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Tracking Methodologies in RFID Network

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1. Introduction

RFID is a wireless communication technology that uses radio waves. The RFID system consists of a reader, tags and antenna. The RFID reader is sometimes called Interrogator as well and RFID tag is called transponder (K. Finkenzeller, 2003). This transponder is attached to or embedded in a physical object to be automatically identified. The transponder, which doesn't usually possess its own power supply, is not within the interrogator zone of a reader it is totally passive. This transponder is activated when it is within the interrogator zone of the reader. In contrast to it, a transponder is called active, if it has own source of power.

In this chapter, passive transponder is assumed along with the fixed RFID interrogators. This tracking system consists of RFID Interrogators, RF transponders, ZigBee (Stanislav Safaric et al. 2006; J. A. Gutierrez et al. 2001) modules, Tracking application, and back-end database that stores tracking vectors collected by ZigBee enabled RFID Interrogators.

Virtual Route Tracking (VRT) algorithm is designed to keep track of object in ZigBee enabled RFID Mesh Network. The object can be any person or article in the network. A RFID transponder is attached to the object. The RFID interrogators are connected by the ZigBee wireless network (Stanislav Safaric et al. 2006; J. A. Gutierrez et al. 2001), herein consist of densely deployed RFID interrogators. The proposed algorithm have feature of tracking as well as tracing the object. Tracking knows where an object is and tracing knows where an object has been. The RFID back-end database helps in storing history (past information) and the present status of the transponder movement. There are many technologies for tracking and tracing. Using RFID is one of the most cost effective methods.

In today's world tracking objects with RFID is important everywhere (Lionel M Ni et al, 2003; RFID Journal, 2008) i.e. supply chain, asset and people. Optimizing data exchange between partners in the supply chain is traditionally done through organizations like EAN, today known, as GS1. The influence of GS1 and Electronic Product Code (EPC) is highly important in the development and acceptance of RFID technology throughout the world. Allowing a person to discover the location of things and their co-works has long been identified as an interesting topic in ubiquitous computing (J. Hightower, 2001; A. Ward, et al, 1997; R. Want et al, 1992). Therefore, we are proposing the use of EPC (RFID Journal, 2008) for identifying the transponder in the RFID mesh network.

An Electronic Product Code (EPC) is a unique object identifier. An EPC consists of version number, manufacturer, product and serial number (K. Finkenzeller, 2003). The version

Source: Radio Frequency Identification Fundamentals and Applications, Bringing Research to Practice, Book edited by: Cristina Turcu,
ISBN 978-953-7619-73-2, pp. 278, February 2010, INTECH, Croatia, downloaded from SCIYO.COM

number specifies the EPC format i.e. 64-bit EPC, 96-bit EPC and 256-bit EPC. The manufacturer field is a unique number assigned to a particular manufacturer. The product number is a unique number allocated to a specific product class produced by a manufacturer. The serial number is a unique number assigned by the manufacturer to every individual product. The manufacturer within a product class should not duplicate the serial. Therefore, triplet of manufacturer number, product number, and serial number uniquely identifies an object. This EPC will be used for the purpose of tracking object in the mesh network.

The chapter is organized as follows: fundaments of object tracking are discussed in section 2. Section 3 presents the technique to formulate a RFID network using ZigBee protocol as backbone. Section 4 explores the scope of suitable database based on the characteristics of RFID data. Section 5 has a focus on the architecture of tracking applications. The algorithm for tracking an object in RFID network is presented in section 6. Finally, a conclusion is presented in the last section.

2. Fundamental of object tracking

The locating and identification of a tag can be classified as: Discrete and Continuous (Christian Hillbrand et al., 2007). Discrete mode identifies tag on predefined locations and intervals, while Continuous mode works seamlessly to locate the object continuously. These two modes are very effective in designing the system for location estimation. Here, we define location estimation technique as the process of estimation of physical coordinates of an object in RFID field. The coordinates may correspond to some location in the plane. The location information is useful for warehouses to locate product, in hospitals for locating equipments, in library for locating books etc to name a few. Whatever is the use of location information, underlying techniques to locate may differ from each other. Different applications and areas require different types of information pertaining to location. The types of information can be physical location, symbolic location, absolute location and relative location (Hightower and G. Borriello, 2001).

Physical location: This is expressed in the terms of co-ordinates, used to identify a location with 2-D/3-D map.

Symbolic location: This is expressed in neutral-language like near reception; lobby, in the drawing room.

Absolute location: It is expressed by using shared reference grid for all located objects.

