Invited Paper

An Improved Concurrent Search Algorithm for Efficiently Finding Patients' Locations in Medical Environments by RFID

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ABSTRACT

The technique of radio frequency identification (RFID) is very suitable for medical affairs due to its low-power transmitting frequency and wireless tracking capability. It has currently been used in many medical centers for tracking highly contagious and dangerous patients. In this paper we propose an improved concurrent search algorithm to find patients' locations quickly by RFID. It is mainly based on patients' moving regularity in medical environments to find RFID tags efficiently on a hierarchical RFID architecture. Experimental results also show the performance of the proposed approach.

Key words: radio frequency identification, concurrent search, RFID tag, medical affairs, mobile communication network.

1. INTRODUCTION

Medical safety is very important for hospitals and has attracted much research, especially after the SARS epidemic. Consequently, both hospitals and patients anticipate that the degree of safety of medical affairs may be greatly raised. Medical safety includes not only people but also medical procedures. The safety of people depends to a great extent on the prevention and tracking of infectious diseases. Most hospitals today still perform sickness management in a passive way. For example, doctors usually only tell patients the things they need to notice for some legal infectious diseases, such as the advice that patients should not go to public places. The management thus depends on the moral conscience of the patients. An example is the situation with SARS. When SARS became pandemic, many patients did not obey the isolation stipulation and went out, and as a result, some serious group infections appeared at that time.

RFID technology has matured in recent years since many researches have been devoted to the field. It is usually combined with communication and information techniques in applications and has also been widely used for medical services, to enable a better development of medical treatments. Particularly, it is commonly used for drug control and patient management. RFID systems are wirelessly tracked, which makes them very suitable for applications of medical

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security and the attendance of seriously-ill patients (Jeong, Kim & Peter, 2004; Tsai, Liu & Hsu, 2003). However, RFID systems still have some problems, such as signal delay, data redundancy, and waste of signal cost. In this paper, we will propose an improved concurrent search algorithm to find patients' locations quickly in medical environments by RFID. It mainly modifies the concurrent search algorithm used in mobile communication networks to search for targets efficiently and effectively reduce transmission signal cost. The proposed approach considers the particularity of medical care to further improve the original concurrent search approach, thus being more suitable and more efficient in finding patients' locations.

2. RADIO FREQUENCY IDENTIFICATION SYSTEMS

Radio frequency identification, which is an electronic carrier system for information, was invented early in 1969, but found applications in many important industries after 30 years. Some examples include migration tracing in traffic, material and inventory management in manufacturing industry, entrance-guard system administration, and even clinical care in hospitals. Furthermore, due to its promise as a substitute for traditional bar codes, RFID has attracted the attention of many companies and researchers. Its characteristics of wireless access and high storage capacity also make it widely used in automated management applications (Finkenzeller, 1999).

The RFID system is composed of three main parts (Finkenzeller, 1999): a RFID reader, a tag and an antenna. An RFID reader contains a micro controller and a unit for signal delivery; the quality and the angle of the antenna may affect the access accuracy of an RFID system. RFID tags are usually divided into two kinds, active and passive, according to whether they need to include batteries. A passive tag can receive power transmitted from its corresponding RFID reader, and uses the power for internal circuit operations. Thus, it does not need extra batteries to work. It has the merits of small size, low price and long lifetime. Its disadvantages are small memory capacity, short delivery distance, and lack of re-write capability, such that its applications are limited. It is commonly used in the warehousing and the distribution businesses.

On the contrary, an active tag provides internal electric power for operations. It usually has a large amount of memory and can write the data repeatedly. An active tag thus has a wider range of applications than a passive tag. However, the physical size of an active tag is usually large and the price is high. Also, the batteries need to be often replaced. Active RFID tags are commonly used in healing institutes for detecting the locations of patients.

3. MOBILE COMMUNICATION NETWORKS

In the past, the public switched telephone network (PSTN) was used for communication, in which all lines were installed in advance. It was thus called the fixed network and users dialing telephones clearly knew the current locations of the receiving users. In a mobile communication network, the communication scheme becomes complex and the above situations no longer hold. Mobile management needs to trace the positions of both calling and dialing users and even their related status (Chen, 2004). Figure 1 shows the hierarchical management architecture commonly used by current mobile communication networks.

