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RFID data processing in a real-time monitoring system for marathons

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Abstract

In all marathon events, an organizer needs to determine the winners. However, this is a complicated process since such events have many participants and starting points within a limited space. Under such condition, runners cannot start concurrently and thus those who cross the finish line first are not always the winners. To judge the top runners with accuracy and fairness, an organizer needs to acquire net times that rank participants. The net time is the difference between a runner's time recorded at the finish line and his/her time recorded at the start. This must be calculated for each runner. Currently, RFID technology is widely used to record times and determine the performance of runners in several marathon events. However, most RFID-based solutions for marathons are commercially available and licensed on a yearly basis. The cost of a commercial product can be as high as 2,000,000 baht. This study presents an implementation of RFID technology for a marathon organizer to determine the winners by recording the times at the check in point, the starting point, the checkpoints, and the finish point. Furthermore, the developed system also reports the results of the marathon in real-time via a web application that can be viewed on any online electronic device. The cost of the proposed solution is estimated to be about 200,000 baht. It can reduce the processing time from one hour to just five minutes, which is about one-tenth that of a commercial product.

Keywords: Real-time monitoring, RFID, Information tracking, RFID for marathon

1. Introduction

In each marathon event, there are many steps to conduct before an organizer can officially announce the winners. An international marathon event usually consists of three running types: 1) Marathon (42.195 km), 2) Half Marathon (21.10 km) 3) Mini Marathon (11.55 km). Each year there are more than 100 race events in Thailand. For each of these events, there are 5,000 competitors. In a simple and small event, the runner who reaches the finish line first is the one who wins the race. However, in major marathon events with more than 1,000 runners, it is more complicated because there are many participants who cannot concurrently be at the starting points that have limited space. Thus, in such case, the runner who reaches the finish line first is not always the one who wins the race. A marathon organizing committee needs to have a net time of each runner is required to rank them in each category. The net time is the time taken to go from the start to the finish. It can be computed by the difference between the time recorded at the finish minus with the time recorded at the start.

RFID systems have been applied to identify and capture time for runners in the event [1]. RFID technology is used widely and commercially available in several marathon events [2-7]. The usage of RFID technology requires both hardware and software systems that are licensed on a yearly basis. A hardware system consists of many components and equipment to work together synchronously. A software system needs to have well-written logic programs to handle several complex and complicated conditions. The overall system needs to ensure that the race result will be announced fast and accurately. Thus the cost of such system is extremely high, such as one of marathon organizers paid 2,000,000 Baht several years ago.

This paper presents an implementation of RFID technology to keep the times of runners in different points and report the results of the marathon series in real-time. The developed system can reduce the cost of processing steps match up to one tenth of the commercial system. We have evaluated our system in four race events that are 1) Siamrathani 2013, which had 192 participants, 2) Nakhon Phanom University – Khammouan International Marathon 2013, which had 605 participants, 3) the 16th Srinakarin Minimarathon, which had 791 participants, and 4) the 11th Khon Kaen International Marathon, which had 5,113 participants. Based on our experience in using such system, the chip reader could not read all chips thus there were several errors. This paper proposes and presents the design and development of the system that has the estimated cost as 200,000 Baht.

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2. Materials and methods

2.1 Related work

Some important web applications for managing racing events include the innovative timing system (Jaguar) [2], other desktop applications [3-7], and EnduRan [8].

Figure 1 Innovative Timing System Application [1]

Figure 1. shows an innovation timing system. Based on our experiences, it could not connect to a server and merge online results. This system runs on the Ethernet machine system connected directly from the controller that retrieved data reading from the chip. The computer processor connected and fed data from the memory buffer on the controller. The information was collected separately for each controller. Thus, it took an excessive amount of time to integrate information from each controller and retrieved the final results of the competition time.

Another related work is EnduRan, which is a web application to manage racing events as shown in Figure 2. The EnduRan was used in a racing event that spanned across multiple days and whose participants had to run (on foot) for 100 miles. In such events, many checkpoints were needed to provide runners with access to food, water and, if necessary, medical assistance. At these checkpoints updates on participants' health status and race timings needed to be sent to a central location so that followers across the globe could monitor the overall progress of the race as well as the current situation of individual racers. This system was the real-time application but without data processing part while our proposed system supports real-time data processing.