Relative location: This is expressed by known nearness of the reference points.

The localization can be of broadly classified as Indoor and Outdoor. The Indoor location can be sensed by various wireless technologies, which can be classified on the basis of: (1) positioning algorithm (2) employed infrastructure. In general RFID positioning systems consists of tag, receiver and central computer (Shomit S et al, 2004). There are four different system topologies for positioning systems (C. Drane et al, 1998). First, remote positioning system, where measuring unit receives the transmitter signal and transmitter (signal) is mobile. The second, self-Positioning system where the mobile measuring unit receives the signal from other transmitters kept at known locations, and contributes in its location finding based on measured signals. Third, indirect remote positioning system where the measurement results from self positioning system is send to remote site using wireless link

for location computation. Fourth is indirect self-positioning, where mobile unit receives the measurement result from remote positioning side.

In the outdoor environments, the Global Positioning System (GPS) is the most widely used technology to acquire the position of an object. For wearable system it becomes difficult for the GPS to achieve stepped level of precision due to constraint on size and weight of the hardware. The other disadvantage of GPS includes its exclusive use in outdoor applications, as it requires satellites to be "visible". In proximity of narrow valleys, raised buildings, forests, the signals of the GPS system has shadowing effects. Positioning technologies provided by GSM are: Network-based, Device-based and Hybrid systems (Christian Hillbrand et al., 2007). The Network-based method uses service provider network (cellular phone) to determine the position of a mobile device. For capturing positions of the mobile terminal device, service provider identifies its relative position in relation to a serving GSM Base Transceiver Station (BTS) (Christian Hillbrand et al., 2007). Device-based system for positioning purposes captures the data on the mobile terminal device (Christian Hillbrand et al., 2007). Either or both interacting GSM and non-GSM components are used by Hybrid GSM systems for positioning of mobile device. Assisted GPS (A-GPS) is an example of hybrid GSM systems. A mobile terminal device now comes with GPS equipped receivers. The positioning accuracy reported ranges between 3m and 30m (Christian Hillbrand et al., 2007). Here, in this chapter we are introducing a concept of discrete time locating technique known as virtual route tracking. Let's understand with the help of figure 1. This consists of RFID readers ($R_1 \ldots R_{20}$). Each row in the plane has five readers. When a tagged object starts moving from R_1 to R_{16} then R_7, R_8, R_4, R_{10}, R_{15}, R_{19}, R_{18}, R_{12}, R_{16} intermediate readers interrogates the tag.

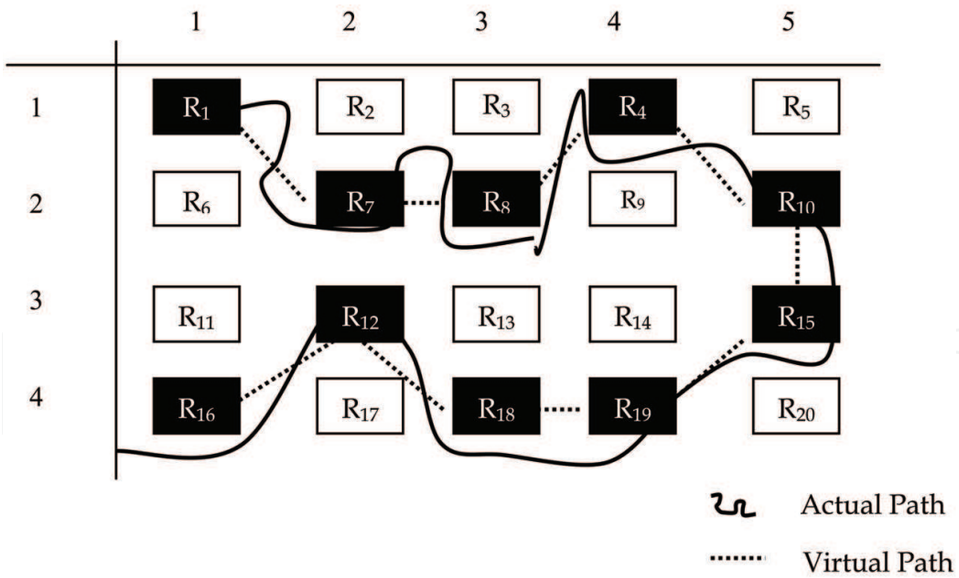

Fig. 1. RFID reader network

When the tag moves from reader R1 to R7, the straight line between them is regarded as the track (virtual) of the transponder. The thick curve in the RFID Network denotes the real path of a person or object. So, the track of the figure 1 is as follows:

$$Track = Virtual\ Track = (1,1) \rightarrow (2,2) \rightarrow (2,3) \rightarrow (1,4) \rightarrow (2,5) \rightarrow (3,5) \rightarrow (4,4) \rightarrow (4,3) \rightarrow (3,2) \rightarrow (4,1)$$

This grid base placement of the reader is an ideal situation but in real environment they may be placed in mesh fashion. In the following section, we would discuss the background of formulating such mesh-based placement.

