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RFID Based Indoor Positioning System Using Event Filtering

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Abstract – Recently, location systems using RFID technology have been studied in indoor environments. However, the existing techniques require high computational cost to compute the location of a moving object because they compare the location proximity of all reference tags and objects. In this paper, we propose an RFID based location positioning scheme using event filtering, which reduces the computation cost of calculating the locations of moving objects while maintaining the accuracy of location estimation. In addition, we propose an incremental location update policy to reduce the location update cost for moving objects. We also compare the proposed scheme with one of the localization schemes, LANDMARC using a performance evaluation. As a result, the proposed scheme outperforms LANDMARC in terms of the computational cost of location estimation. The proposed scheme also reduces the cost of location update by using the RFID-based update policy.

Keywords: LBS, Indoor, RFID, Event filtering, Location tracking, Location update

1. Introduction

The development of sensor and communication technologies have recently led to the development of location based services (LBS). Demand for LBS, which provides information related to certain locations or the locations of certain objects, has increased significantly [1, 3]. One of the most well-known location-aware services is the global positioning system (GPS). However, GPS is inherently limited when it comes to accurately determining the location of objects inside buildings [1]. Nonetheless, LBS are an important for outdoor as well as indoor Ubiquitous environments. For indoor location based service, the LBS needs to provide the accurate locations of objects within a small area [4, 21, 22, 25]. However, it is presently impossible to provide accurate location estimation via indoor LBS because of the inaccuracy of the locations that are provided based on GPS [7, 18, 19]. To overcome the latter problem, various sensor technologies such as Active Badge [13], RADAR [14], and Cricket [15], TELIAMADE [21], Smart-Condo [24], LEMON [28] have been proposed.

Radio frequency identification (RFID) is an electronic identification technology used for real-time tracking and monitoring, and is one of the core technologies for Ubiquitous services [10]. RFID tags are attached to objects and then used to detect the locations of the objects. RFID technology is widely applied in many fields such as logistics and supply chain management, retail, healthcare, factory automation, security, aviation industry, postal package tracking, defense, and the military [2, 4]. RFID consists of tags, reader, antenna, and software. RFID tags are uniquely identified by a tag ID.

RFID tags can be classified into passive and active types. The passive tags do not have a battery, and can only be read at a very short distance. However, the active tag is connected to a powered infrastructure or uses energy stored in an integrated battery, and consequently it can be read at a distance of one hundred feet or more [2]. The RFID reader sends energy via RF signal to the tag, and the tag sends back a modulated signal [4]. RFID uses radio frequency waves to transfer data between the readers and tags. Using a chip, the antenna can also transmit sensed data to a reader. RFID streams can be generated quickly and automatically and provide very large volume data [4]. Since most RFID streams that are sensed by the reader are useless to the application, semantic event processing is required to detect more meaningful and useful data for applications.

Generally, RFID location based systems use RSSI to measure the signal strength from each tag to the readers. These systems are classified into two schemes. In the first scheme the RFID tags are attached at certain fixed locations and the RFID readers are attached to the moving objects [15]. In this scheme, there is a problem in that the system involves a high cost for construction since the RFID readers are very expensive and the readers are attached to each object. In [8], the authors proposed an indoor location estimation system based on UHF based RFID. [8] assigns a unique ID number to each tag and attaches the tag to the ceiling. The RFID reader is attached to the person. The location of the person is calculated based on the coordinates of the detected tags. In [9], the authors performed various simulations according to the tested-geometric distribution of reference tags, multiple-level ranging, detection rate, percent standard deviation of

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detection range, and detection range. When the moving object was equipped with a reader with the reference tags and a computing machine to estimate the coordinates, [9] performed simulations to determine the design parameters of an RFID-based location system.

The second scheme has RFID readers attached at a certain fixed location, while the RFID tags are attached to the moving objects [6, 7, 16, 17]. This scheme requires a relatively low price to construct the system. To increase the accuracy of detecting the locations of objects, as many RFID readers as possible are required. In addition, since the readers are expensive, methods to increase the accuracy and reduce the number of readers have been researched. One of these approaches uses reference tags to correctly detect the locations. LANDMARC is a location sensing prototype system that uses RFID technology for indoor location systems to improve the overall accuracy of location detection [7]. LANDMARC applies the concept of using reference tags to serve as reference points in the system. Recently, there have been many studies for improving the performance of LANDMARC. One in particular, VIRE, uses virtual reference tags without using additional readers or reference tags to improve the location accuracy of an object, and has the same system construction costs as LANDMARC [5]. To reduce the cost and complexity of location systems and improve the accuracy of location estimation, OFS, which uses only one moving reader, has been proposed [6]. The approach reduces system cost since the tag is cheaper than other RFID devices.

The GPS based location system can determine the transmission of locations data of moving objects to a server according to the update policies in mobile devices. However, the RFID reader transmits the RFID stream to RFID middleware without any additional operations or filtering. Therefore, the update policies of the GPS based location system have not been applied to RFID based location systems. Presently, the update policies of RFID based location system have not yet been studied.