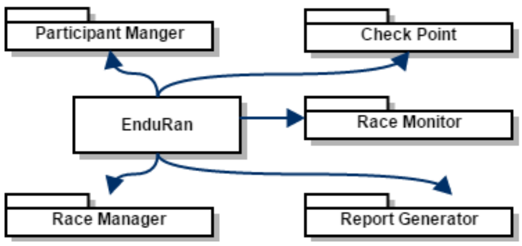

Figure 2 EnduRan System Level Diagram [7]

Wang et al. [9] proposed an event-oriented framework to automate the transformation of physical RFID observations to semantic data in various applications. Then, they evaluated their work with their developed simulator of an RFID-enabled supply chain system. Later, Zang and Fan [10] had implemented the architecture and the event processing mechanism in enterprise information systems based on RFID. In addition, they also proposed optimization strategies to detect complex event effectively. On the other hand, our work has tested with an actual real-time event.

RFID has also been applied in real-time manufacturing information tracking for enterprises. Zhang et al. [11] presented the framework and methods to capture real-time manufacturing data. However, they did not evaluate their proposed infrastructure but used a case study to demonstrate their work.

2.2 Design and methodology

In this section, we will describe the system data flow, web application, web service, and RFID system [12].

2.2.1 RFID data flow

We designed and developed the system with the workflow as shown in Figure 3. The data comes from an RFID controller with the machine controller reading data from an RFID tag through an antenna. The controller sends readable data through the internet to our proposed web service.

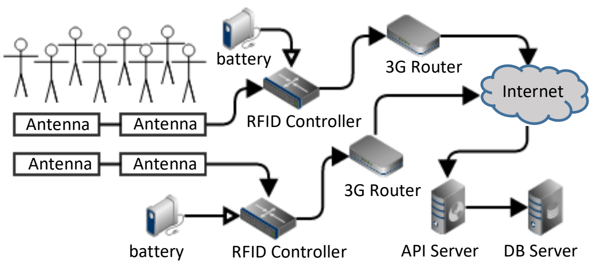

Figure 3 System Data Flow

In a system design RFID controller will read RFID chip tag and send a real-time of chip data to the database server via the developed web service. It will then process data and notification to staff on a web application. The goal of the system flow is to record the times at different points which include the check in point, the start point, checkpoints and the finish point. At the check in point, each runner needs to check chip data before the start of the running time about 20 – 30 minutes. We designed and arranged the check in point and the start point are near to each other. After the runner passed the check in point and the start point, then he/she are will run pass the checkpoint stations. Finally, they will reach the finish point which is in the same position as the start point. All of four kinds of points are shown in Figure 4.

2.2.1.1 Web service design and development

Our team has designed and developed a web application based on PHP programming language [13]. First, we tested the web service on top of Slim framework [14], running on Apache web server [15]. However, there was the problem of concurrency and performance for storing data to MySQL server [16]. Because PHP has a non-blocking I/O architecture, during PHP processing between receiving data and storing data to a database, PHP based system cannot receive another request. As a result, our system based on PHP could not handle multiple requests at the same time. This time delay problem causes poor performance and efficiency. We therefore shift to using Node.js platform [17] which is a platform built on Chrome's JavaScript runtime.