3. Formulation of RFID network

We have chosen ZigBee communication technology to formulate mesh network of RFID readers because ZigBee operates in the industrial scientific and medical (ISM) band. The ZigBee offers three frequency bands, with 27 channels specified as following (McInnis, M. 2003; J. A. Gutierrez, 2001):

Frequency Band	Channels	Data Rate
868 and 868.6 MHz	Channel 0, 10	20 Kbps
902.0 and 928.0 MHz	Channel 1-10	40 Kbps
2.4 and 2.4835 GHz	Channel 11-26	250 Kbps

Table 1. ZigBee features

The ZigBee has capability to self-organize and self-healing dynamic mesh network based on the standards. The ZigBee standards define two types of devices, a full-function device (FFD), and reduced function device (RFD) (McInnis, M. 2003; J. A. Gutierrez, 2001). These two types of devices have different mode of operation. The FFD can operate in three different modes depending on the requirement *viz*. personal area network (PAN) coordinator, a coordinator ore a device (McInnis, M. 2003). However, RFD is intended for application that minimal resource and very low data transfer rate. A system conforming to IEEE 802.15.4 consists of several core components.

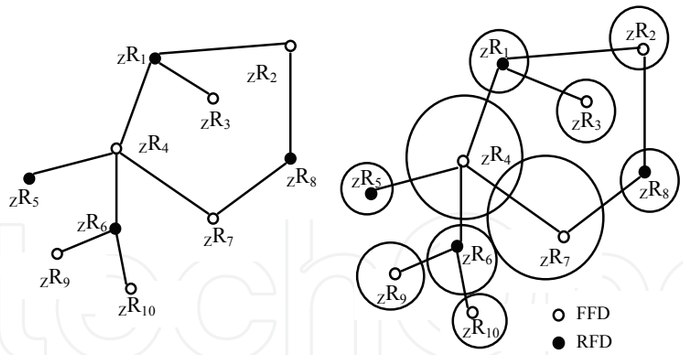

Fig. 2. Mesh network of RFID readers

This network (Fig. 2 a) consists of five full function device and five reduced function device. This FFD and RFD are attached with a standalone interrogator, which transmits the information to the host computer (central) when it reads the tag. In, figure 2 b, we have shown the intersecting zone by the circles. We are proposing a vector that will contain information about the transponder, which he has interrogated. The vector contains following attributes:

$$<E_i, t_j, {}_ZI_k> = < \textit{EPC code i, TimeStamp j, InterrogatorID k} >$$

Here, EPC identifies the transponder uniquely across the globe. This EPC is stored in the memory of the transponder (RFID Journal, 2008). The TimeStamp is the time when interrogator has red the tag. The zInterrogatorID will uniquely identify the ZigBee enabled RFID Interrogator on the network. To deduce the relationship between the interrogators, an interrogator neighbour matrix (INM) is formed.

$$\begin{bmatrix} 0 & 0 & 0 & 0 & -1 & -1 & -1 & -1 & -1 & -1 \\ 0 & 0 & 0 & -1 & -1 & -1 & -1 & 0 & -1 & -1 \\ 0 & 0 & 0 & 0 & -1 & -1 & 0 & 0 & -1 & -1 \\ 0 & -1 & 0 & 0 & 0 & 0 & 1 & 0 & -1 & -1 \\ -1 & -1 & -1 & 0 & 0 & 0 & -1 & -1 & 0 & -1 \\ -1 & -1 & -1 & 0 & 0 & 0 & 0 & -1 & 0 & 0 \\ -1 & -1 & 0 & 1 & -1 & 0 & 0 & 0 & -1 & 0 \\ -1 & 0 & 0 & 0 & -1 & -1 & 0 & 0 & -1 & 0 \\ -1 & -1 & -1 & -1 & 0 & 0 & -1 & -1 & 0 & 0 \\ -1 & -1 & -1 & -1 & -1 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Fig. 3. Interrogator neighbour matrix