In this paper, we propose a new location positioning scheme, using RFID tags and readers, which reduces the cost of computing locations and guarantees the accuracy of location computation. The method classifies the RFID tags into object tags and reference tags. The reference tags and readers are attached at fixed locations to recognize the object tags attached to the moving objects. The reference tags are used as assistants to correct the locations of the object tags. The reader periodically records the information of both the reference tags and object tags. To reduce the cost of computing the locations of objects, we adapted a filter phase that ignores the unnecessary reference tags sensed by readers. In addition, we propose an efficient method to update the locations of tags by reducing the amount of communication between the server that manages all of the data from the RFID readers and the service that provides the appropriate information to the end users.

The rest of this paper is organized as follows. Section 2 describes related works. Section 3 introduces the proposed scheme architecture and presents our proposed method for detecting the location of RFID tags and updating the locations efficiently. Section 4 shows the superiority of our proposed methods through performance evaluation. Finally, the summary and future works are described in Section 5.

2. Related Work

2.1 RFID based positioning system

OFS is proposed to reduce the cost and complexity of object locating systems and improve the accuracy of location detection [6]. OFS uses at most two movable readers to locate objects. The reader's location is P_{t+1} at time $t+1$ when the reader first detects the tag. The reader in P_t does not detect the tag at time t. The average coordinate $P_{avg1}(x_1, y_1)$ is calculated between P_{t+1} and P_t. Similarly, the average coordinate $P_{avg2}(x_2, y_2)$ can be calculated between $P_{t'}$ and $P_{t'+1}$. Two locations of a moving object are estimated by using these two coordinates. To determine one location of the moving object, the reader turns right at distance r. If the reader turns right and detects the tag, the tag is placed at its right side. Otherwise, the tag is placed at the left side. If P_{avg1} is more than $2r$ apart from P_{avg2}, then the reader does not need to turn right. The location of a moving object is calculated directly and its location is $(x, y) = (x_2 + x_1 / 2, y_2 + y_1 / 2)$.

LANDMARC is a prototype indoor location system based on active RFID [7]. LANDMARC uses the concept of reference tags, which serve as reference points to improve the overall accuracy of locating objects. It was shown through LANMARC that active RFID is a viable and cost-effective candidate in an indoor location system. However, the approach does not work well in a closed area with severe radio signal multi-path effects. However, LANDMARC does not work well in a closed area with severe radio signal multi-path effects. Moreover, since the accuracy of localization relies on the placement of reference tags, more reference tags are needed to improve the accuracy of location estimation [10].

There have been many studies on enhancing the weakness of LANDMARC [5, 10]. VIRE used the concept of virtual reference tags to more accurately track the locations of objects without the need for additional tags or readers [10]. Since it provides denser reference coverage in the sensing area instead of using many real reference RFID tags deployed in the area, VIRE utilizes virtual reference tags. To alleviate the effects of uncharacteristic signal behavior, a proximity map is maintained by each reader. To estimate the possible location of an object, VIRE can eliminate those unlikely locations based on the information obtained from different maps with certain design parameters. [5] proposed a nonlinear interpolation algorithm in order to calculate the RSSI values of virtual reference tags and used a sub-region selection mechanism in order to reduce the redundant computation. However, the signal strength of the virtual reference tag is set to that of the real reference tag within the recognition range of each reader. Consequently, the signal strength of the virtual reference tag within the range of the corresponding reader must be recomputed when the signal strength of the real reference tag changes as a result of obstacles or environmental factors. Another problem is that it needs to check the corresponding maps of all readers to measure the location of an object.

2.2 Sensor based positioning system

There have been many studies on sensor based positioning systems in the indoor environment [19, 20, 25]. [19] proposed a novel data fusion framework by using an extended Kalman filter to integrate WiFi localization with pedestrian dead reckoning. [20] proposed a sensor fusion framework for combining WiFi, PDR and landmarks for indoor localization. [22] designed a real time location system architecture using multiple sensor technologies. To estimate robot position and orientation, [26] used a sensor system consisting of static ultrasonic beacons and one mobile receiver. In [27], a sensor network consisted of beacons and anchors. The ranges between each of the beacons and each of the objects was estimated using signal time of arrival (TOA).

The TELIAMADE system is an indoor positioning system based on the time-of-flight (TOF) of an ultrasonic signal, which is used to estimate the distance between a receiver node and a transmitter node [21]. TELIAMADE is organized around a master-slave topology with a coordinator node and a set of end nodes via the ZigBee protocol. The distance between nodes is calculated from the TOF measurement of the ultrasound signal using the speed of sound.

[23] proposed a location predicting scheme for indoor localization in wireless sensor networks. In [23], a path-planning model is generated to constrain the movement trajectory of the mobile object according to an indoor architectural pattern, and then maximum likelihood estimation (MLE) is used to obtain one certain kind of location result. The possible position of the object is predicted based on the path planning model and some previous localization results of the object. The MLE result and prediction result were weighted to obtain the final position.

