Passive and Cost effective People Location Tracking System for Indoor Environments Using Distributed Wireless Sensor Network

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Abstract—**To be context-aware, one of the central issues in sensor networks is location tracking, whose goal is to monitor the tracking path of a moving object. This paper describes our indoor location-tracking system for in-building, mobile, location-dependent healthcare applications. Ceiling-mounted beacons are spread through the building which publish location information on RF and ultrasonic signals and allows applications running on mobile and static nodes to learn their physical location. The target to be tracked carries listener node, this node listens the beacons information as they arrived and forwards these beacons to the base station .At the base station the multilateration was used to determine the location of the listener. This information at the base station was further processed to check the activity of the person. In the location-tracking system we also could calculate the user's activity, that is, how much the user moves in span of time. The monitored activity data of the patient can support doctor or caregiver to see the status of the patient.**

Keywords— **Indoor Location, Beacons, Listener, Base Station Context aware.**

I. INTRODUCTION

In recent, sensor networks have opened new vistas for a wide range of application domains. These sensor networks usually comprise small, low-power devices that integrate sensors and actuators with limited on-board processing and wireless Communication capabilities. Since sensor networks are typically used to monitor the environment, one fundamental issue is the location-tracking, whose goal is to trace the roaming paths of moving objects in the network. One of the most important areas where the advantages of sensor networks can be exploited is for tracking mobile targets. Scenarios where such network may be deployed can be tracking patients at hospital, tracking elderly person at home, tracking the activities of the suspicious person etc. The importance and promise of location-aware applications [1] has led to the design and implementation of systems for providing location information, particularly in indoor and urban environments where the GPS [2] does not work well. Typical indoor applications require different types of location information such as physical space, position and orientation. Determining location in the indoor environments presents special engineering challenges. The scale of indoor environments is such that the location information desired should be defined grained. There are many indoor locations tracking system available like RADAR [3], Active Bat [4], Active Badge [5] etc. User privacy, accuracy, architecture and cost etc. determine the usefulness of the tracking system. Our goal is to develop an architecture that is different from existing indoor location systems like the Active Badge or Active Bat, which use passive ceiling mounted receivers that obtain information from active transmitters carried by users. The indoor tracking system uses sensor nodes with an ultrasonic sensor and a receiver, MCS410CA (Crossbow Technology Inc. USA) [6]. This sensor node is designed for low-power operation and can be used as a location-aware sensor computing node (running TinyOS [7]), to which a variety of sensors can be attached. In this system the beacons are working as an active transmitters and the listener as a passive listener. It uses a combination of RF and ultrasonic hardware to enable a listener to determine the distance to beacons, from which the closest beacon can be easily determined. This system uses the decentralized mechanism i.e. all beacons is independent to each other and there is no need to connect each other.

II. SYSTEM ARCHITECTURE

The objective of the target tracking is to generate accurate estimate of the target position and the realization of physical space like room. In some application it is also important to determine the origin and identity of the target. Distributed sensors can improve tracking accuracy by providing complementary information in determining the location. The architecture which is used for tracking system also has several constraints. The centralized architecture has some constraints related to high cost and privacy issues. The distributed architecture does not provide optimal performance but require less computation and is more robust since there is no single point of failure. In this location tracking system the sensors are following the distributed approach which is more desirable as per our design goal. The components of the system architecture are shown in Fig. 1, dividing components according to their functionality. This indoor tracking system consists of location beacons that were attached to the ceiling of a building, and receivers, called listeners, attached to the target and the base station connected with a base node using RS-232 serial interface.

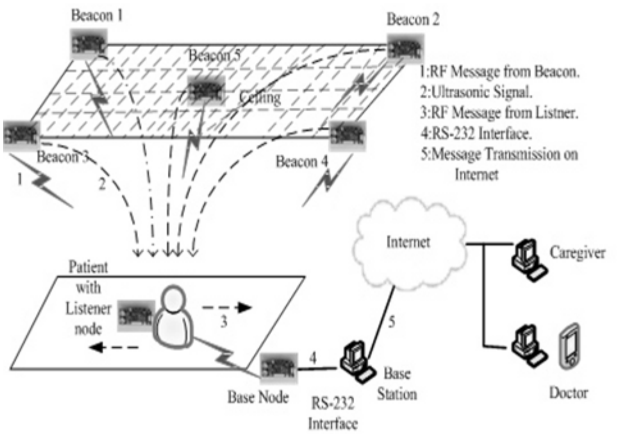

Fig. 1 Architecture of the proposed indoor location tracking system

The person to be tracked carries a listener. By carrying only the listener node the cost of the tracking system can be reduced as the location tracking information is more useful to the caregiver compared to the patient. It is the advantage of this system compared to cricket indoor location tracking system. A beacon is a small device attached to some location within the geographic space it advertises. A listener is a small device that listens to message from beacons, and uses these messages to infer the space it is currently in. The listener, beacons, base node had same structure but we distinguish each other in their program.