The network is formed in a mesh fashion; therefore determination of the adjacent or neighbour becomes subjective matter. The interrogators are not placed in a matrix form, so there can be number of neighbour/adjacent in omni direction. Hence, we proposed an interrogator adjacency matrix, which will contain the information about the relationship viz. neighbour: 0, intersecting: 1, non-neighbour: -1. Two interrogators i and j are called neighbours, if transponder moves toward interrogator j and j is the only interrogator to interrogate it. Two interrogators i and j are called intersecting interrogator, if the tag will be interrogated by two or more interrogators. This situation occurs in a mesh network where there is intersecting interrogation zone. Two interrogators i and j are intersection to each other, if transponder enters into a zone where two interrogators i and j interrogate it. The interrogator neighbor matrix is defined as below:

INM (i, j) = 0 if *i, j* are neighbor interrogators
= 1 if *i, j* are intersecting interrogators
= -1 if *i, j* are non- neighbor interrogators

Two Interrogators *i* and *j* or intersection to each other, if transponder enter into a zone where two interrogators *i* and *j* interrogate it. This can be done manually, by measuring RF filed strength and pattern of *i* and *j*.

In this work, we have considered the reader collision protocol, so network can't generate two or more tracking vectors with same timestamp for any transponder *Ei*. Presently, we haven't exploits the ZigBee neighbor table for the purpose of identify and updating INM. Here, we are using ZigBee as a wireless media to transfer the data to host computer.

4. Database for tracking objects

The database is an important aspect of tracking system to ensure the persistence of data. We have stored reader, Interrogator neighbour matrix and tracking information into different

table. These tables are created in Oracle 8i relational database management system. These tables are as follows:

Reader _ID	Location_ID
111.123.123.134	0001: Security check

Table 2. Reader

Reader table contains information reader identification and location identification. The reader identification coding is akin to the IP address while the location ID is four digit integer numbers to identify a particular location within the premises. The Interrogator neighbour matrix table identifies the relationship among the readers. In the following, the relationships of reader ID 111.123.123.134 with other readers are shown. Here, '"0" represents neighbour, "1" represents intersecting relationship and "-1" represents no relationship among readers.

Reader_m	Reader_n	Relationship
111.123.123.134	111.123.123.130	0
111.123.123.134	111.123.123.130	1
111.123.123.134	111.123.123.136	1
111.123.123.134	111.123.123.140	1
111.123.123.134	111.123.123.149	-1
111.123.123.134	111.123.123.132	-1
111.123.123.134	111.123.123.104	-1

Table 3. INM

The tagged object is interrogator by the readers as soon enters into the vicinity of some other reader. This movement changes the state of the object as it modifies information like location of the object, interrogation time, and duration of stay in particular vicinity. The tracking table has been designed to store the sufficient information about the moving tagged object. The EPC field in the table contains the identification of the tag in EPC format. The duration contains the difference between the last read timestamp and the first read timestamp.

EPC	TimeStamp	Reader_ID	Duration
E_1(96 bit format)	t_1	${}_zR_4$	t_4-t_1

Table 4. Tracking

5. Application architecture

The proposed architecture of the tracking system consists of four layers as shown in Fig. 4. The layer 0 is a hardware layer, which consists of RFID interrogators, antenna, and ZigBee modules. This layer reads the raw data from the RFID transponder. This event data is transferred from the antennas/readers to the middleware layer (layer 1) via ZigBee transceiver module. The layer 1 performs the data filtering and aggregation. The data that is relevant for the higher layers (back-end layer) is transferred to the middleware. Middleware

is typically installed in the data center (Christian Floerkemeier et al, 2007). The layer 2 is the repository for the filtered data. This repository will be used for deducing the virtual track as well as trace. This layer transfers the data to the layer 3 (application layer) upon triggering a query from the tracking application. The application layer consists of GUI based application where users can track/trace the route of the particular transponder by specifying the EPC. The application layer will trigger a query to the back-end layer. The back-end layer, in turn will select the data from the tracking database and transfer back to the application layer. Based on the data received from back-end layer, tracking application will graphically draw the route of the transponder.

