Automated Switching Mechanism for Indoor and Outdoor Propagation with Embedded RFID and GPS in Wireless Sensor Network Platform

Farhana Ahmad Poad, and Widad Ismail

Abstract— **The present paper relates to a development of tracking system using active Radio Frequency Identification (RFID) embedded with Global Positioning System (GPS) for wirelessly receiving and transmitting indoor and outdoor location data within the coverage area to a host computer via a Wireless Mesh Sensor Network (WMSN) platform to monitor the location of RFID tag remotely. The main novelty of this work is the implementation of an automated switching mechanism for indoor and outdoor tracking either from active RFID tag or a GPS receiver on a single system and platform. The GPS receiver covers the localization of outdoor environment that are done through the satellite system, while active RFID tag provides an identification for each tag holder and cover the localization for certain places that cannot be done with the GPS especially near or inside buildings using WMSN protocol. In WMSN, one of the methods uses to localize tag location is by measuring Received Signal Strength (RSS), and translates the RSS value into the distance between reader, routers and tags. In this paper, we proposed an efficient design of an RFID reader and tag with switching mechanism and present the experimental study that have been done related to the RSS measurement and embedment of GPS with an RFID tag.**

Index Terms— **Localization, Radio Frequency Identification, Global Positioning System, Wireless Mesh Sensor Network, Switching, Received Signal Strength**

I. Introduction

NOWDAYS, technologies that track, trace and locate are emerging, diverse, and are developing considerably. A great deal of research has focused on the tracking such as buses, containers, logistics, vehicles, humans, assets and so on, either for indoor or outdoor environment [1-6]. However, few have been done with the tracking of both indoor and outdoor especially when involving Wireless Sensor Network (WSN) platform [5]. For outdoor environment, GPS is the best solution to track the location since it is unable to work completely indoors or in an environment with obstacles, while for indoor environments, RFID is used to track location since it can provide an accurate indoor location estimation which might fill the gap that is not addressed by other technologies today. Therefore, the development of 2.45 GHz Active Integrated RFID embedded with GPS in WSN platform may constitute an important technological opportunity that could provide companies with the full potential of both positioning technologies. The WSN is utilized to extend the range of data transmission to the reader for real-time monitoring.

In this work, a new RFID system consists of RFID readers and an RFID tag embedded with a GPS receiver is proposed and developed by applying switching mechanism in order to provide identification and sequence location detection for the indoor and outdoor environment in WSN platform, respectively. The RSS value is chosen to calculate the distance and perform the localization since it is an inexpensive Radio Frequency (RF) based approach with low configuration requirements and can be retrieved from the active RFID tag itself without using any external hardware devices. A few experimental studies have been done based on RSS measurement to investigate and validate the signal propagation and system performance of the developed system before and after embedment with GPS receiver in a single hop network.

II. Design of RFID Reader and Tag

A. Hardware Development

RFID is a means of storing and retrieving data through electromagnetic transmission to an RF compatible integrated circuit. A standard RFID system consists of three major components: RFID tags, RFID readers, and middleware software for communication. RFID readers read the data emitted from RFID tags through a defined radio frequency (RF) and protocol to transmit and receive data. RFID tags are classified into two broad categories: passive and active. Passive tags, operating without a battery, reflect the RF signal transmitted to them from readers and add information by modulating the reflected signal. On the other hand, active RFID tags contain a radio transceiver powered by an embedded battery. Due to the onboard radio, active tags have a longer working range than passive tags.

The application of RFID is capable for machine to machine communication (M2M) and such, it is appropriate to be used in this proposed system. Real-time location monitoring system application may require long range tag detection, due to this reason, active RFID tag is developed based on its ability to transmit over long distances and offer

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larger memory capacities. Figure 1 shows the overview of the system architecture that can be used to track humans for example Hajj pilgrims in an indoor and outdoor environment. The RFID tag can be given to each person (Hajj Pilgrims) that consist of Active Integrated RFID embedded with GPS receivers. The GPS receiver will cover the localization of outdoor environment that are done by the satellites, while RFID will give identification for each tag holder and cover the localization for certain places that cannot be done with the GPS especially near or inside buildings using WMSN protocol.