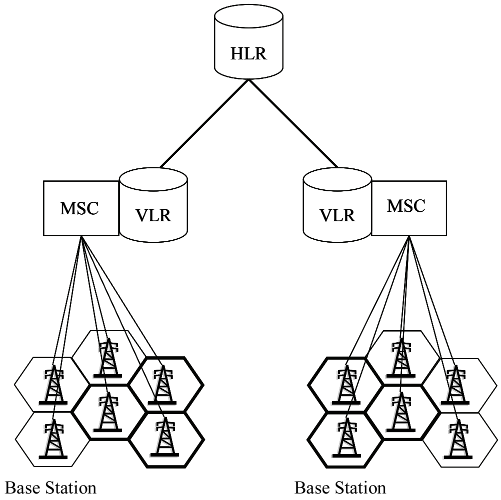

Figure 1. The hierarchical architecture for mobile communication networks.

In Figure 1, a mobile communication network may contain several mobile switching centers (MSC), each of which may cover several location areas (LA). Each location area includes one or several base stations (BS), each with its covering range and acting as the basic unit for recording related mobile information. The architecture has two kinds of databases, which are called home location register (HLR) and visitor location register (VLR). When a mobile user applies for a new mobile phone number, his/her related data will be permanently kept in the HLR. VLR, on the contrary, keeps the dynamic information of mobile users. When a mobile user enters a mobile switching center, the corresponding VLR will generate a temporary record for the user. It also sends the information up to the HLR. The HLR can thus get users' newest migration information in this way (Podrguze, 1990; Plassmann, 1994) to help communication in the whole system.

4. THE CONCURRENT SEARCH ALGORITHM

Gau and Haas (2004) proposed the concurrent search (CS) algorithm for searching for moving users in mobile communication networks. It could not only search for multiple mobile users at the same time, but also effectively reduce the cost and the delay of messenger calls. In this paper, we propose a search approach based on the CS algorithm to improve the search efficiency of RFID in medical environments. Therefore, the principle of the CS algorithm is first stated as follows.

4.1 Principle of the Concurrent Search Algorithm

Assume there is only one MSC in a mobile communication network. As mentioned above, the MSC is responsible for the transmission work of several base stations. Let the number of base stations handled by the MSC be n. The MSC will maintain n queues, denoted Ω_1, Ω_2, …, Ω_n in the communication process. Each queue corresponds to a base station and has a buffer to keep the recognition packets of the users to be searched for. The size of the buffer thus represents the maximum number of packets which can be temporarily kept in the queue. Whenever a mobile call arrives at the MSC, the MSC will duplicate the recognition packet of the call into n copies and put each copy in a queue. The recognition packet stores several important data, such as the identification code of the receiving user, the arrival time of the call, and so on.

Let $PK_j(i)$ represent a packet i in the j-th queue and $A_j(i)$ represent the arrival time of $PK_j(i)$. As mentioned above, when a recognition packet arrives at the MSC, the MSC will duplicate it into n copies and put them in the queues (nearly) at the same time. Thus all the arrival times for the packet i to the queues can be thought of as the same. That is,

$$A_1(i) = A_2(i) = \ldots = A_n(i).$$

The CS algorithm uses the concept of time slots in a search. A time slot is thought of as a basic processing time unit. It represents the processing interval for a new search action after the previous search has ended. The CS algorithm thus searches for desired users only in each fixed discrete time.

In general, a base station has several paging channels to simultaneously search for mobile users. The number of channels is usually fixed. Thus, when the number of call requests increases, the waiting length in a queue will increase as well. Each base station will first carry out the requests located at the front of the corresponding queue. The requests at the back of the queue have to wait until paging channels are released. Consequently, some delay in system processing will occur. An important task in mobile management is thus how to spend less time searching for desired mobile users such that the system delay can be reduced, especially when there is a large number of requests.