2.3 Location update policy

In traditional location services, the locations of moving objects are acquired by GPS in mobile devices and are then transmitted to a server whenever the locations of moving objects change. In the server, the location database continuously updates the current locations of moving objects. To reduce the communication cost and management cost of continuously updating the locations of moving objects, various location update policies have been adapted to deal with mobility and uncertainty.

In [11], the authors introduced a deviation update policy. The deviation update policy updates the location whenever the deviation between the actual location and the expected location exceeds a given threshold. Three update policies, such as a point policy, a vector policy, and a segment-based policy were proposed in [12]. The point policy uses a constant location prediction that assumes that the object is located at the location given by the most recent updates. In order to predict locations, the vector policy uses the direction and speed of a moving object. It assumes that an object moves linearly and with a constant speed in the most recent update. The location of a moving object is predicted in the segment-based policy according to its speed and the shape of the road on which the object is traveling.

3. The Proposed Location Positioning System

3.1 System architecture

We propose a new indoor location positioning scheme using active RFID tags to reduce the computation cost and improve the accuracy of location computation when RFID readers and reference tags are located in a fixed location and the object with the tags attached moves only in an indoor environment. The RFID tags are classified into reference tags and object tags. The reference tags, which serve as reference points, are placed at a fixed location to reduce the number of RFID readers and improve the location computation accuracy; they are also similar to LANMARC. The object tags are RFID tags that are attached to the moving object and move about indoors. The RFID middleware collects the RFID stream from multiple readers and continuously transmits a large volume of RFID stream to applications after raw data filtering and aggregation.

For a large volume of RFID stream, only a few reference tags are actually used to calculate the location of an object tag. That is, we need to extract the necessary reference tags to acquire the location of the object. To improve the computation cost and the location accuracy, we use an event filtering to rapidly determine the neighbor reference tag required to acquire the location of a moving object. The proposed scheme manages the relationship between an object tag and a reader, and the relationship between a reference tag and a reader, by using a grid structure. It extracts the list of readers that recognize an object in the grids. By doing so, the proposed scheme selects the adjacent reference tags of the sensed object using the readers that are adjacent to the object. Therefore, when it measures the location of an object, it uses just the few

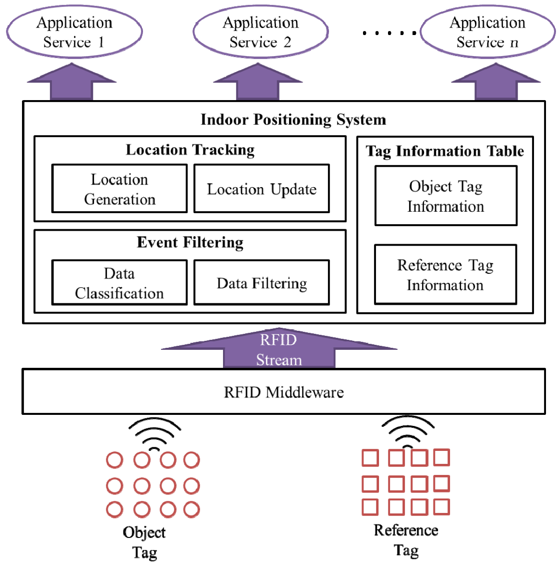

Fig. 1. The proposed location positioning system

readers that recognize the object and the few reference tags selected by the readers. The proposed scheme selects as the only *k* reference tags of elements in vector *E* as the number of the selected adjacent reference tags. This improves the location accuracy of an object by using only the most reliable reference tags when the location of an object is computed. We also adopt a location update policy to reduce the location update cost for moving objects.

Fig. 1 shows the architecture of the proposed scheme. To rapidly acquire the object location and preserve location estimation accuracy, our scheme consists of an event filtering module and location tracking module, where the event filtering selects the necessary reference tags to compute the accurate location of an object tag, while the location tracking calculates and updates the location of object tags. In the event filtering, data classification classifies the RFID stream transmitted from the middleware into object tags and reference tags, and it then stores the RFID stream into each index structure according to the kind of tags. The reference tags are used to assist in determining the locations of object tags by comparing the strength of the signal between the object tags and reference tags.

The data filtering prunes the unnecessary reference tags to calculate the location of object tags. Not all the reference tags are necessary to determine the locations of the object tags, since only a few neighboring reference tags are used to calculate the location of the object tag. Data filtering reduces the computation cost of calculating the locations of objects using the reference tags.