All the information gathered from the tag will be networked to the RFID reader connecting with the main computer at the monitoring station. The RFID tag will periodically send out location data from GPS receiver to RFID reader at the monitoring station to track and trace the movement and sequence location of the Hajj pilgrims only when the GPS having valid signals from satellites. However, if there are no valid signals from satellites, the localization will be done with the RFID tag using RSS values retrieve

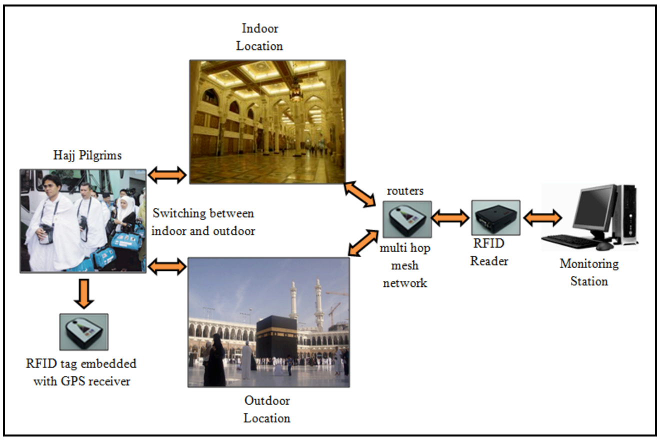


Fig. 1. Overview of the system architecture.

from the module. The RSS value will be asked periodically or by request from the RFID reader to update RSS value information which can be used to calculate distance from anchor node (static node) which having a fixed location in this network. Instead of tracking indoor and outdoor, the RFID tag node identification can be reset from the RFID reader based on user requirement and this application contributes to M2M communication without human intervention. Figure 2 shows the block diagram of the embedded hardware architecture.

B. *Software Development*

The RFID reader and tag proposed in this work is the in house built in 2.45 GHz multi-modes integrated RFID with the mesh network capability system using ZigBee Technology. The development of a complete system consist of a workstation connected to a reader, routers and tags with multiple mode's state such as continuous and sleep mode. The algorithm implemented in this work is designed with the ability of switching for indoor and outdoor application. The RFID tag transmits continuous data to the RFID reader if the GPS has a valid location data, therefore in this situation the system can be regarded as Tag Talk First (TTF) since the RFID tag will start the communication to the RFID reader. However, if the GPS has invalid location data, the RFID tag is put into sleep mode and woken up periodically according to its schedule while waiting for an incoming broadcast frame from the RFID reader (command) asking for RSS value to estimate the distance. Therefore in this situation the system can be regarded as Reader Talk First (RTF) since the RFID reader will start the communication to the RFID tag. The incoming broadcast frame sending from RFID reader to RFID tags to find an indoor location can be sent manually by pressing a request button or periodically send the command when alarm is triggered by the real time clock (RTC) every an hour to RFID tags available in the network. The node identification in the RFID tag also can be reset from the RFID reader based on users' request. All communications between RFID reader, routers and tags are in application programming interface (API) mode and application transparent (AT) mode.

III. Experimental Study

This paper only focussed on a system consists of an RFID reader and tag embedded with GPS receivers that are tested to communicate in a single hop ZigBee network. The