Let $Q_j(t)$ denote the queue length of the j-th base station in the t-th time slot. It thus represents the number of call requests which have not yet been connected. Suppose each base station has m paging channels, meaning it can call at most m users at the same time. Thus, $min(m, Q(t))$ is the maximum number of simultaneous calls of a base station in a time slot. If $m < Q(t)$, this means that the number of requests not served is greater than the number of paging channels, therefore the first

m requests in front of the queue will be first served and the others will wait. On the contrary, if $m \geq Q(t)$, then all the packets in the queue can be simultaneously served in the time slot.

4.2 Packet Priority

The packets in a queue are attached with priority values when they enter into the queue. Their positions in a queue are then decided according to the ascending priority values. The priority value of a packet may be changed in the communication process. Formally let $PR_j(i)$ represent the priority value of $PK_j(i)$ and $V_j(i)$ represent the priority change. Then $PR_j(i)$ is set as follows:

$$PR_j(i) = \lambda * A_j(i) - V_j(i),$$

where $A_j(i)$ is the arrival time of $PK_j(i)$ as mentioned above and λ is a real number larger than one. A smaller $PR_j(i)$ value has a better processing priority. The $V_j(i)$ value depends on the search situations of all the base stations and will be stated later. According to the formula, the requests coming early are usually served first. Let n be the number of queues (base stations). When a packet is first put into a queue, its $V_j(i)$ value is set as $1/n$.

After the end of each time slot, each base station stops its search and removes the packets which have been searched for by it or have been successfully positioned by other base stations. It then updates the priority of each packet which is still in its queue as follows. Assume there are r base stations searching for packet i in the previous slots but do not successfully find its position. Then the corresponding MSC will set the value $V_j(i)$ of the priority change as $1/(n-r)$, instead of $1/n$. Thus, if more base stations search for packet i in the previous slot, the priority of i in the current time slot will become smaller, meaning i has a higher priority. This is because when more base stations have unsuccessfully searched for packet i in the previous time slot, the remaining base stations can search for i with a higher probability. The priority of i in each remaining base station will thus be:

$$PR_j(i) = \lambda * A_j(i) - 1/(n-r).$$

When a base station searches for the positions of mobile users, two recognition packets may have the same priority (Gau & Hass, 2004). In the traditional sequential search algorithm, the strategy of first-come-first-served (FCFS) is usually adopted for them. The packet near the front end will thus be served earlier than the other one if the two have the same priority. The current RFID readers search for the RFID tags in the same way.

A simple example is given here. Let m be the number of paging channels in a base station and n be the number of base stations. Here we assume, for simplicity, $m = 1$ and n is an even number. Also assume there are two calls, denoted as packet 1 and packet 2, coming at the same time. Since the arrival times of the two calls are the same:

$$A_j(1) = A_j(2) \text{ and } V_j(1) = V_j(2) = 1/2, \ \forall j \in 1, 2, \ldots, n.$$

Thus $PR_j(1)$ is initially equal to $PR_j(2)$ according to the above formula. Because there is only one paging channel in this example (m = 1), all the base stations will first search for packet 1 in the first time slot if they follow the series number when the priorities of two packets are the same. Search for packet 2 will thus wait until the next time slot. Totally $2n$ paging costs will be taken for processing these two packets. Taking too many paging costs for base stations is currently a problem for the whole system.

The CS algorithm thus adopts the strategy of random selection (RS) to avoid the above shortcoming in FCFS for packets with the same priority. For the above example, if a base station can randomly select a packet to process from the ones with the same priority, it will have an equal probability of choosing packet 1 or packet 2. Thus on average, $n/2$ base stations will search for packet 1 and the other $n/2$ base stations will search for packet 2. In the best case, the system will spend only n paging costs to finish the job although it still needs to take $2n$ paging costs in the worst case. Using the RS strategy can indeed reduce the paging cost. This has been confirmed in Chen (2004).

5. EFFICIENTLY FINDING PATIENTS' LOCATIONS BY RFID

The previous section has described the principles and characteristics of the CS algorithm. It can simultaneously search for multiple mobile user services, can reduce the messenger delay in system performance, and can reduce the paging cost. These merits make it very suitable for usage in RFID systems to find RFID tags. In this section, we will further improve the CS algorithm for RFID systems under medical environments in order to find desired RFID tags efficiently.