In location tracking, location generation calculates the real locations of objects based on the filtered RFID stream from the data filtering. The location update decides whether or not the location of the object tag is updated according to the update policies. According to the decision, the locations of objects are updated and the service is then notified in order to update the locations. This reduces the communication cost between the location management system and application.

```
Algorithm location_management()
{
    for(RFID stream sensing RFID reader)
    {
        process data classification;
        select the adjacent readers and the reference tag;
        calculate the new location of an object;
        if (the update condition is satisfied){
            update the previous location of an object;
            transmit the new location to an application service;
        }
    }
}
```

Fig. 2. The algorithm of the proposed scheme

Fig. 2 shows the algorithm of our scheme. To calculate the location of an object, we first classify the RFID stream transmitted from the middleware as object tags or reference tags. We use two grid based index structures to indicate the occurrences of tags: an object-reader index and a reference-reader index. If the RFID stream is an object tag, then it sets its cell to ‘1’ in the object-reader index structure. If the RFID stream is a reference tag, then it sets its cell to ‘1’ in the reference-reader relation index. After data classification, we can find the set of object tags and reference tags that were simultaneously sensed by common readers using the index structure, and select the adjacent readers and the reference tags that directly affect the calculation of the locations of the objects in the data filtering. The locations of the objects are then calculated using selected readers and reference tags. If a previous location of an object exists, then the update of the previous location of an object is determined by the update policies of the application. If the update condition is satisfied, then the previous location of an object is updated and its new location is transmitted to the application service. Otherwise, the update is omitted.

3.2 Event filtering

To acquire the locations of moving objects, we manage an object tag table and a reference tag table which present the RFID tag information sensed by the RFID reader. The object tag table stores the tag information of moving objects, while the reference tag table stores the information of the reference tags used in LANMARC. To provide a location based service, we have to register the moving objects that are monitored by the applications. The registration of a moving object means that it stores the physical identifier of the RFID tag attached to the moving object into the object tag table. After registration, a logical identifier is assigned to the tag and stored in the moving object table.

PID	*LID*	*Info*
epc_1	1	$<t_1, (x_1, y_1), (v_{x1}, v_{y1})>$
epc_2	2	$<t_2, (x_2, y_2), (v_{x2}, v_{y2})>$
epc_3	3	$<t_3, (x_3, y_3), (v_{x3}, v_{y3})>$
epc_4	4	$<t_4, (x_4, y_4), (v_{x4}, v_{y4})>$
epc_5	5	$<t_5, (x_5, y_5), (v_{x5}, v_{y5})>$

(a) object tag table

PID	*LID*	*Info*
epc_6	1	(x_1, y_1)
epc_7	2	(x_2, y_2)
epc_8	3	(x_3, y_3)
epc_9	4	(x_4, y_4)
…	…	…

(b) reference tag table

Fig. 3. Tag Information Table

Fig. 3 shows the tag formation table to be used for mapping the physical identifier to the logical identifier. PID is a physical identifier, which is the EPC code of a moving object, LID is a logical identifier, and *Info* is the current location of the moving object and is initially null. Info consists of $<t_i, (x_i, y_i), (v_{xi}, v_{yi})>$, where t_i is the time, (x_i, y_i) is the location of an object tag, and (v_{xi}, v_{yi}) is the velocity vector. Initially, *Info* is null. *Info* stores the location information of the object tag after the location generation module is processed. The reference tag table is similar to the object tag, except for Info. In the reference tag table, *Info* only stores the locations in which the reference tag is deployed.

To calculate the location of a moving object, the data classification first classifies the RFID stream received from middleware into object tags and reference tags. We use two index structures, such as the OR (Object tag-Reader) index and RR (Reference tag-Reader) index. The index structures indicate the occurrences of the object tags and reference tags sensed by the readers. Fig. 4 shows two index structures, which are the grid based index structure to represent the relation of tags and readers, where OT_i is an object tag, R_i is a reader, and RT_i is a reference tag. Fig. 4 (a) is the OR index that represents the occurrences of the object tags sensed by multiple readers. Fig. 4 (b) is the RR index that represents the occurrences of the reference tags sensed by multiple readers. Initially, all the values of each cell in the two grid index structures are set to '0'. If the reader senses multiple tags, then the reader transmits RFID streams to the middleware. We then classify the RFID stream into object tags and reference tags. If the physical identifier of a tag exists in the object tag table, then we set the cell representing the reader and the object in the OR index structure to '1'. If the physical identifier of a tag exists in the reference tag table, then we set the cell representing the reader and the reference tag in the RR index structure to '1'.

To process the data classification from the RFID stream sensed by the reader, the tag information table and gird based index structure are used. Fig. 5 represents the procedure for data classification. The RFID stream transmitted from the RFID middleware is defined as a tuple $<EPC, RID, TS, SS>$, where EPC is the unique identifier of the tag defined by the electronic product code standard, RID is the identifier of RFID reader, TS is a timestamp that represents the time when the tag is sensed by the RFID reader, and SS is the signal strength of the tag. If the RFID stream transmitted through the RFID middleware exists at t_1 as shown in Fig. 5, then we decide that the sensed RFID stream is classified through the Tag information table and the cell representing the sensed tag and the sending reader is then set to '1' in the two grid based index structure. For example, $<epc_1, r_1, t_1, 3>$ is the

Object domain	R_1	R_2	R_3	R_4	R_5
OT_4	0	0	0	0	0
OT_3	0	0	0	0	0
OT_2	0	1	1	0	0
OT_1	1	1	0	0	0

