0.75m, 1.5m and 3m, respectively. The test bed was set at distance equal to Y from metal media. The distance Y was varied from zero to 3m in increments of 0.75m. The data of each experiment was collected using mobile RFID reader from nine different predefined locations from within the zone of each experiment. The user was assigned to a set of predefined nine locations to operate mobile RFID reader and to capture the signals received from the reference tags in each setting. This process is then repeated at a set of time intervals, referred to here as “Duration”. Data was collected for different durations of 15, 30, 45 and 60 seconds at every point and at each of the nine locations. RSSI was used as the main attribute for signal measurement to process the captured data. Proximity method was used to analyze the capture RSSI data to calculate the RFID reader's location. The different scenarios of each set of experiment are summarized in Table 1.

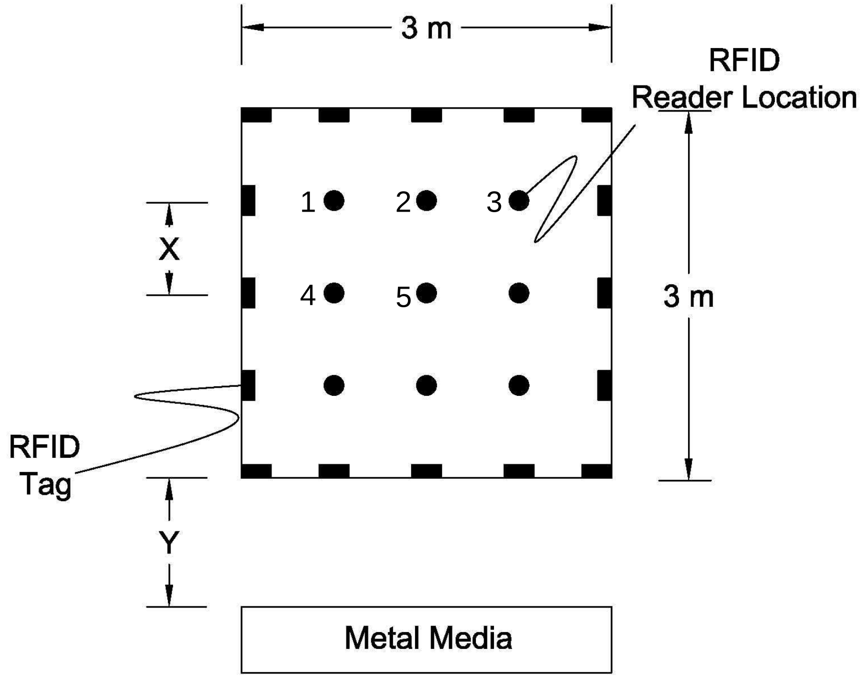

Figure 1- Test bed setup

Table 1: Different characteristics of each sets of experiment

Experiment #	X (m)	Y (m)	15 sec	30 Sec	45 Sec	60 Sec	Metal Proximity Group	Total # of RFID Tags Group
1	0.75	3	√	√	√	√	A	1
2	0.75	2.25	√	√	√	√	B	1
3	0.75	1.5	√	√	√	√	C	1
4	0.75	0.75	√	√	√	√	D	1
5	0.75	0	√	√	√	√	E	1
6	1.5	3	√	√	√	√	A	2
7	1.5	2.25	√	√	√	√	B	2
8	1.5	1.5	√	√	√	√	C	2
9	1.5	0.75	√	√	√	√	D	2
10	1.5	0	√	√	√	√	E	2
11	3	3	√	√	√	√	A	3
12	3	2.25	√	√	√	√	B	3
13	3	1.5	√	√	√	√	C	3
14	3	0.75	√	√	√	√	D	3
15	3	0	√	√	√	√	-	-

Figures 2 and 3 show the errors in all 15 test beds over the 4 data capturing durations used in the study. As a general trend observed in all the experiments, there is a peak in error when the data is captured at zero distance from the metal media as observed in test beds 5, 10 and 15. In test bed 15, there was zero distance between the test bed and metal media, and only 4 tags present with two tags not functioning to serve the desired purpose due to ultimate proximity to the metal. Therefore, the readings for this test bed could not result in a meaningful translation to finding the location of objects; and no results could be calculated for the test bed 15.