We describe the approach in our proposed hierarchical RFID system architecture. An example of the architecture for a hospital is shown in Figure 2, where a hospital is divided into several (say four) main areas, each with a RFID reader. These include areas for emergency treatment, outpatient service, radiation examination, and sickrooms. Each main area is further partitioned into several blocks, called cells. Each cell is equipped with a field generator (FG), which is usually cheaper than a reader and consists of an antenna and some other electronic devices. An FG, instead of a reader, is in charge of searching for RFID tags within the range of a cell and the role of a reader is thus simplified. It simply transmits signals with the FG and writes data to the RFID tags if necessary. Each main area is equipped with a cache DB server to keep the information of the tags in that area. This design can thus distribute and speed up data processing.

This research assumes patients' moving in medical environments is not as frequent as people's moving in mobile communication networks. It is because the treatment process usually needs a period of time, which is especially apparent for the hospitalized patients. According to this observation, if a reader in a main area would like to search for the tag of a patient, the FG of the cell in which the patient is located at the beginning will put the request at the front of its queue and the patient's tag can be quickly detected with a high probability. On the contrary, the FGs in the other cells handle the search for the patient by the mentioned random selection strategy in the CS algorithm. The flow chart of the proposed approach is shown in Figure 3.

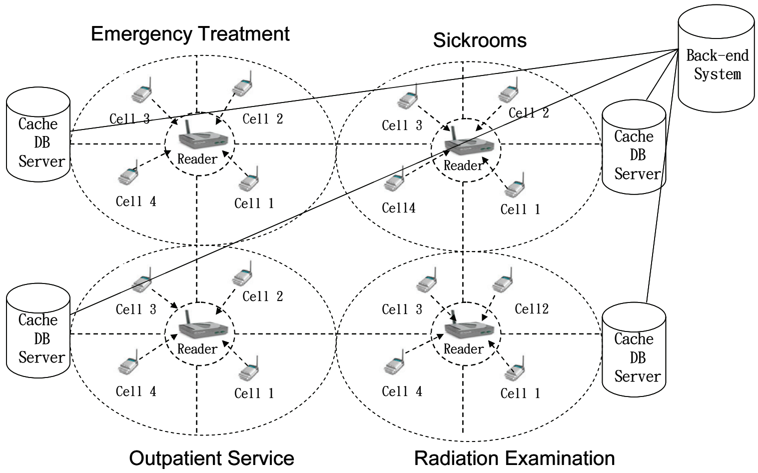

Figure 2. A hierarchical RFID system in a hospital.

In Figure 3, when the number of requests for RFID tags in a cell is larger than the paging channels, the requests for the tags which appeared in the cell at the beginning will be searched for first. The requests for the tags which didn't appear in the cell at the beginning will then be searched for by the random selection strategy in the CS algorithm. The RFID tags which are successfully located in the current time slot are then removed from the queues. The RFID tags which have been unsuccessfully searched for by a cell's FG are also removed from the queue of that FG. All the FGs then repeat the same procedure in the next time slot.

6. AN EXAMPLE

In this section, an example is given to illustrate the above idea. Assume there are eight patients in the main area for emergency treatment and they are initially located as shown at the left of Figure 4. After a period of time, the patients are located as shown at the right of Figure 4. As can be seen from the figure, patients 1, 3, 4 and 7 have not moved from their original cells. Patient 2 moves from cell 4 to cell 1, patient 5 moves from cell 1 to cell 4, patient 6 moves from cell 3 to cell 1, and patient 8 moves from cell 1 to cell 3.