Reader domain

(a) OR index structure

Reference Tag domain	R_1	R_2	R_3	R_4	R_5
RT_5	0	1	0	0	0
RT_4	1	0	0	0	0
RT_3	0	0	0	0	0
RT_2	0	1	1	0	0
RT_1	1	0	1	0	0

Reader domain

(b) RR index structure

Fig. 4. A grid-based index structure

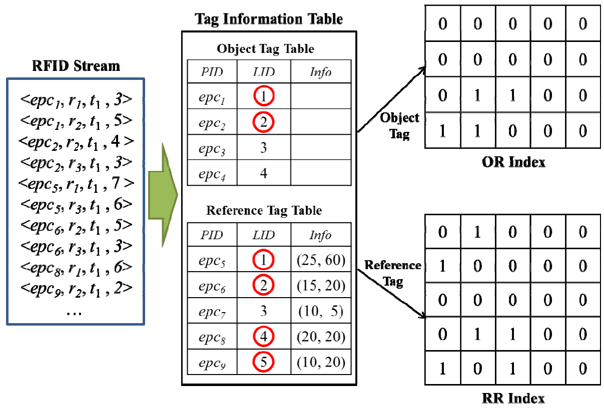

Fig. 5. An example for data classification process

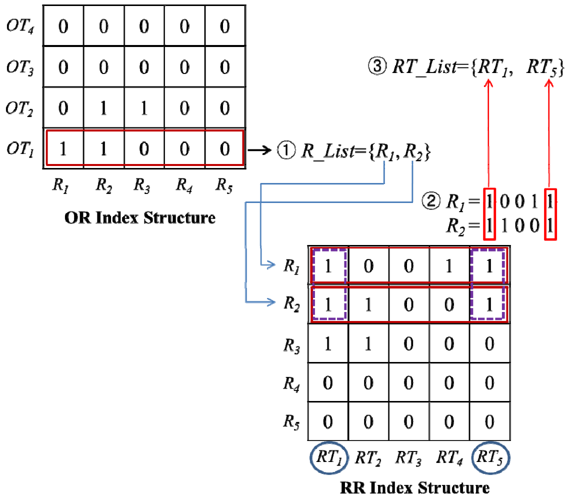

Fig. 6. Selection process of adjacent candidate objects

object tag because the *PID* of epc_1 exists in the object tag table. Therefore, the cell <1, 1> representing the sensed tag epc_1 and the sensing reader r_1 is set to '1' in the OR index. The rest of the received RFID stream is processed in the same way as above.

We determine the set of reference tags and readers required to calculate the locations of object tags through a data filtering module. The data filtering module uses the OR index and RR index. First, we create the set of readers sensing object tags from the OR grid structure. After the set of readers is made, in the RR index structure we find the bit patterns that represent the reference tags recognized by the readers. After that, we find the set of reference tags that are recognized by the readers in common through the 'AND' operation between the bit patterns of the readers.

Fig. 6 presents the selection process of the candidate reader from the OR and RR index structures for an object OT_1. In the OR index structure, a set of readers sensing an object OT_1 is $\{R_1, R_2\}$ at time t_1. The set of readers sensing an object OT_1 are the physically adjacent readers at time t_1. To find the reference tags simultaneously sensed by a reader sensing an object, we examine the bit patterns of readers R_1 and R_2 sensing an object OT_1. The bit patterns of R_1 and R_2 are '10011' and '11001', respectively. As shown in Fig. 6, we can obtain a set of adjacent reference tags commonly sensed by the readers through the 'AND' operation between the bit patterns of the readers sensing the object. Therefore, the reference tags found by the bit pattern of the readers in the RR index structure are only the candidates used for calculating the location of the object.

3.3 Location tracking

To generate the location of an object, we use the adjacent readers and reference tags selected in the previous steps. We suppose that n and m denote the number of the selected adjacent readers and adjacent reference tags, respectively. E_j means the difference of signal strength between an object and reference tag RT_j and is computed by Eq. (1). Here, S_i represents signal strength between an object and the reader R_i that recognizes the object and θ_i represents signal strength between an object and the reader R_i that recognizes the reference tag. That is, we compute E_j as the Euclidean distance of the signal strength difference between an object and a reference tag that are recognized by the same reader.

$$E_j = \sum_{i=1}^{n} (\theta_i - S_i)^2, j \in (1, m) \tag{1}$$

We select k number of the reference tags that have the minimum $E = (E_1, E_2, \ldots, E_m)$ value among the selected reference tags. We use only k number of reference tags to increase the accuracy of the location to be estimated, by using the reference tags that have the highest reliability. The E values of the k-selected reference tags are used to correct the location of the object with weights, according to the similarity of the signal strength between the object and the reference tags. The weight w_j is calculated by Eq. (2). Using the location information of the k-selected reference tags and their weights, we create the location of the object through Eq. (3).