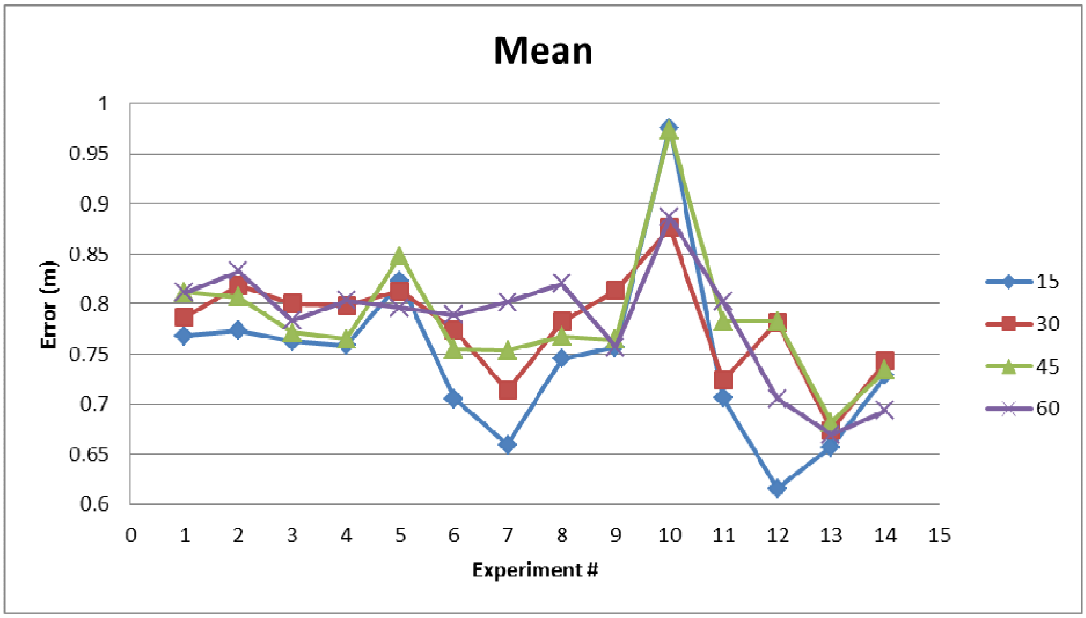

Figure 2- Average errors under different durations in all test beds

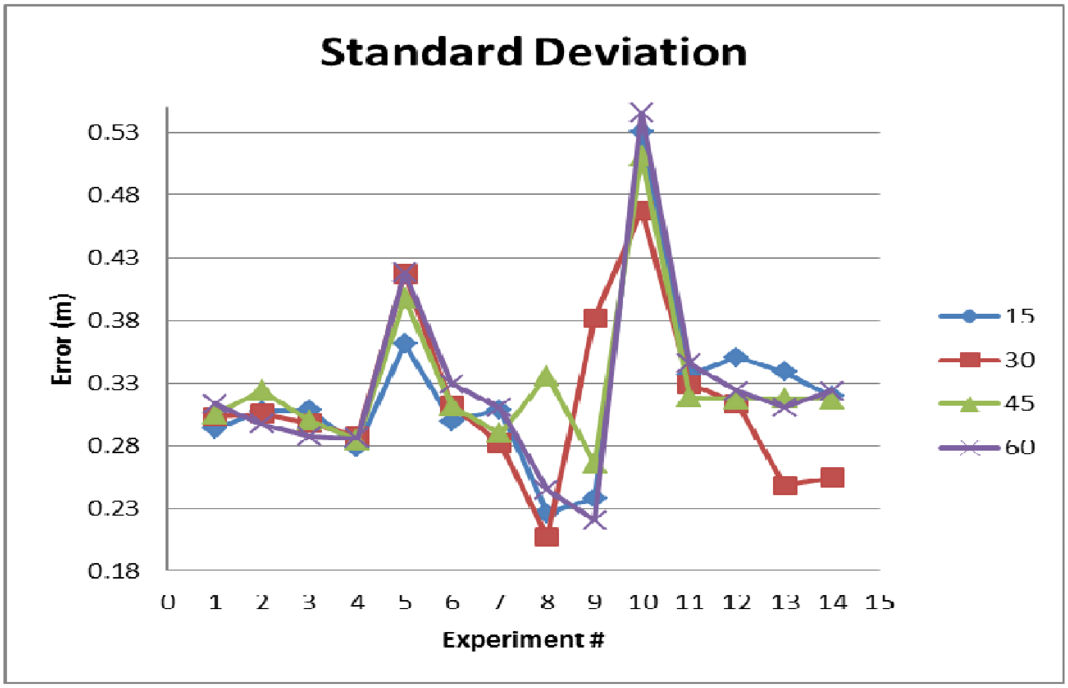

Figure 3- Standard deviation of errors under different durations in all test beds

As shown in Figure 4, the best location to capture data is at the centre of the test bed where there is equal distribution of signals received from the RFID reference tags. The accuracy of localization decreases as the reading locations diverge from the centre of the zone.

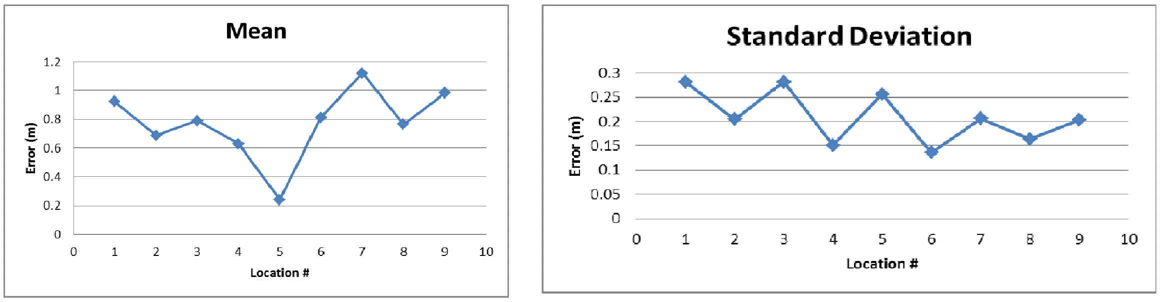

Figure 4- Error observed in the 9 different predefined locations

Results of the experiment divulge that the least error prone sets of readings were captured while the duration for data collection was 15 seconds. As the time window of data capturing increases, the error in identifying location increases. Shorter time durations lead to less amounts of radio waves reflections (Figure 5). The effect of metal medium was one of the other factors under study. In test beds of group E, which was at zero distance to the metal object, the errors were substantially greater than the other groups (Figure 6).