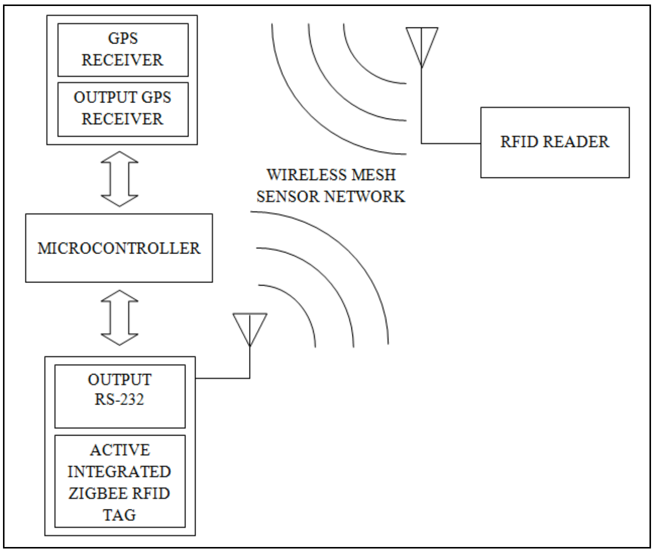


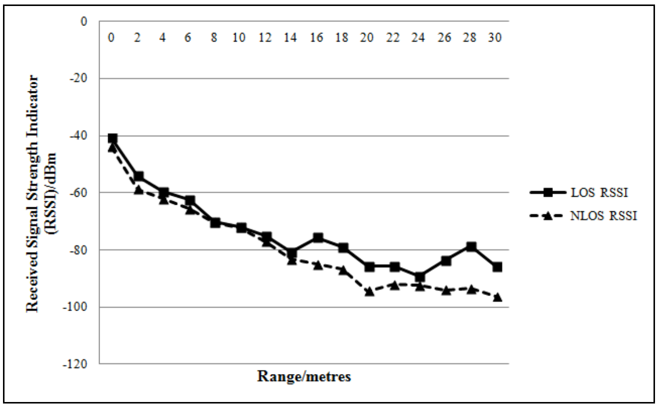
Fig. 2. Block diagram of the embedded hardware architecture.

measurement of RSS is performed using two different types of antenna in a single hop wireless ZigBee network to validate the signal propagation and capability of the system for indoor and outdoor environment, respectively. Future work will be done to communicate with multi hop ZigBee network and the successful deployment of WSN will be evaluated by some others basic performance parameters such as coverage ranges, link failure probability, packet delays and throughputs.

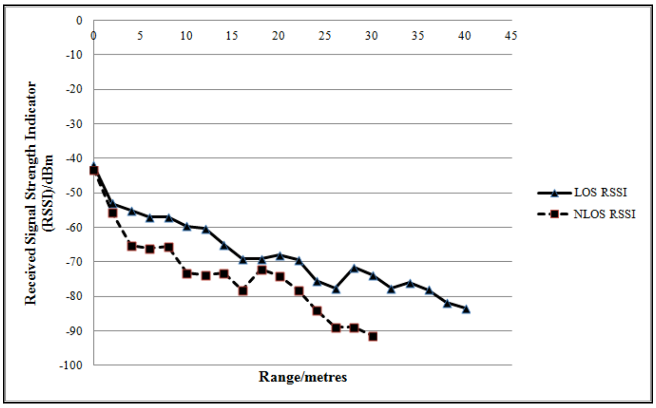
A. *RSS Measurements*

The Received Signal Strength (RSS) is the signal level of the last received packet that is expressed in – dBm. There are three ways to read RSS values which are by encoding into pulse width modulated signal available at Pin 6 of the RFID module, via an API command or AT command. The RSS values reported by the RFID module in this experimental study are between -40 dBm to -104 dBm. However, the commonly reported value is accurate between -40 dB and the sensitivity of the module. The RSS measurements are implemented by connecting RFID reader and RFID tag as a coordinator and a router/end device and then vary the distance between them to measure the relationship between RSS values and distances.

The RSS measurements are done in the line of sight (LOS) and non line of sight (NLOS) directions in a parking area and inside building. Figure 3 and 4 show the comparisons between RSS values for LOS and NLOS indoor and outdoor location using chip and whip antenna, respectively. The graph show that the RSS values of chip antenna are slightly differences for outdoor location by about +1 dB to + 17 dB , while for indoor location the differences are about +0.1 dBm to +15 dBm. For outdoor location using whip antenna, the RSS values differences are in the range of -1.5 dBm to +10 dBm, while for indoor location, the RSS values differences are about -1.8 dBm to +16 dBm. From the results obtained, it can be concluded that the RSS values for LOS are better than NLOS for all situations as described in Figure 3 and 4. The data are



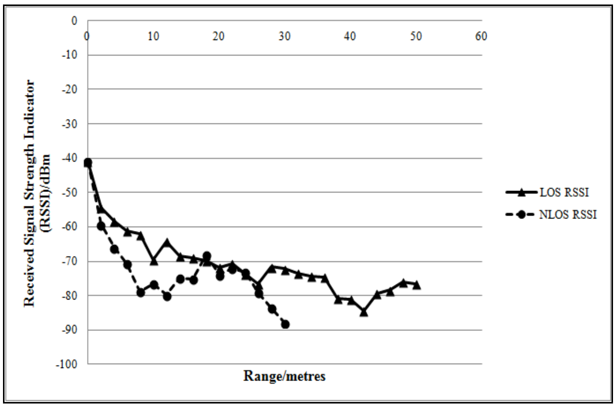
(a)