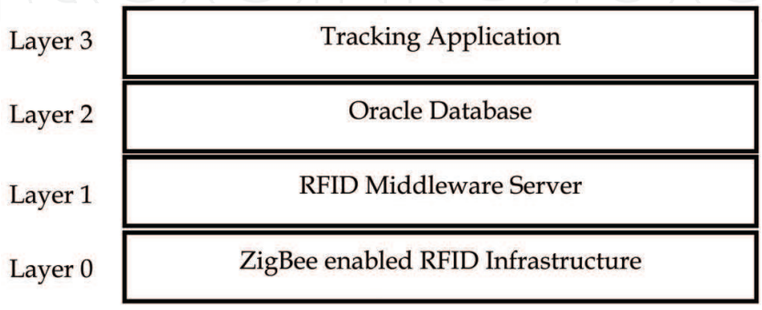

Fig. 4. Application architecture

6. Tracking algorithms

Suppose transponder E_1 enters into the zone of interrogator ${}_ZR_5$ at time t_1 then moves into the zone of ${}_ZR_4$ at time t_2. In this case, the interrogator ${}_ZR_5$ and ${}_ZR_4$ will send following tracking dataset.

$$\begin{matrix} {}_ZR_5 \rightarrow \{E_1, t_1, {}_ZR_5\} \\ {}_ZR_4 \rightarrow \{E_2, t_2, {}_ZR_4\} \end{matrix} \qquad t_1 < t_2$$

Now, virtual route tracking algorithm will analyze the relationship between ${}_ZR_5$ and ${}_ZR_4$ with the help of interrogator neighbor matrix.

```
If INM (5,4)==0 then
        relationship=0 // neighbor
else if INM(5,4)==1 then
        relationship=1 //intersecting
else
        relationship=-1  // non-neighbor
```

Second, the algorithm will analyze about the values of E_1 and E_2.
If the values of E_1 and E_2 are equal, two tracking dataset are derived from the same source then the track would be deduces as follows:

$$\text{virtual track} = {}_ZR_5 \rightarrow {}_ZR_4, \text{where } t_1 < t_2$$
$$\text{virtual track} = {}_ZR_4 \rightarrow {}_ZR_5, \text{where } t_1 > t_2$$

To deduce the path correctly, VRT algorithm will always keep on grouping the tracking dataset according to the values of E_i i.e. $E_1=E_2$; tracking dataset belong to same transponder, so put it into one group.

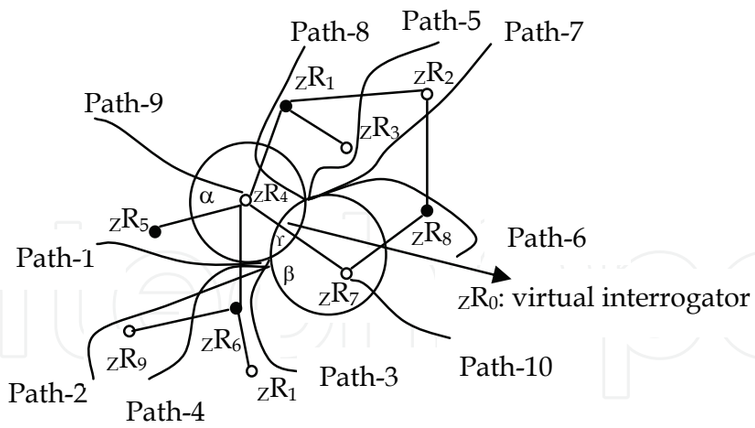

Fig. 5. RFID mesh network with possible path

Suppose, transponder enters into the intersecting zone, as in path (1, 2 or 3) in Fig. 5. In this case, all the two interrogators will interrogate it at different time slot. Therefore, two tracking dataset will be independently generated containing different timestamps. However, only one interrogator and its corresponding tracking dataset shall remain in the database. The deduction of this knowledge will be based on the position of the previous and the next interrogator of these two interrogators along the track. So, the algorithm will first find out the last interrogator who has interrogated transponder E_i as follows.

1. Find the ${}_ZR_p$, previous interrogator for the transponder E_i.
2. The relations of the previous interrogator can be as follows:
   a. ${}_ZR_p$ is neighbor of ${}_ZR_4$ but ${}_ZR_p$ is not neighbor of the ${}_ZR_7$ (Path-1)
   b. ${}_ZR_p$ is not neighbor of ${}_ZR_4$, but ${}_ZR_p$ is neighbor of ${}_ZR_7$ (Path-3)
   c. ${}_ZR_p$ is neighbor of ${}_ZR_4$, but also neighbor of ${}_ZR_7$. (Path-2)
   d. ${}_ZR_p$ is not neighbor of both ${}_ZR_4$ and ${}_ZR_7$. (Path-4)

Case 1:

${}_ZR_p$ is neighbor of ${}_ZR_4$ but ${}_ZR_p$ is not neighbor of the ${}_ZR_7$ (along path-1 in Fig 3), the algorithm will choose ${}_ZR_4$, whereas deleting the tracking dataset $R_7 \rightarrow \{E_1, t_2, {}_ZR_7\}$.