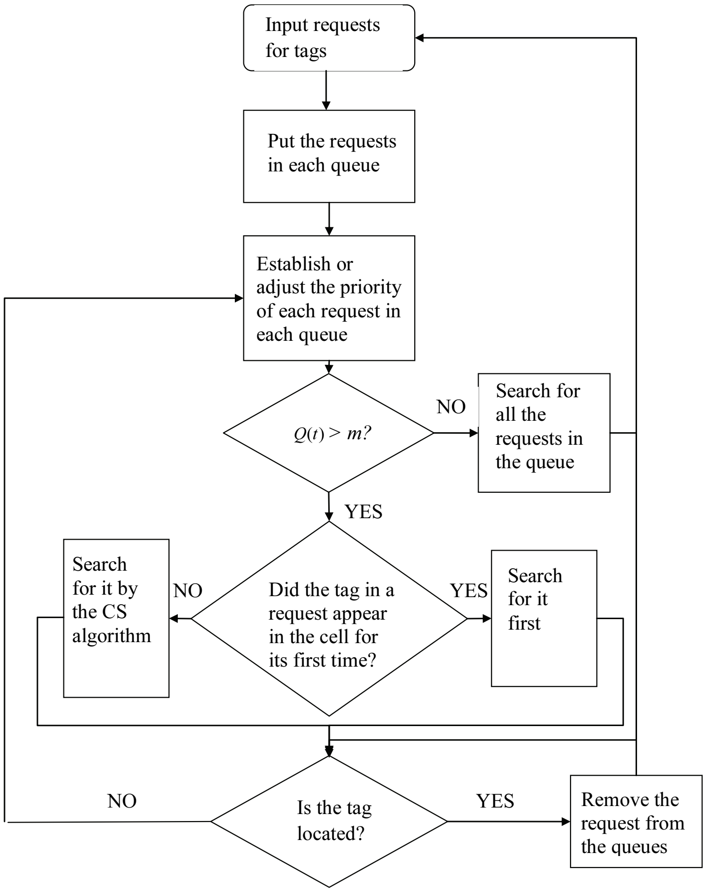

Figure 3. The flow chart of the proposed approach.

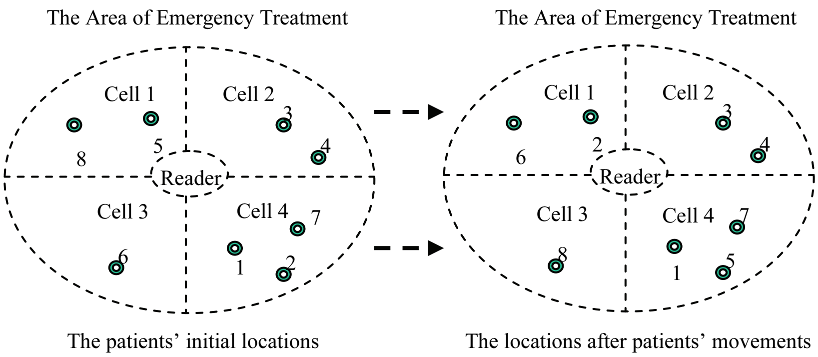

Figure 4. An example for the migration of RFID Tags.

Now assume there are five requests respectively for tags 1 to 5 coming into the system at the same time. Also assume the maximum number of channels for each FG is 3. Like the original CS algorithm, each FG keeps the requests in a queue. The five requests are thus copied and put into the queue of each FG. The initial queue length $Q(0)$ in all the FGs is thus 5. Because $Q(t) > m$, each FG first finds the requests for tags initially appearing in its area. In this example, cell 1 only has tag 5 initially located in it among the requests. The FG in cell 1 thus searches for tag 5 using the first channel. The other two channels in cell l will then select the other requests in a probabilistic way. Let $f(i, j)$ represent the request processed by the i-th FG using the j-th paging channel. Thus $f(1, 1) = 5$ in this example. Assume the second channel of the FG selects the request for tag 1 and the third channel selects the request for tag 4. Then FG 1 will process the following requests it the first time slot:

$$f(1, 1) = 5, f(1, 2) = 1, \textit{ and } f(1, 3) = 4.$$

Similarly, the other FGs will select their own requests to process as follows:

$$f(2, 1) = 3, f(2, 2) = 4, \textit{ and } f(2, 3) = 5;$$

$$f(3, 1) = 1, f(3, 2) = 2, \textit{ and } f(3, 3) = 5;$$

$$f(4, 1) = 1, f(4, 2) = 2, \textit{ and } f(4, 3) = 3.$$

Note that cell 3 totally adopts the random selection strategy in the first time slot because all the five tags to be located are not initially in the cell. After the first time slot, tags 1, 3 and 4 have been successfully located. The requests for the three tags are then removed from the queues. The requests for tags 2 and 5 are then processed in the next time slot.

