Autonomous Patrolling Robot for Security and Monitoring

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Abstract: ***The basic idea is to construct a mobile patrolling robot for security and monitoring. For an on-demand robotic system, a location aware module provides location information of objects, users, and the mobile robot itself. The probability-based location aware module is modified to handle RSSI measurements with a maximum of calibration. The resultant location calibration module will be more light-weight. In addition, coherent functional global patterns and principal of emergence is introduced into the mobile robot. The use of WSN sensors increases the flexibility of mobile robot. In addition to this, a communication algorithm is designed with minimal overhead for transmitting process request and feed between the robot, WSN, user and server. The location aware module and the message passing algorithm makes use of DVR algorithm to compute the distance between the mobile robot and WSN. A fault tolerant feedback control system is programed to handle fault up to certain extent. The light weight location calibration and communication module is integrated into a current formation mobile robot with intruder detection system having the capability of capturing and transmitting live feed of the area under surveillance to the user's mobile in real time.***

Keywords*:* Location aware system, received signal strength indicator, security robot, sensor network, gossip

1. Introduction

Conventional security systems have various limitations and shortcomings. For instance, a security agent using conventional security systems has to dispatch security guards to respond to alarms. This creates a heavy burden for security agencies, especially considering a high portion of alarms are actually false alarms. Furthermore, it normally takes some time for the security guard to reach the alarm location to handle the situation. Critical time may have already been lost by the time the security guards arrive on the scene. One possible solution for such problems is to install a large number of security cameras throughout the guarded area to monitor any possible abnormal conditions. However, this solution may require high installation costs and pose privacy issues. The development of robotic security and monitoring systems for indoor environments such as home, offices, etc. provides sufficient flexibility to help security guards that lowers the relative cost as long as the demand for adequate security is satisfied.

Unlike a stand-alone security robot, which is normally equipped with a variety of sensors but has only a limited sensing range, on-demand security robots can obtain information thorough sensory nodes of the guarded area and make it available online. When integrated with the WSN, a security robot can acquire information from the entire sensed environment in real time.

For an on-demand robotic system, a locational aware module is required to provide location data of objects, users and of the mobile robot itself. Localization algorithms should meet the requirements of various hardware configurations such as signal transmission, power requirements, and computational complexity. There are three main approaches to gather location information: range-free, range-based, and fingerprinting.

Range-free localization is based on the connectivity of the network. It does not require any special hardware and the content of the messages is received through simple operations. Range based localization, on the other hand, estimates the distance between nodes using certain ranging techniques. The distance information can then be used to locate the position of unknown sensor nodes. Most range-based localization algorithms adopt the received signal strength indicator (RSSI) technique to estimate the distance based on the strength and path loss model of the signal that was received. The finger printing approach is based on the concept of identifying a specified position by relying on RSSI data received from nearby nodes. This approach uses two phases, a training phase, and an estimation phase.

The currently available location-aware solutions, suffer from the requirement of prior parameter training and retraining in different application areas. This makes it very difficult or even sometimes impossible to build up a location aware system in a totally new environment.

2. Existing System

To overcome limitations posed by uncertainties of RSSI, a novel probability-based approach for estimating location by modelling the RSSI versus distance relationship with discrete probability density functions is designed and used. This approach aims to provide a straightforward method of describing different distributions without losing generality.
While most current approaches use mathematical equations to model the RSSI versus distance relationship, this method adopts the original RSSI versus distance data to construct its own model. Furthermore, instead of using trilateration or fingerprint techniques, the location is estimated by accumulating a probability histogram observed from several reference nodes on a local probability map.

This approach will be shown to have better tolerance against fluctuations and inconsistencies inherent with the RF signal. It is also flexible because it uses the available number of the RSSI measurements and the deployment of ZigBee nodes. This method first assume that the locations of all reference nodes are already known and the RSSI between each pair of nodes can be received. It contains a calibration phase that models the RSSI versus distance relationship and a localization phase that estimates the location using a filtered 2-D probability map.

The calibration phase estimates the distance between the nodes based on the RSSI measurement. Instead of using a mathematical path-loss model, the RSSI versus distance relationship is collected and modelled with a series of probability histograms, which records different distances measured under a fixed RSSI. The histogram therefore represents the discrete probability density function (pdf) of a given RSSI value.