Case 2:

In a similar way, tracking dataset $R_4 \rightarrow \{E_1, t_1, {}_ZR_4\}$ will be deleted when transponder follow path-3 and interrogated by ${}_ZR_4$. However, we need to apply more intelligence when the previous interrogator is neighbor of both ${}_ZR_4$ and ${}_ZR_7$.

Case 3:

In the third case, being neighbor of both the interrogators one has to observe the next interrogator who will read it. So, algorithm will now find out the next interrogator who has interrogated transponder E_i as follows.

1. Find the ${}_ZR_n$, next interrogator for the transponder E_i.
2. The relations of the next interrogator can be as follows:
   a. ${}_ZR_n$ is neighbor of ${}_ZR_4$ but ${}_ZR_p$ is not neighbor of the ${}_ZR_7$ (Path-4)
   b. ${}_ZR_n$ is not neighbor of ${}_ZR_4$, but ${}_ZR_p$ is neighbor of ${}_ZR_7$ (Path-6)
   c. ${}_ZR_n$ is neighbor of ${}_ZR_4$, but also neighbor of ${}_ZR_7$. (Path-5)
   d. ${}_ZR_p$ is not neighbor of both ${}_ZR_4$ and ${}_ZR_7$. (Path-7)

Now, consider transponder E_1 that moves along with path 4 in Fig. 5, so the collected tracking dataset are as follows.

$\{E_1, t_1, {}_ZR_6\}$
$\{E_1, t_2, {}_ZR_4\}$
$\{E_1, t_3, {}_ZR_7\}$
$\{E_1, t_4, {}_ZR_1\}$

As Fig. 5 illustrated, tracking dataset generated by interrogator ${}_ZR_7$ will be deleted and the resulting dataset will be as:

$\{E_1, t_1, {}_ZR_6\}$
$\{E_1, t_2, {}_ZR_4\}$
$\{E_1, t_4, {}_ZR_1\}$

Virtual Route for transponder E_1 is: ${}_ZR_6 \rightarrow {}_ZR_4 \rightarrow {}_ZR_1$ Now, consider transponder E_1 moves along with path 6 in Fig. 5, so the collected tracking dataset are as follows.

$\{E_1, t_1, {}_ZR_6\}$
$\{E_1, t_2, {}_ZR_4\}$
$\{E_1, t_3, {}_ZR_7\}$
$\{E_1, t_4, {}_ZR_8\}$

As Fig. 5 illustrated, tracking dataset generated by interrogator ${}_ZR_4$ will be deleted and the resulting dataset will be as:

$\{E_1, t_1, {}_ZR_6\}$
$\{E_1, t_2, {}_ZR_7\}$
$\{E_1, t_4, {}_ZR_8\}$

Virtual Route for transponder E_1 is: ${}_ZR_6 \rightarrow {}_ZR_7 \rightarrow {}_ZR_8$ Now, consider transponder E_1 moves along with path 5 in Fig. 5, so the collected tracking dataset are as follows.

$\{E_1, t_1, {}_ZR_6\}$
$\{E_1, t_2, {}_ZR_4\}$
$\{E_1, t_3, {}_ZR_7\}$
$\{E_1, t_4, {}_ZR_3\}$

As Fig. 5 illustrated, tracking dataset generated by interrogator ${}_ZR_7$ will be deleted and the resulting dataset will be as:

$\{E_1, t_1, {}_ZR_6\}$
$\{E_1, t_2, {}_ZR_0\}$
$\{E_1, t_4, {}_ZR_3\}$

In, this case a virtual interrogator has been created at the mid point area Υ to correct the track. Virtual Route for transponder E_1 is: ${}_ZR_6 \rightarrow {}_ZR_0 \rightarrow {}_ZR_3$

Case 4:

Now, we will investigate another case, in which transponder is moving around the vicinity of the particular interrogator. Suppose transponder E_1 is roaming around ${}_ZR_4$, so at different interval of time it will generate the following tracking dataset.

$$\left\{\begin{matrix}\{E_1, t_1, {}_ZR_4\}\\ \{E_1, t_2, {}_ZR_4\}\\ \{E_1, t_3, {}_ZR_4\}\\ \{E_1, t_4, {}_ZR_4\}\end{matrix}\right\} \rightarrow \left\{\begin{matrix}\{E_1, t_1, {}_ZR_4\}\\ \{E_1, t_2, {}_ZR_4\}\\ \{E_1, t_4, {}_ZR_4\}\end{matrix}\right\} \quad t_1 < t_2 < t_3 < t_4$$

Assuming, the difference between two successive interrogation timestamp is negligible, therefore, tracking database will store first tracking dataset along with the duration (t_4 - t_1) of stay in the vicinity of the interrogator as shown in Table 4.