Then the next time slot starts. Since cell 1 has only the requests for tags 2 and 5 remaining in its queue and it has processed the request for tag 5 in the previous time slot, tag 5 will thus be removed from the queue and only tag 2 needs to be located by FG 1. Therefore, FG 1 will search for tag 2 using only one channel. Similarly, FG 2 will only search for tag 2. FG 3 doesn't need to search in this time slot because no request remains in its queue. FG 4 will search for only tag 5. The search process can thus be finished in two time slots.

Assume the paging cost for an FG to search for a tag is 1. The cost in the above example is 15. If the original CS algorithm is used, then the cost will be 20. The proposed approach can thus reduce the paging cost when compared to the original CS algorithm for locating patients in medical environments.

7. EXPERIMENTS

This research is based on the assumption that patients in a medical environment will move less frequently than in a general mobile communication network, therefore the proposed approach for the RFID system can become efficient. To verify this assumption, the moving behavior of patients in a large hospital in Kaohsiung was observed by actually recording the moving frequencies and locations of tags. The results showed that the cell for a patient to be initially located is usually the activity area of the patient later in the hospital.

7.1 Experimental Environments

The experimental environments are first explained here. The hardware part includes RFID readers (PTA9201R), field generators (PTA9201FG) and RFID tags (model: PT9201T), all produced by the Pretide Corporation. Since the RFID readers were equipped with the RS232 interface, a gateway program was thus first designed as a bridge between the data received and the database. The FG itself verified whether a tag had been located according to the information written to the tags by the RFID readers. The overall system architecture for the experiments is shown in Figure 5.

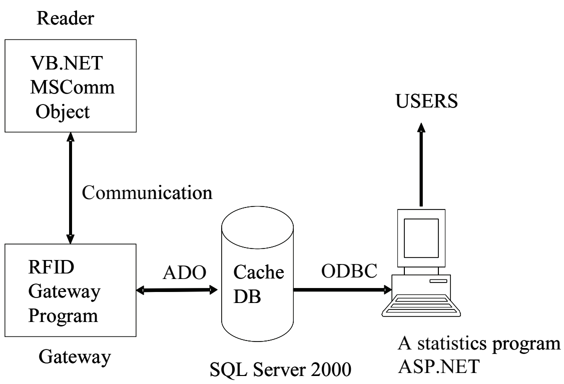

Figure 5. The system architecture for the experiments.

In Figure 5, the RFID gateway program was used to connect the data in a RFID reader and in a cache database in the back end for analysis. An external object, MSComm, was mainly used for communication control. The gateway program was responsible for receiving and delivering related tag information from a reader to a database by the ADO object. In addition, a statistics program written in ASP.NET was used to analyze the moving behavior of patients. The program could easily access the tag information from the cache database through a user-friendly graphic interface. Two main databases were used in the experiments, neamely, TAGDB and TRACKDB. TAGDB was the database for managing tags. It was the main place for storing the tags received from the program. The other database, TRACKDB, mainly stored the summarized statistics data used to analyse the moving characteristics of patients. Some databases in the hospital information system were also used in the analysis.

The data were collected from the main area for emergency treatment in the hospital and because this area was the busiest and most crowded area in the hospital, the results obtained from the area could be thought of as the worst case for the hypothesis. The area for emergency treatment was further divided into four cells in our experiments. They are shown in Table 1.

The ID number 4 was not used due to a Chinese taboo associated with this number in healing institutes. The ID number 0 was retained to represent the case in which no FG could successfully locate a tag. The management interface for the initial setting of the system was designed as shown in Figure 6.

Figure 7 shows the screen for the execution of the gateway program. As mentioned above, the program received tag information from the reader and then sent it to the cache database. It also accessed desired data from the database and sent them to the reader, such that the reader could write it into the targeted tag to verify the moving behavior of the patients.

In Figure 7, the sentence "Tag 4143, change to FG 101" represents the RFID tag with ID 4143 moved to the first cell and was detected by the FG with ID = 101.

Table 1. *The four cells in the main area of emergency treatment*

ID	FG	Cell Name
1	101	Drawing Blood
2	102	Examination
3	103	Diagnosis and Treatment
5	105	Observation

Figure 6. The management interface.