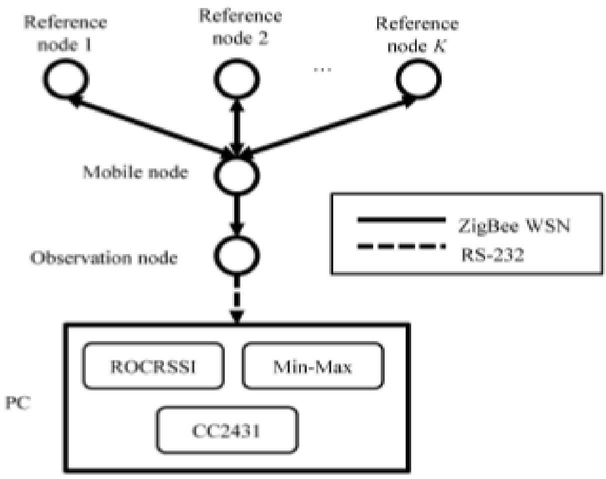

Figure 1: Dataflow in existing location calibration techniques

In the next step, the location of the mobile node is estimated using the RSSI values measured from several nearby reference nodes. The concept is to apply the 2-D multilateration method with the estimated pdfs. A trilateration method determines the location by finding the intersections of circles given from: 1) the centres of the reference nodes and 2) distance between the mobile node and several reference nodes.

3. Proposed System

For an on-demand robotic system, a location aware module provides location information of objects, users, and the mobile robot itself. A probability-based approach is used to build a location aware system. Since the RSSI measurements are handled with minimum of calibration by considering offline calibration measurement of a ZigBee sensor network. The on-demand robotic system uses a probability-based location aware module to get location information of objects, users, and the mobile robot itself. The mobile robot makes use of WSN which includes a pyro sensor, infrared sensor and a microphone connected over a ZigBee network with a moving bot. Whenever, the sensor detects any sign of an intruder, it sends the signal to the moving bot. The moving bot gets the location information from the location aware module. The location is computed based on RSSI values. The bot then moves to the area where intruder was detected and transmits the live feed of the area to the user's smartphone and security agency over a Wi-Fi network. Since the WSN is been used here, the flexibility of the mobile bot is increased considerably.

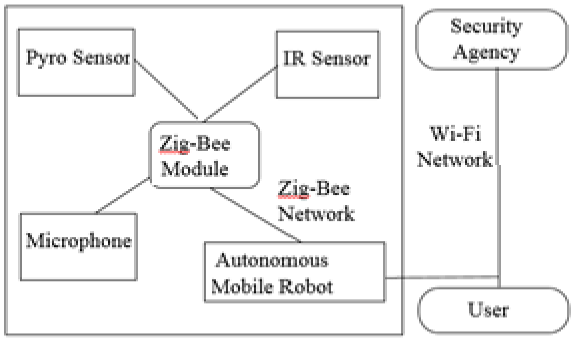

Figure 2: System architecture

In this approach, the inconsistencies often seen in RSSI measurements are handled with a minimum of calibration. The location aware system is integrated with an autonomous mobile robot with three alarm sensors to monitor abnormal conditions. If an intrusion is detected, the robot immediately moves to the location and transmits scene images to the user in real time. The signal uncertainty is handled by making the sensor nodes localized since the RSSI measurements are handled with minimum of calibration by considering offline calibration measurement of a ZigBee sensor network without taking into account the previous RSSI values.

The entire communication is done using a gossip protocol. Gossip protocol proves handy in scalable systems for communication since it's inspired by the way that gossiping propagates messages in a network and disseminate content through a network based on periodic exchanges of data with random members of the network.

The specific problem that is being addressed here is the overhead when the sensor nodes are localized. Furthermore, the position of the reference node is utilized by saving and sending it to the mobile node in the localization phase. The Location aware computation can then be performed on the ZigBee module by taking into consideration even the previous RSSI values. It's designed to function robustly and efficiently. Each node of the system is required to periodically exchange information with a number of its peers. The choice of which peers nodes communicate with, is crucial to how information gets disseminated through the network.

Theoretically, a node could randomly select a subset of all the available nodes in the network. In practice, however, this is not feasible since it would require each node to store a complete network membership table which is expensive to store and maintain. So the peer sampling framework of [JGKS07] is considered where each node instead maintains a relatively small local membership table providing a partial view of the network which is periodically updated using a gossiping procedure.

Furthermore, it is also interesting to examine the performance of the target tracking with the proposed method. In addition to this, the secondary objective is the optimization problem, which minimizes the overhead of location calibration by using DVR algorithm.