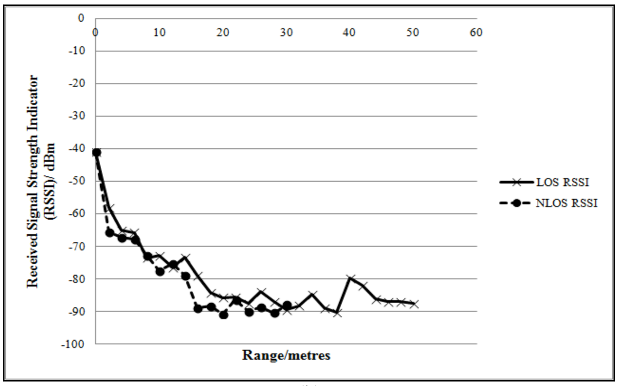
(b)

Fig. 3. Comparison between LOS and NLOS location detection based on RSSI using RFID with chip antenna (a) Outdoor, (b) Indoor.

fluctuated due to the multipath propagations occurred inside building and obstacles around the building area. Based on Figure 5 (a) and 5 (b), the average RSS values using RFID with chip and whip antenna are having some differences both for indoor and outdoor location. However chip antenna gives the best RSS values compared to whip antenna and more practical as a mobile tag in this work due to its compact physical structure, flexibility, stability and practicability.

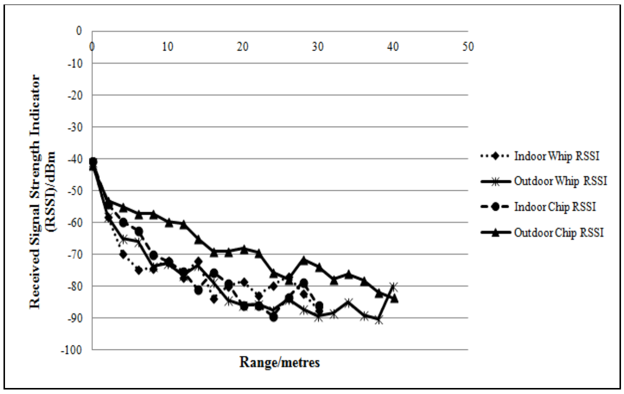


(a)

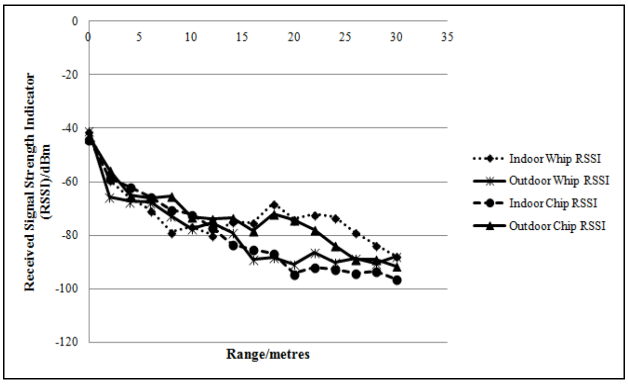


(b)

Fig. 4. Comparison between LOS and NLOS location detection based on RSSI using RFID with whip antenna (a) Outdoor, (b) Indoor.



(a)



(b)

Fig. 5. Comparison of RSSI values using RFID with chip and whip antenna (a) LOS, (b) NLOS.