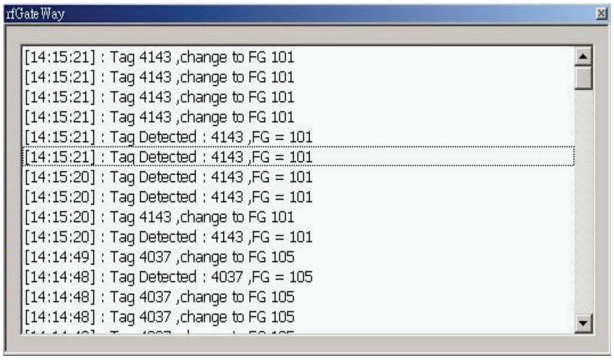

Figure 7. The screen displaying the execution of the gateway program.

7.2 Experimental Results

The FGs were set to detect the tags every 15 seconds. The corrected data excluded the signals which were not successfully received by the FGs. The system operated for one day and successfully received 442 data signals from 96 patients in the emergency treatment area. This emergency treatment area could be further divided into five branches according to the database in the hospital management information system. The branches included the department of internal medicine, the department of surgery, the emergency treatment room, the department of pediatrics, and the department for seriously ill patients. The locations, stay times and moving tracks of the patients were thus recorded into the databases and analyzed by the statistics program according to the five branches. An example of the statistical results for the patients in the department of internal medicine from the program is shown in Figure 8.

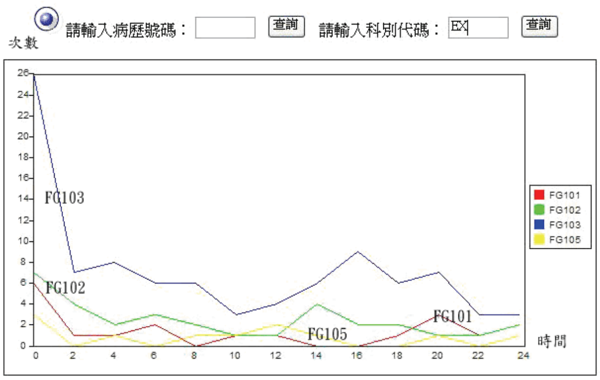

Figure 8. An example of statistical results for patients in the department of internal medicine.

In Figure 8, the *x*-axis represents the time and the *y*-axis represents the number of tags which were successfully located by the FG in each cell. There are four curves in the figure, with each representing the statistical results of a FG. It can be observed from the figure that most patients were located in the diagnosis and treatment region, and least in the observation region. The results for the patients in the other branches are similar.

Table 2 then shows the most located cells in which patients initially stayed, the average staying time in the initial cell, and the average moving frequency, according to the branches of the emergency-treatment area. It may be observed from the table that the patients in the department of internal medicine, the department of surgery, and the department of pediatrics were initially mostly located in the region of diagnosis and treatment (FG 103), and those in the emergency treatment room and in the department for seriously ill patients were mostly located in the examination region (FG 102). The average staying time was from 10 to 23 minutes, and the moving frequency was between 3 to 6 times.

According to the above results, the branches were clustered into two groups. One included the department of internal medicine, the department of surgery and the department of pediatrics, and the other included the emergency treatment room and the department for seriously ill patients. The data were thus analyzed according to the cells (FGs) and the two groups of branches. The results are shown in Table 3.

It can be observed from Table 3 that the patients in the first group were mostly located in the diagnosis and treatment region at first time and the patients in the second group were most located in the examination region. The average moving frequency was calculated by the total moving times over the total number of patients in that statistical region. The tags which were initially located in each cell were thus searched first by the FG of the cell if they were requested. Thus, these patients could be quickly and correctly located if they stayed in the initial cell. Table 4 shows the statistical results for the regions in which patients were most frequently located and their staying time according to the branches.