$$w_j = \frac{1/E_j^2}{\sum_{j=1}^{m} 1/E_j^2} \tag{2}$$

$$(x, y) = \sum_{j=1}^{m} w_j (x_j, y_j) \tag{3}$$

To update the location of an object, the application services can register and manage the update policies. First, we find the latest location information of epc_i in the object tag table, and we then compare the varieties between the latest location and the new location of epc_i. In location based services, the methods that update an object's locations can be categorized into a point policy, a vector policy, and a segment-based policy. The segment-based policy can be used in road networks, while the point and vector policies can be used in indoor location based services. Eqs. (4) and (5) represent formula for location updates in the point and vector policies, respectively. In Eq. (4), when x_i and y_i represent the coordinates of the x and y coordinates at time t_i, and x_j and y_j represent x and y coordinates at time t_j, the distance variation d_{ij} means the distance between the location of an object at time t_i and its location at time t_j. The point policy performs location updates when w_j is over threshold. In Eq. (5), the speed variation (x, y) means the difference between a real location at time t_j and the predicted location, where $p(x_j)$ and $p(y_j)$ is the predicted location of x and y coordinates at time t_j based on the

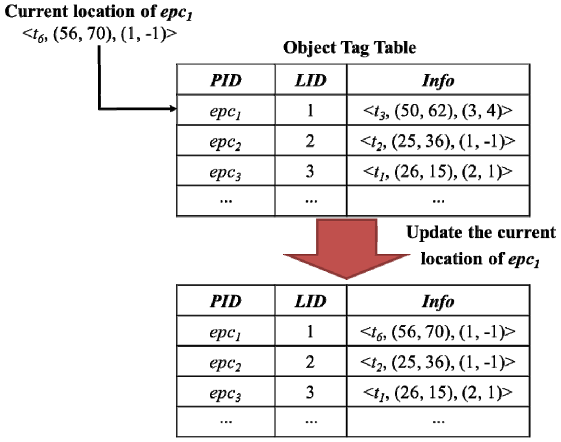

Fig. 7. An example of update operation

moving velocities at time t_i. $p(x_j)$ and $p(y_j)$ are computed by Eqs. (6) and (7). v_{xi} and v_{yi} in Eqs. (6) and (7) represent the moving velocities of x-axis and y-axis and are calculated by Eqs. (8) and (9). The vector policy performs location updates when v_{ij} is over threshold.

$$d_{ij} = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2} \quad (4)$$

$$v_{ij} = \sqrt{(x_j - p(x_j))^2 + (y_j - p(y_j))^2} \quad (5)$$

$$p(x_j) = x_i + v_{xi}(t_j - t_i) \quad (6)$$

$$p(y_j) = y_i + v_{yi}(t_j - t_i) \quad (7)$$

$$v_{xi} = \frac{x_i - x_{i-1}}{t_i - t_{i-1}} \quad (8)$$

$$v_{yi} = \frac{y_i - y_{i-1}}{t_i - t_{i-1}} \quad (9)$$

Fig. 7 shows an example of the update operation. Location based services establish a location update policy in the location recognition system and receive the updated location information according to the policy in order to utilize the continuous location changes of an object. It is assumed that a particular location based application service sets the distance variation d_{ij} to 5 to use the point policy as a location update policy. The moving object table maintains the latest location information of objects from the application services. For example, we assume that the location of an object epc_1 is (50, 62) at time t_3. If the new location of epc_1 becomes (50, 70) at time t_6, d_{36} is 10 by using Eq. (4). In this case, since the distance variation d_{ij} of the point policy is over, the application service receives the new location of the object at time t_6 and updates the moving object table.

4. Experimental Evaluation

Recently, various location recognition schemes using RFID such as LANDMARC, OFS, and VIRE have been proposed. LANDMARC can recognize the location of an object using reference tags in various indoor environments. OFS uses movable readers instead of fixed readers in order to reduce location positioning costs. In OFS, the movable readers should be additionally provided. It detects the locations of an object by using trigger times set in the readers. Therefore, OFS does not detect objects when they pass through the recognition ranges of readers in the non-trigger time. As a result, OFS cannot be applied to general indoor location based services. VIRE uses virtual reference tags in order to improve location accuracy without using additional readers and reference tags in LANDMARC. At this time, the signal strength value of a virtual reference tag is set based on the signal strength values of real reference tags within the recognition range of each reader. Therefore, when the signal strength value of a real reference tag is changed due to obstacles or environmental factors, the signal strength values of virtual reference tags within the ranges of the corresponding readers should be recomputed. It has also a problem that it should check the states of all of the readers and tags in order to measure the location of a moving object. The proposed scheme reduces computation costs and guarantees accuracy for location recognition by using general readers and RFID tags. OFS does not conduct indoor location recognition using general readers and tags. It also degrades the accuracy of location recognition when readers move. Although VIRE improves accuracy over LANDMARC, it has problems that it is hard to recognize location according to the changes of an indoor environment and should check the states of all of the readers and tags. Therefore, we chose LANDMARC as the existing scheme for performance comparison since it can perform location recognition using general readers and tags in various indoor environments.