B. Integration of Active RFID Tag and GPS Receiver

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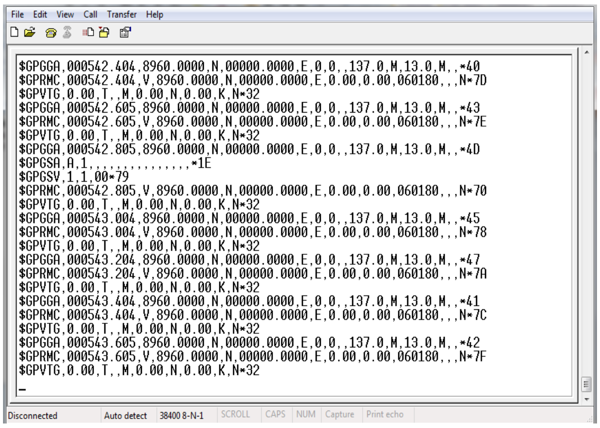
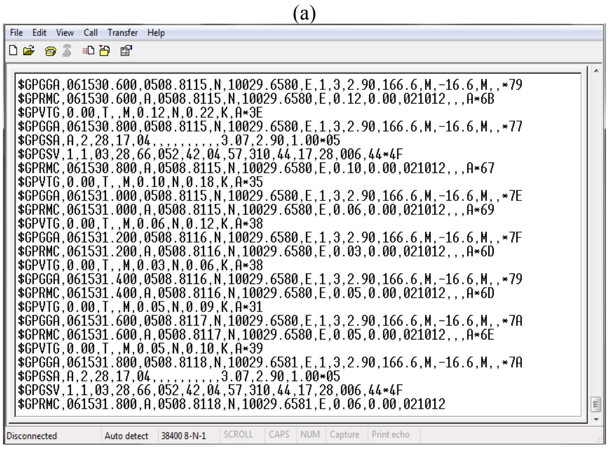
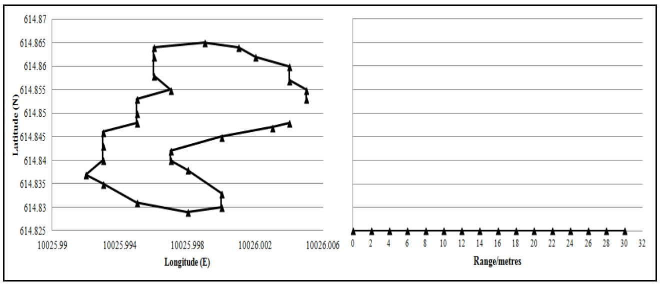


(a)



(b)

Fig. 6. Data received from the GPS receiver without embedment with RFID tags, (a) Indoor , (b) Outdoor.



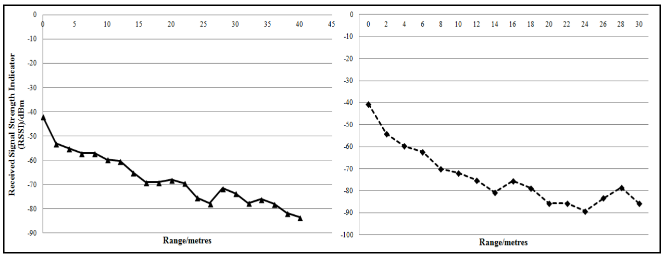
(a) (b)

Fig. 7. Location detection using GPS only without switching mechanism, (a) Outdoor, (b) Indoor.

A complete indoor and outdoor tracking system using ZigBee active and long range RFID system complied with ISO 18000, Part 4 (2.45GHz) standard viable for practical implementation embedded with switching mechanism to GPS is successfully developed in this research work. The sample area taken for this tracking system is a university area with several buildings. The tracking tag is embedded with GPS and having a special ID addresses which represents a person. Since the GPS receiver only works in areas that can be detected by the satellites, RFID is used to identify and localize the location of the tagged person when no GPS location data. Figure 6 shows the example of raw data received from GPS receiver, while Figure 7 shows the longitude and latitude data at certain locations for indoor and outdoor propagation using GPS receiver only without embedded with RFID tags.

The data show that the GPS receiver can only give values for outdoor locations, however, for indoor locations the signals received by the GPS receiver are weak and disappeared at certain location due to the obstacles in the building. The main disadvantage of the GPS receiver is it does not provide any identification to a person that is tracked by the module and the data received by the GPS receiver cannot be wirelessly transferred to another location in long range distance.

RFID usually uses to identify and locate things or person either indoor or outdoor locations. The locations predicted by RFID are less accurate compared to GPS receiver, especially in an outdoor environment, however, in an indoor environment the GPS receiver signals are weak and disappeared making the RFID is more useful to track the locations. There are several techniques to predict the locations of RFID tag for example Receive Signal Strength (RSS), Time of Arrival (ToA), Time Differentials of Arrival (TDoA), Angle of Arrival (AoA) and etc [7]. However, in this work, the RSS values have been chosen to predict the location since ZigBee technology has the capability to retrieve the RSS values from the module itself. Figure 8 shows the RSS values for indoor and outdoor location using RFID only. From the graph, the RFID system is able to give RSS values in both indoor and outdoor locations compared to a GPS receiver that gives location data in an outdoor environment only based on satellite reception. Theoretically, the maximum value of RSS is -40 dBm and the minimum value is -104 dBm and the RSS will decrease according to range increases. Figure 8 (a) describes the RSS values are decreasing with range from -42 dBm to -84 dBm for 0 m to 40 m in an outdoor environment while Figure 8 (b) shows the RSS values are decreasing with range from -41 dBm to -90 dBm for 0 m to 30 m in an indoor environment with line of sight (LOS) direction. All the measurements related to RSS are done in the range of 30 m to 50 m due to the limited space available inside and outside building.