6.1 Proposed tracking algorithm

In the analysis of various scenarios in section 3, now we will present the algorithm for tracking virtual route. The part of the algorithm will be executed in the middleware layer and the rest will be in the application layer.

Step 1. Check Mesh topology

If changes took place then

update(INM)

else

go to step 2

Step 2. Filter and Aggregate

Upon receiving tracking dataset, classify the dataset weather it belongs to one transponder or not. This will make a group of the transponders, whose contents of E_i are same. Using a Structured Query Language (SQL) and the special constructs provided in the Middleware can do filter and aggregate.

$$\left\{\begin{array}{l}\{E_1, t_1, {}_ZR_4\}\\ \{E_1, t_2, {}_ZR_1\}\\ \{E_2, t_1, {}_ZR_2\}\\ \{E_1, t_4, {}_ZR_5\}\\ \{E_2, t_4, {}_ZR_6\}\\ \{E_3, t_7, {}_ZR_7\}\\ \{E_3, t_3, {}_ZR_7\}\end{array}\right\} = \left\{\begin{array}{l}\textit{G1:}\\ \{E_1, t_1, {}_ZR_4\}\\ \{E_1, t_2, {}_ZR_1\}\\ \{E_1, t_4, {}_ZR_5\}\end{array}\right\} \quad \left\{\begin{array}{l}\textit{G2:}\\ \{E_3, t_7, {}_ZR_7\}\\ \{E_3, t_3, {}_ZR_7\}\end{array}\right\}$$

$$\left\{\begin{array}{l}\textit{G3:}\\ \{E_2, t_1, {}_ZR_2\}\\ \{E_2, t_4, {}_ZR_6\}\end{array}\right\}$$

Step 3. Eliminate redundant interrogation If a transponder is roaming around a particular interrogator then the successive timestamp t_i and t_j will be negligible. Therefore, find out the difference between the first interrogated timestamp and last interrogated timestamp from the interrogation tracking dataset series.

Step 4. Check relationship

By using interrogator neighbor matrix, deduce the track using the previous and next interrogator reader relationship as discussed in the section 3.

Step 5. display the virtual track on the screen from list of track

6.2 Simulation of the algorithm

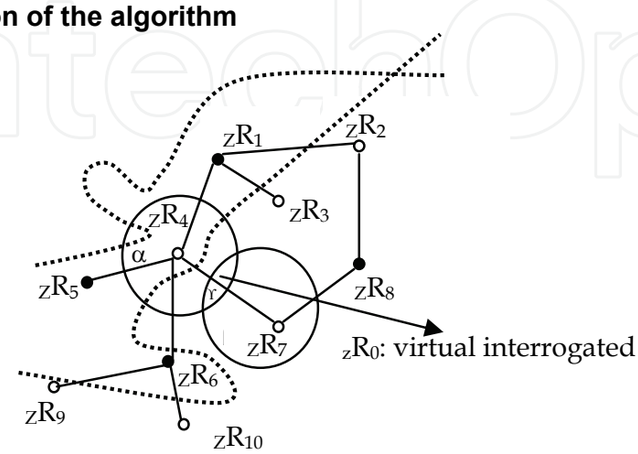

Fig. 6. Transponder movement in RFID network

We have simulated the proposed algorithm of tracking virtual route by developing tracking application in the Microsoft .Net framework. The tracking dataset and other database have been created using the Oracle 8*i*. The virtual tracking algorithm is implemented in the application layer, but in future work we will implement filter and aggregate functions in middleware layer. In the present version, we have manually entered all the values in the interrogator neighbor matrix. Initially, we provided data for the two transponders, which begin to move at the same time.