III. SOFTWARE ARCHITECTURE

Wireless sensor nodes run application software for getting location information that was developed using ‘nesC language'[8] which runs on TinyOS. The beacons and the listener run the different application software. The parameters like the ultrasonic time interval between the beacons, distance measurement considering the effect of temp on the speed of the sound can be configured. The same node can work as a listener and as a beacon but their application software is different. At the base station two program is working one is showing the position of the target and other is calculating the motion activity of the person. These programs are developed using java language. As the target is moving in the space its position and space information is also saved in data base for further use. The position of the target is continuously updated on the base station.

IV. SYSTEM OPERATION

Beacons periodically transmit an RF message containing beacon specific information such as a unique space ID, the beacon’s coordinates, the physical space associated with the beacon, etc. With an RF message it also sends an ultrasonic signal. As the speed of the RF signal is much faster (>=10^6 times) than the ultrasonic signal, the listener determines the time difference of arrival (TDOA) between these two signals. If the speed of the ultrasonic signal is known than by multiplying this speed with TDOA, determines the distance from the beacons. The listener listens from each beacon and calculates its distance from each beacon. At the same time the listener also transmits the distance message to the base station mote which is connected with a server PC. At the base station all the calculation is done and the space and the coordinate of the listener are determined. Our tracking system works on the triangulation algorithm [9]. For implementing this algorithm the listener at least receive three beacons message. The beacons are localized manually i.e. they are assigned the space ID and the three dimension coordinates by using a reference coordinate system. Space id is user- or application-specified names associated with spaces such as rooms or parts of rooms. The range of the beacons message also plays a prominent role as at least a listener should hear three beacon messages for determining its location. It should be insured that the beacons should not form a circle or square when deployed. The position of the target is calculated using triangulation algorithm at the base station. We used some application program provided by cricket location tracking system [10] for visualizing our output. The location of the listener is displayed on GUI and continuously updated as the user moves in the environment

The activity of the person is determined by calculating the distance traveled by the target in the given span of time. The location information at the base station can be transferred further to the doctor’s computer and the caregiver of the patient. We can make this system more effective by providing the information to the person concerned through handheld devices.

V. Sensor node deployment for test

This tracking system was evaluated in an open room as shown in Fig. 2. For an easier estimate of the tracking error we marked the local coordinate reference system and we deployed the sensor nodes according to that local reference coordinate system. The beacons that are placed on the ceiling have been localized manually. The performance of the developed indoor tracking system was evaluated using five beacons that were placed on the ceilings of a room and the target to be tracked carries the listener node. In Fig. 2 we have shown the placement of the beacons in the ceilings. The distance between each beacon is also shown. For getting space information, beacons were named as DSU0, DSU1, DSU2, DSU3, and DSU4 for our convenience. The deployment is done in two environment one is full of interference sources and other is lack of interferences sources.