(a) (b)

Fig. 8. RSS values for location estimation using RFID only without switching mechanism, (a) Outdoor, (b) Indoor.

In this work, the term inside and outside building referring to indoor and outdoor environment and the building is located in between of other buildings which can affect the values of RSS for outdoor measurement as well as indoor. Figure 9 describes the differences between indoor and outdoor RSS values in LOS direction, where the RSS values for outdoor are better than indoor by about -1 dBm to +17 dBm. This is due to the multipath propagation occurs inside a building that can reduce the RSS values and minimize the coverage range of the RFID module. To overcome the disadvantages of GPS receiver and RFID module, it is suggested to combine both technologies to provide localization for outdoor environment that is covered by a GPS receiver and indoor environment by the RFID module. As mentioned earlier, the RFID module has its own

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address number which able to differentiate and identify the module and able to send data in the WSN platform to provide long range detection to the person that is located by GPS receiver.

To prove this concept, a simple testing has been done by using the developed system with switching mechanism in a university campus, where the identification data from RFID and location data from GPS receiver embedded with RFID tags are sent to the RFID reader at the base station using a single hop wireless transmission when the satellite having a valid signal as shown in Figure 10 (a). However, if the valid signals are not detected by the GPS receiver, RFID will do

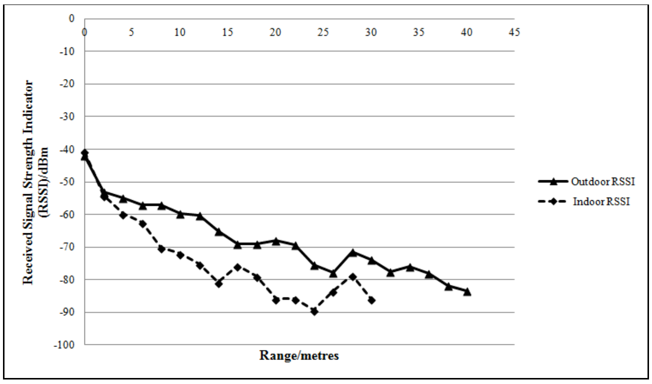
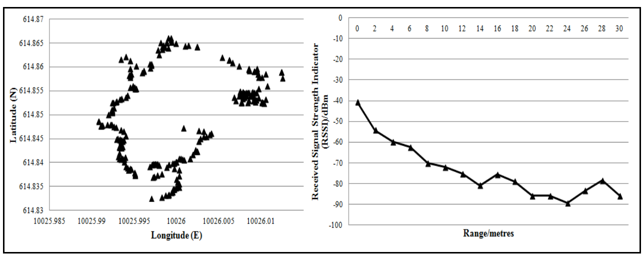


Fig. 9. Comparison of RSS values between indoor and outdoor location using RFID only.

the location estimation by using RSS values that are retrieved from the module as shown in Figure 10 (b). From the results, it can be concluded that the embedment between GPS receiver and RFID tag are successfully done, since it can provide the location and RSS data based on its situation either outdoor or indoor location with the proposed switching mechanism on a single system. The identification is also provided by the RFID tag along with the location or RSS data to the RFID reader in WSN environment. Further work will be done using more than one tag in the multi hop wireless network to investigate the performance of the developed system when more than one tag involved in the transmission.

IV. Conclusion

The proposed system has many advantages, the main advantages are its reusability, since the architecture is reusable, it is expected that the whole system platform can be reused by professionals and non-professionals user. The system also able to be configured in mesh networks with wireless nodes that are capable of multi-year battery lives with the ability of switching for indoor and outdoor application in a single system. The solution allows broad based deployment of reliable wireless networks with low complexity and low costs, where various types of equipment from any numbers of vendors can be integrated plus the embedded GPS for improved localization solution. By implementing this proposed wireless mesh network, a low cost and low power location monitoring system for indoor and outdoor environments where other positioning system has typically performed poorly can be implemented. It is not possible to locate people or other objects in an indoor environment without using other expensive devices.



(a) (b)

Fig. 10. Location detection with switching mechanism, (a) Outdoor, (b) Indoor.

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