We performed various simulations on a Pentium4 3GHZ processor with 1GB RAM. The simulations were developed with JAVA 1.5. The simulation parameters are shown in Table 1. The objects were randomly arranged in 50m×50m~200m×200m environments and the communi-cation range of a reader was set to 20m. The reference tags were

Table 1. Simulation parameters

Parameter	Value
Simulation area	50m×50m~200m×200m
Communication range of a reader	20m
The total number of object tags	100~400
The number of monitoring tags	20%
The deploy interval of reference tags	2m

Table 2. The number of readers and reference tags according to simulation areas

Simulation area	# of readers	# of reference tags
50m×50m	49	625
100m×100m	169	2,500
150m×150m	361	5,625
200m×200m	625	10,000

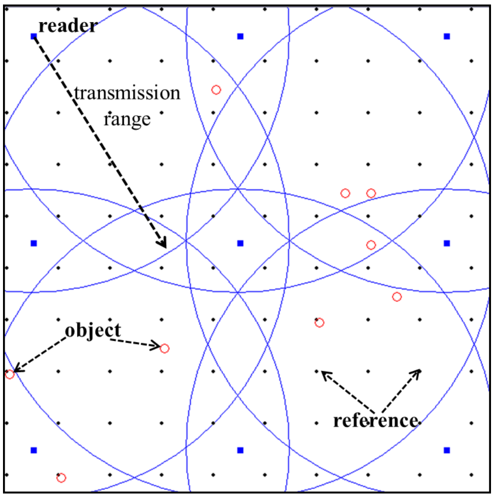

Fig. 8. The simulation environments

deployed at intervals of 2m. We set the amount of objects to be monitored to 20% of all objects. Table 2 shows the number of reference tags and readers according to simulation areas. We used 625 reference tags in the 50m×50m environment and 10,000 reference tags in the 200m×200m environment. The minimum number of adjacent readers that the error rate between the real location of a moving object and its measured location by operations can be ignored is 3. We placed the RFID tags and readers so that the minimum number of adjacent readers communicating with an RFID tag was 3. Therefore, in total we used 49 readers in the 50m×50m environment and 625 readers in the 200m×200m environment. Fig. 8 shows the simulation environments.

We evaluated computation cost, computation time, accuracy, and transmission cost. LANDMARC-like location recognition schemes compute E_j and w_j in order to recognize the real location (x, y) of an object. E_j and w_j are computed by repetitively comparing readers and reference tags used for recognizing the location of the object. Therefore, the computation cost is evaluated as the product of NR and NRT used for computing E_j and w_j as shown in Eq. (10). Here, NR is the number of readers sensing the RFID tags, and NRT is the number of the participated reference tags to calculate the locations of object tags. To measure the accuracy, we compared the computed locations of objects with their real locations. Eq. (11) is the error distance e between the computed location coordinates $(x,\ y)$ and the real location coordinates (x_0, y_o) of objects. The transmission cost was measured by the amount of data transmitted to the application services via location update. In the experimental environment, we set 40% of the object tags to move over the update threshold.

$$CC = NR \times NRT \tag{10}$$

$$e = \sqrt{(x - x_0)^2 + (y - y_o)^2} \tag{11}$$

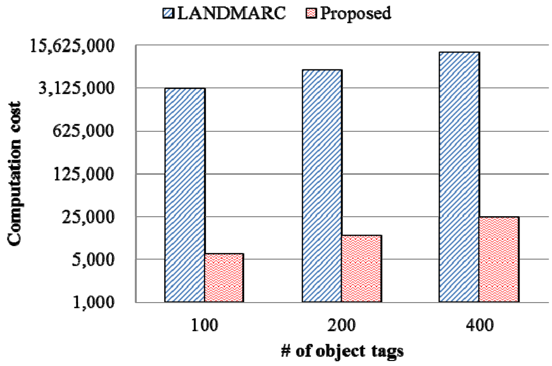

Fig. 9. Computation cost according to the number of object tags

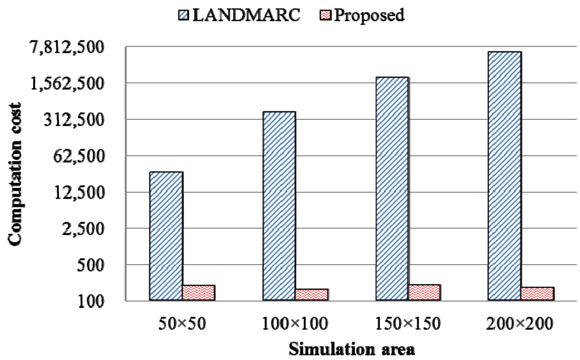

Fig. 10. Computation cost according to simulation area

To provide a real-time location based service in an indoor environment, one of the most important factors is the computation cost needed to compute the location of objects to be monitored. We evaluated the computation cost based on the number of object tags and the size of the simulation area. Fig. 9 and Fig. 10 show the computation cost. Fig. 9 is the cost of computing the location of objects according to various numbers of object tags, from 100 to 400. The proposed scheme is about 500 times faster than LANDMARC. The reason is that the proposed scheme reduces the records to be used to compute the locations via the filtering module.