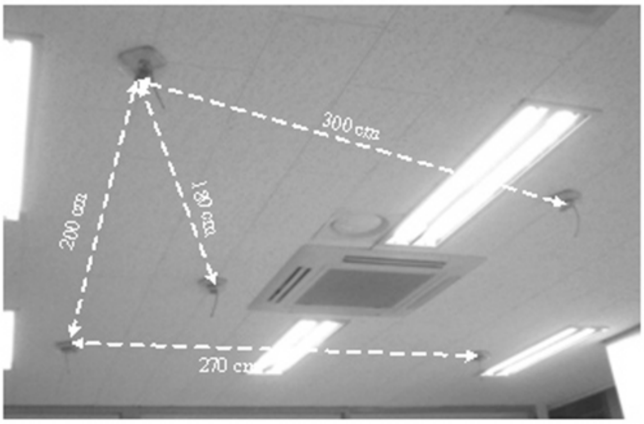

Fig. 2 Deployment of the beacons in the ceilings for practical test

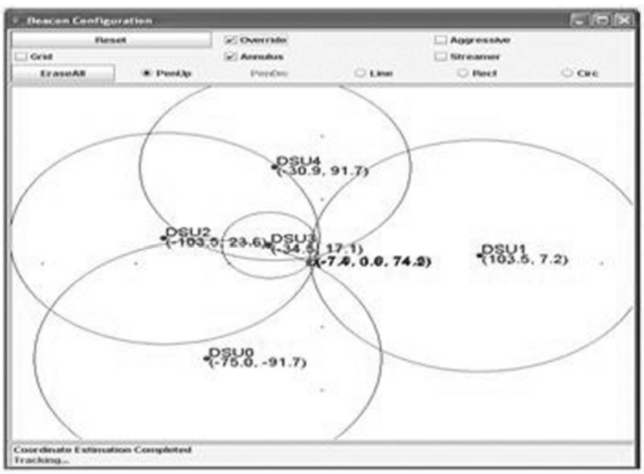

Fig. 3 Location information of the target at the base station

VI. Performance evaulation

In this part the experimental procedure and results obtained from the evaluation of our indoor tracking system is summarized. The procedure for tracking the moving target is in first part, the activity monitoring of the target is in second part and the overall results obtained from the experiments is summarized in last part separately.

A. Tracking the moving target

The target to be tracked carries a listener node. The beacons send the messages one by one to the listener. The beacons message contains its location information in three dimensions with space information. The beacons information also contains beacons configuration information. By seeing the diagnostic LED provided on the sensor node we can check whether the listener is getting the RF and ultrasonic signals well or not and also can check the battery level. At the base station the distance information is displayed on the GUI (graphical user interface) and further can be transferred to concerned authorities. In Fig 3, the location of the target is shown and the location is continuously updated as the target moves in the environment.

B. Target activity monitoring

The monitoring of patient's activity is more useful in home healthcare [11] and in hospital. The activity means the traveled distance for a specified duration by elderly person or patient. Sometimes it's required to store the motion of the patient in the data base such that if in the future any healthcare professional can check the activity of the person. The activity of the person may be like visit frequencies per room, the lapses of time the resident spend in every room and the last motion events. We have developed one application which stores the motion history of the person in terms of space and three dimension coordinate information. The distance traveled by the person can be calculated using time stamping. Currently, time stamping is done at the base station when motion events are received. In the back-end, data are stored in a database.

C. Experiment results

For the practical test of our developed system, the location of the target was tested by putting five beacons on the ceiling and measuring the coordinate and space information at the base station. The testing was done by putting the beacons 200 cm apart and 500cm apart separately. As the user moves in this testing environment, his 3D coordinate and space information is determined at the base station and displayed on GUI as shown in Fig 3. The coordinate and space information provided by this tracking system sufficiently accurate compare with the coordinate information calculated by scale manually. The accuracy of the coordinate was 5~10 cm. As the distance between the two beacons increased beyond 500 cm the space information is correct but the accuracy of the 3D coordinates deteriorates. This accuracy problem can be recovered by putting the beacons closer to other beacons below 500 cm. The activity of the person was measured based on the tracking results obtained from the tracking of the target. The accuracy of the distance is same 5~10cm.

We can also configure how much time the target spent in which space and the total distance traveled by the target. This time duration monitoring at the specified space or room can be used as a very important parameters for the monitoring of healthy parameters for elderly person at home or patients at hospital. The indoor activity parameter and the time duration at the room can be very important parameters for ubiquitous healthcare monitoring when the parameters combine together. Finally storage is made for saving this location information and the concerned authority can access this saved location data for the elderly person or patient.

VII. DICUSSION AND FURTHER WORK

A decentralized architecture was used to determine the location of the indoor targets and experiment evaluation shows that the tracking system works well with accuracy around 5~10 cm. As the target carries only the listener node, the cost of the tracking system reduced as compared to the cricket indoor location tracking system. The location information provided by this system is sufficiently accurate and fine-grained for location awareness in context-aware applications. These results are determined by the performing experimental test under two various beacons position. In the future effort will be made to evaluate the system performance under various environments. We are actively pursuing efforts in deploying experimental infrastructure and applications in our existing work environment. Finally large-scale wireless sensor nodes deployments have to be done in wide floor of our new building, which we will occupy soon. Further work must now be done to design the map of the area where these beacons are deployed such that the healthcare processionals can find the persons location by seeing the map of the area. We believe that the widespread deployment of location-dependent applications inside hospitals and home has the potential to fundamentally change the way we interact with our immediate environment.

VIII. CONCLUSION

In this paper we described the implementation and testing of the indoor location tracking system. This system is the result of three design goals: decentralized architecture, low cost and portion-of-a-room granularity. The accuracy in our experiment is fairly good and fine grained for tracking in indoor environments. The activity monitoring of the target is a first step towards enabling a rich class of application that target our research goals. We have presented the detail of our system that is based on ultrasonic technology. The initial effort described in this work has been valuable for the experience and we hope to extend that with a breadth of experiments that describe in detail the behavior of the many facets of this kind of system and application.

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