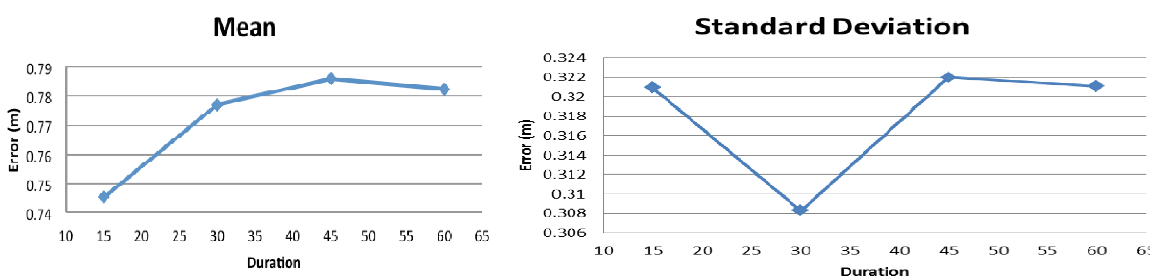

Figure 5- Error observed in all test beds with different durations

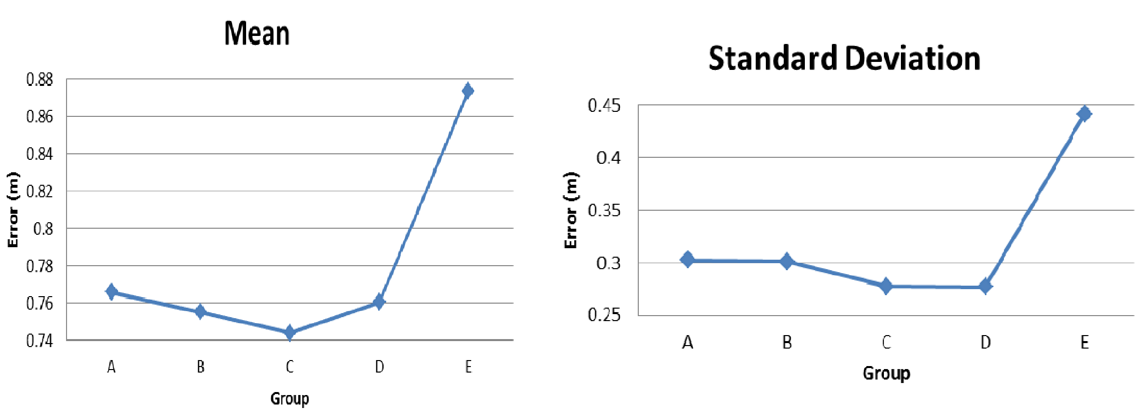

Figure 6- Error observed in all test beds due to metal proximity

Figure 7 indicates that the more tags were deployed in the experiment, the higher the error with the main reason being the interference of many RFID waves. However, when there are less numbers of tags the risks of not yielding results is higher especially with the presence of metal media with zero distance from the tags .

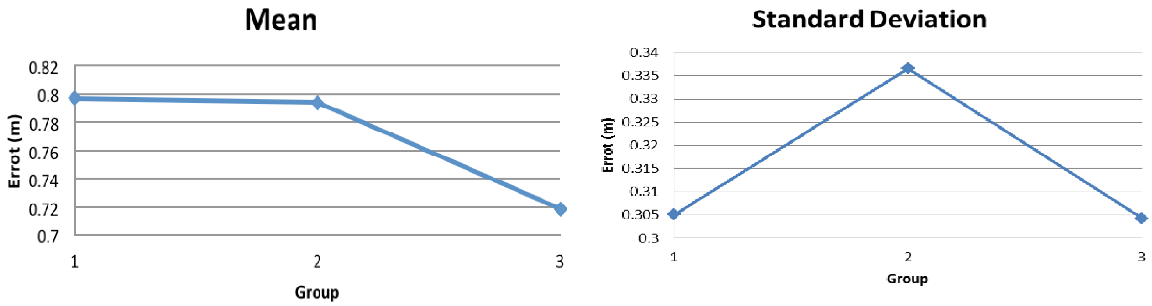

Figure 7- Error observed in all test beds due to the number of deployed tags

CONCLUSIONS

This paper presents a study recently conducted to address the effective use of UHF passive RFID technology in location sensing. The effects of four factors on localization using RFID tags were studied in 15 different settings. These factors include the distribution of RFID tags, proximity to metal objects, location of data capturing point and the time of data capturing. The results prove that least erroneous settings to capture data is the test bed which is furthest away from the metal object, where the reader is located at the center of test bed, has the least duration of data capturing and the least number of surrounding tags. RSSI was used as the main attribute for signal measurement to process the captured data. Proximity method uses RSSI as a weighting method to express how near the reader is to the reference tags. The study resulted in a number of observations, findings, and lessons learned for data acquisition with higher accuracy for indoor location sensing in construction.

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