4. Pseudocode Used

This code is executed at the node each time it receives a query message {e;w;B}.

```
...
Resources:{....,4=>(Link0,150),5=>(Link1,100)}
procedureUtilFn(BALL,BIN,ALLOC)
...
for all OBALL in cloudserver except BALL do
OBIN <- Alloc[OBALL]
if OBIN != NULL && OBIN != BIN then
for all LINK in PATHtoLCA[BIN][OBIN] do
UTIL[LINK] <- BW[BALL][OBALL] + BW[OBALL][BALL]
if OBIN == NULL then
for all LINK in PATHtoROOT[BIN] do
UTIL[LINK] <- BW[BALL][OBALL] + BW[OBALL][BALL]
if OBIN != NULL && OBIN==BIN then
for all LINK in PATHtoROOT[BIN] do
UTIL[LINK] <- BW[BALL][OBALL] + BW[OBALL][BALL]
```

The (n X m) matrix used to store both offline and online RSSI values at every point it time, t is solved using the equation

$$E(j) = \sum_{i=1}^{n} C(i,j) + A(j) \quad (1)$$

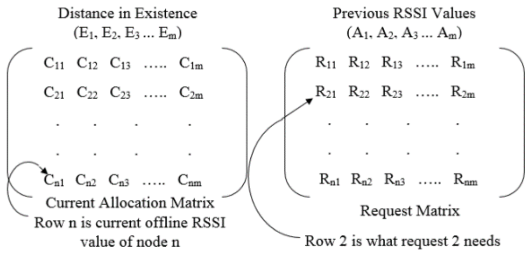

Figure3: Computation matrix

5. Performance Analysis

The proposed system was analysed for performance and overhead with existing location computation techniques. The result of performance analysis is visualized in the form of graph to provide a clear insight on the improvements achieved. This analysis was carried out on the following metrics: throughput, failed task, fairness index, efficiency and message delivery cost. The resultant values is tabulated.

Table 1: Parameter measurements

Metric\ Scale	2	4	6	8
Throughput Ratio	.552	.558	.563	.692
Failed Task Ratio (%)	27.2	28.6	29.8	21.7
Efficiency	.58	.57	.56	.72
Fairness Index	.542	.558	.651	.668
Message Delivery Cost	.470	.506	.528	.591

The tabulated values are graphicaly plotted below for comparison of the existing and the proposed system. Series 1: Existing System, Series 2: Proposed System.

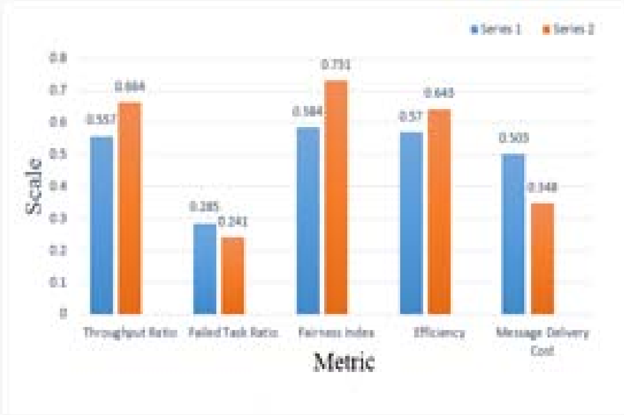

Figure 4: Performance analysis of proposed system vs existing system

The overhead reduction achieved for computing the location based on analysis result, is visualized using a pie chart.

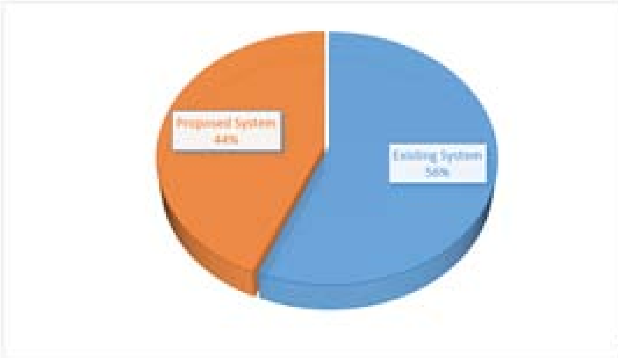

Figure 5: Computational Overhead

The values and the graph proves that this system is more efficient than any existing location calibration techniques based on the ground of fairness, adaptability, scalability and minimal cost for communication and calibration and has minimal computational overhead.

6. Conclusion

This entire work is based on creating a light weight communication and location module to provide location information using RSSI measurements with offline and online calibration and previous RSSI values. Technically speaking, the solution is to use the position of the reference node by saving it in a matrix and sending it in the localization phase whenever needed to compute the location information. The Location aware computation can then be performed on ZigBee module by including the previous RSSI values. The computational overhead of location and communication module has decreased from 56% to 44%. The overall efficiency of the proposed system has increased to 64.3% where as that of existing system is at an average of 57%. Furthermore, the overall delivery cost has being reduced considerably from 50.3% to 34.8%.

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