Fig. 10 shows computation costs according to simulation areas in order to distinguish whether it is possible to measure locations in real time in a large scale environment. In other words, it shows the computation costs when the transmission range of a reader is 20m, and the reference tags and readers are deployed. The computation cost means the amount of computation of vector E for measuring the location of an object according to variations of the experimental environments. If the size of an environment area is increased, then the amount of computation is increased in LANMARC. The reason is that as the scale of an experimental environment becomes larger, the number of comparison computations for vector E is increased due to the increase in numbers of readers and reference tags. However, the proposed scheme significantly reduces the amount of computations over LANDMARC since it

Table 3. Computation time

Simulation area	Computation time(s)	
	LANMARC	Proposed scheme
50m×50m	1.361	0.037
100m×100m	22.660	0.096
150m×150m	118.348	0.137
200m×200m	358.070	0.204

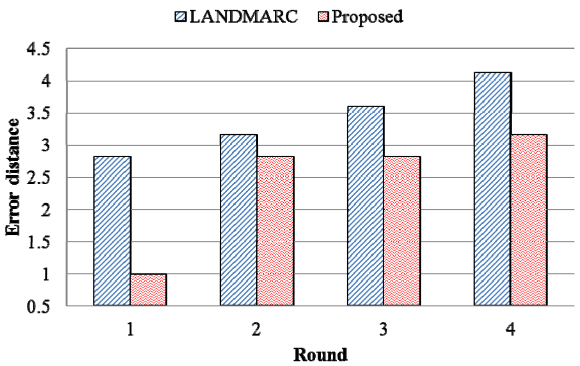

Fig. 11. The accuracy of computed locations

measures the position of an object by using only the necessary readers and reference tags. Therefore, the proposed scheme can measure locations in real time even in a large scale environment.

Table 3 shows the computation time according to various simulation environments. It shows that the computation time increases in our proposed method even if the amount of computations is almost the same in all environments. The method spends a lot of time identifying and classifying the data in the middle ware from all the readers and reference tags, and thus the time increases with the number of readers and reference tags. However, the rate of increase is very small and is ignorable when we compare it with that of LAMDMARC.

The purpose of the experiments was to compare the accuracy of the computed locations with the real locations. In each time unit, 50% of the objects moved randomly. We computed the new location of objects, and we then compared the previous location with the current location. If the difference of locations was over a certain threshold, then we updated the objects' location in the system. Fig. 11 shows the accuracy of the computed location. To measure the accuracy, we calculated error distances. The error distance of the proposed scheme was similar to that of LANDMARC. This means that the computed location of the proposed scheme guarantees the same accuracy as that of LANDMARC, even though a smaller number of reader and reference tags than those used for LANDMARC participated in the computation. Therefore, the proposed method reduces the cost of computing the location of while retaining the accuracy of the locations.

Fig. 12 shows the transmission cost between LANDMARC and the proposed method. LANDMARC sends all location data of the objects to the applications

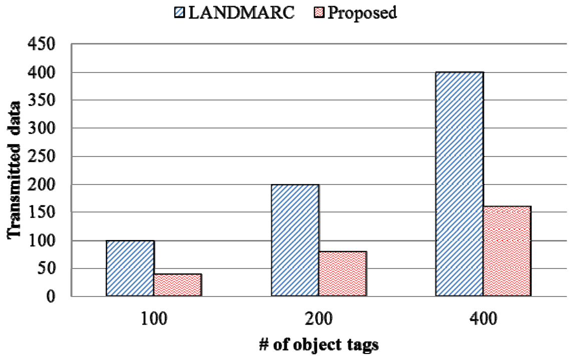

Fig. 12. Transmission cost

regardless of the objects' movements. The proposed scheme compares the previous locations and current locations of the objects and then decides whether or not the location should be updated. Therefore, the proposed method is more efficient than LANDMARC because of the reduction in the amount of transferred data. In addition, LANDMARC is not applicable to indoor location services because most objects are stable indoors.

5. Conclusion

We proposed a new location management scheme to reduce the cost of computing the locations of objects as well as guarantee the accuracy of the locations' computation. Similar to LANDMARC, the proposed scheme classifies RFID tags into object tags and reference tags. We used just a small number of the deployed readers and reference tags to compute the location of objects, while LANDMARC uses all of them. In addition, we proposed an incremental location update policy to reduce the amount of data transferred to the applications. Through the performance evaluation, we proved that the computation cost was reduced by about 50% - 70% compared to LANDMARC. In terms of processing time, the proposed scheme takes 500 times less time to compute locations than LANDMARC. In terms of the amount of data transmitted, our scheme transmits 50%~70% less than that of LANDMARC. In future works, we will propose a method that can detect the movement of objects before computing the location of the objects, to enhance the accuracy of location computation.

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