Table 2. *The most initially located cell in each branch of the emergency-treatment area*

Branch	The most initially located cell (FG ID) (Number of patients in this cell / Number of total patients in this branch)	The average staying time in the initial cell (Minute: Second)	The average moving frequency in the initial cell (count)
Department of internal medicine (32 patients)	FG 103 (24/32)	15:18	4.875
Department of surgery (24 patients)	FG 103 (16/24)	11:05	4.083
Emergency treatment room (8 patients)	FG 102 (8/8)	22:42	3.75
Department of pediatrics (20 patients)	FG 103 (15/20)	12:57	5.5
Department for seriously ill patients (12 patients)	FG 102 (7/12)	10:28	4

Table 3. *The analysis for the initially located data according to the cells (FGs) and the two groups of branches*

Cell (FG)	Branch	The average staying time in the initial cell (Minute)	The average moving frequency in the initial cell (count)
FG 103 Diagnosis and Treatment	Internal medicine Surgery Pediatrics (Total: 55 patients 220 location data)	13	4.82
FG 101 Drawing Blood	Internal medicine Surgery Pediatrics (Total: 9 patients 70 location data)	11	3.52
FG 102 Examination	Internal medicine Surgery Pediatrics (Total: 12 patients 62 location data)	12	5.6
FG 102 Examination	Emergency treatment room Department for seriously ill patients (Total: 15 patients 47 location data)	16	3.88
FG 103 Diagnosis and Treatment	Emergency treatment room Department for seriously ill patients (Total: 5 patients 6 location data)	15	3

Taking the branch of internal medicine as an example; there were 32 patients in the branch and they were successfully located 156 times, among which 94 times were detected by FG 103, indicatinng that the patients stayed most frequently in cell 3. The patients stayed in the most frequent cell with an average staying time of about 17 minutes and with an average of about 3 times. The other rows in the table could be similarly explained.

Table 5 shows the average and the total staying time for patients staying in their initially located areas. The total staying time in their initially located cells was 5,873 minutes. Note that the total staying time in all the cells was 6,108 minutes. This means that a patient stayed in their initially located area with nearly 96% probability.

The above experimental results are very helpful to the proposed approach because the patients located in their initial cell will be searched for with the highest priority by the FG of the cell. They can thus be successfully located with a very high probability. The proposed algorithm can indeed improve the search performance of the whole RFID system, especially when used for finding patients' locations in medical environments.

Table 4. *The analysis for the most frequently located areas according to the branches*

Branch	The most frequently located cell (located number in this cell / total located number in all the cells)	The average staying time in the most frequently located cell (minute: Second)	The average number of located times in the most frequently located cell (count)
Department of internal medicine (32 patients)	Cell 3 (94/156)	17:25	2.9375
Department of surgery (24 patients)	Cell 3 (54/98)	11:05	2.25
Emergency treatment room (8 patients)	Cell 5 (16/30)	31:52	2
Department of pediatrics (20 patients)	Cell 3 (72/110)	16:02	3.6
Department for seriously ill patients (12 patients)	Cell 3 (31/48)	08:15	2.583

Table 5. *The average and the total staying time for patients staying in their initially located areas*

Cell	Branch	The average staying time in the initially located cell (Minute)	The average appearing times in the initially located cell (Count)	The total staying time in the initially located cell (Minute)
FG 103 Diagnosis and Treatment	Internal medicine Surgery Pediatrics Emergency treatment room (Total: 60 patients 226 location data)	16	3.77	3616
FG 101 Drawing Blood	Internal medicine Surgery Pediatrics (Total: 90 patients 70 location data)	12	7.78	840
FG 102 Examination	Internal medicine Surgery Pediatrics Emergency treatment room Department for seriously ill patients (Total: 27 patients 109 location data)	13	2.42	1417

8. CONCLUSION

RFID is an emerging science and technology and a popular and useful tool suitable for a variety of applications, especially for supply-chain management. It can also be used in improving medical affairs. In this paper, we have proposed an improved concurrent search algorithm to use RIFD to quickly find patients' locations in medical environments. It is mainly based on the regularity of movements in medical environments to efficiently find RFID tags in a hierarchical RFID architecture. It is based on the assumption that patients in a medical environment move not so frequently as in a general mobile communication network. Experimental results from a large hospital in Kaohsiung show that the cell where a patient is initially located is usually the activity area of the patient later in the hospital. The experimental results thus verify the assumption and indirectly prove the performance of the proposed approach. We expect the that proposed approach can provide a partial solution to the problems of signal delay and waste of signal cost in RFID systems. Much effort is still needed to use RFID to promote the medical quality and improve medical-service security.

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