The data generated from these two transponders are as follows:

$$\left\{\begin{array}{l}\{E_1, t_1, {}_ZR_9\}, \{E_2, t_1, {}_ZR_5\}\\ \{E_1, t_2, {}_ZR_1\}, \{E_2, t_2, {}_ZR_4\}\\ \{E_1, t_3, {}_ZR_6\}, \{E_2, t_3, {}_ZR_4\}\\ \{E_1, t_4, {}_ZR_4\}, \{E_1, t_5, {}_ZR_7\}\\ \{E_2, t_5, {}_ZR_1\}, \{E_1, t_6, {}_ZR_3\}\\ \{E_1, t_7, {}_ZR_2\}, \{E_2, t_6, {}_ZR_2\}\end{array}\right\}$$

Step 1: No change in the topology

Step 2: Filter and Aggregate

Step 3: Eliminate redundant interrogation

$$\left\{\begin{array}{l}\{E_1, t_1, {}_ZR_9\}\\ \{E_1, t_2, {}_ZR_1\}\\ \{E_1, t_3, {}_ZR_6\}\\ \{E_1, t_4, {}_ZR_4\}\\ \{E_1, t_5, {}_ZR_7\}\\ \{E_1, t_6, {}_ZR_3\}\\ \{E_1, t_7, {}_ZR_2\}\end{array}\right\} + \left\{\begin{array}{l}\{E_2, t_1, {}_ZR_5\}\\ \{E_2, t_2, {}_ZR_4\}\\ \{E_2, t_5, {}_ZR_1\}\\ \{E_2, t_6, {}_ZR_2\}\end{array}\right\}$$

$$\left\{\begin{array}{l}\{E_1, t_1, {}_ZR_9\}\\ \{E_1, t_2, {}_ZR_1\}\\ \{E_1, t_3, {}_ZR_6\}\\ \{E_1, t_4, {}_ZR_4\}\\ \{E_1, t_5, {}_ZR_7\}\\ \{E_1, t_6, {}_ZR_3\}\\ \{E_1, t_7, {}_ZR_2\}\end{array}\right\} + \left\{\begin{array}{l}\{E_2, t_1, {}_ZR_5\}\\ \{E_2, t_2, {}_ZR_4\}\\ \{E_2, t_3, {}_ZR_4\}\\ \{E_2, t_5, {}_ZR_1\}\\ \{E_2, t_6, {}_ZR_2\}\end{array}\right\}$$

Step 4: check relationship

$$\left\{\begin{array}{l}\{E_1, t_1, {}_ZR_9\}\\ \{E_1, t_2, {}_ZR_1\}\\ \{E_1, t_3, {}_ZR_6\}\\ \{E_1, t_4, {}_ZR_0\}\\ \{E_1, t_6, {}_ZR_3\}\\ \{E_1, t_7, {}_ZR_2\}\end{array}\right\} + \left\{\begin{array}{l}\{E_2, t_1, {}_ZR_5\}\\ \{E_2, t_2, {}_ZR_4\}\\ \{E_2, t_5, {}_ZR_1\}\\ \{E_2, t_6, {}_ZR_2\}\end{array}\right\}$$

The final tracking result of this algorithm for transponders is as follows:

$$E_1 \text{ is } {}_ZR_9 \rightarrow {}_ZR_1 \rightarrow {}_ZR_6 \rightarrow {}_ZR_0 \rightarrow {}_ZR_3 \rightarrow {}_ZR_2 \text{ and } E_2 \text{ is } {}_ZR_5 \rightarrow {}_ZR_4 \rightarrow {}_ZR_1 \rightarrow {}_ZR_2$$

Step 5: Display the virtual track

7. Conclusion

In this research work, we have made an attempt to track the virtual route of an object, which is moving in a ZigBee enabled RFID interrogator mesh network. We presented different type of relationship among the interrogators. An algorithm is proposed and implemented to track the path of an object. As shown in the simulation results, the proposed VRT algorithm quite accurately tracks the objects specified in the simulation. This VRT can be used to track any object or person. But, when talking about the person, privacy is always a serious issue that needs to address carefully (Alastair R. Beresford et al, 2003). Privacy had been the scapegoat of the failure in the indoor-location based sensing, but privacy might become irrelevant in the newer business models (Jonathan spinney, 2004).

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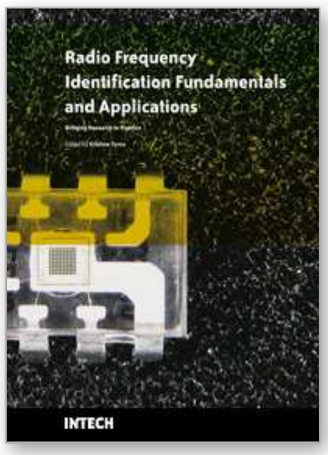

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