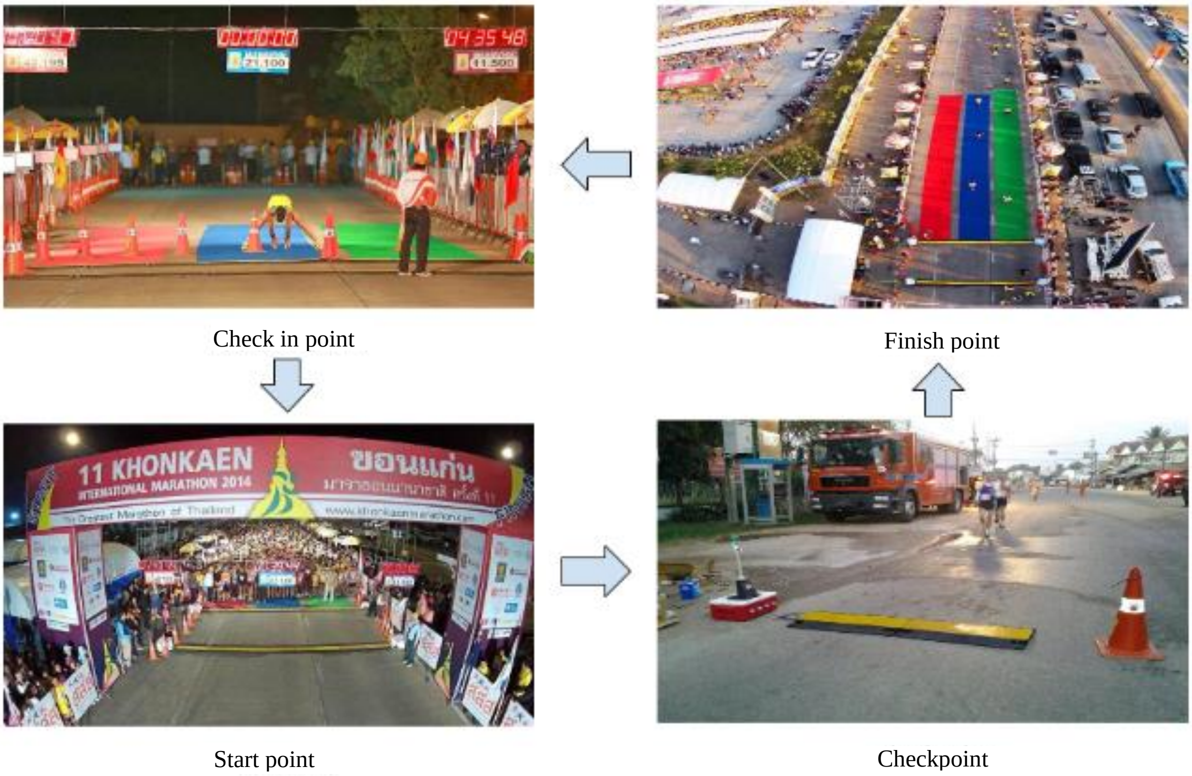

Figure 4 Different Points of the Race

It guarantees 10,000 concurrency requests at once [18] and JavaScript has a non-blocking I/O architecture [19]. By using Node.js with non-blocking I/O architecture, the system can handle a large amount of data quickly without waiting time for the processing of other tasks. These multiple tasks can be executed in parallel and this is the main reason why the operation time of our proposed system is reduced. The system with the web service based on Node.js can transfer RFID data to the database at the same time that it receives the newly sent data from the controller. Our system is shown in Figure 5. We use Node.js to implement a web service and MySQL server to store data.

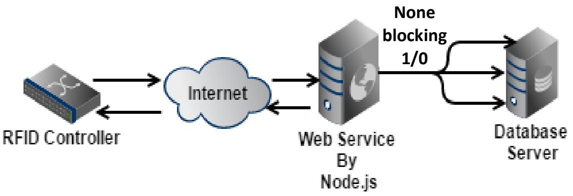

Figure 5 The Web Service with a Non-blocking I/O System by Node.js

2.2.1.2 Web application for race result

We have designed and developed the international Khon Kaen marathon race result website at http://timetrack.kku.ac.th. When a user types a URL address, the browser will display the race result. They system can display the results by the running category and support search by a Bib number or a runner name. The information for each information entry includes Bib number, race type, running category, nation, net time, and finish time. When the web service receives data, the data will be used to save data in a standalone MySQL Server. The information of runners was imported from another database used in the registration system. In addition to a standalone MySQL database server, we have another database as a backup on a different server. The web application developed using PHP language and Yii framework retrieves data from MySQL server. When users make a request to the system, the system will process and display data on the web page. The system is designed to be responsive as shown in Figure 6.

2.2.2 RFID system

An RFID system mainly consists of an RFID controller set and RFID tags.

2.2.2.1 RFID controller set

An RFID controller is a hardware component for reading RFID chip tags from runners and sending chip data to a server over the internet network to the web service. The controller specification is shown in Table 1. The picture of RFID Controller is shown in Figure 7.

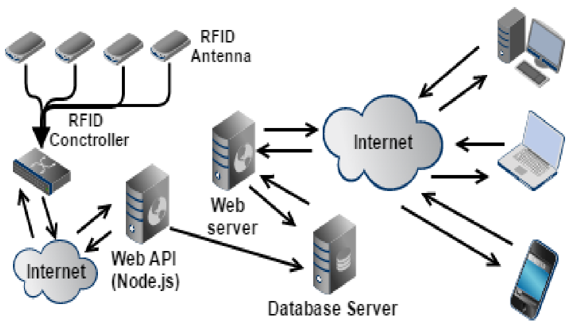

Figure 6 Online Real-time Processing Marathon System

Figure 7 An RFID Controller and RFID Antenna

Table 1 An RFID controller specification

Air Interface Protocol	EPCglobal UHF Class 1 Gen 2 / ISO 18000-6Cac
Antennas	4 high performance, monostatic antenna ports 2 high performance, monostatic antenna ports optimized for Impinj reader antennas (RP TNC)
Transmit Power	+10.0 to +30.0 dBm (PoE) +10.0 to +32.5 dBm (external universal power supply)
Max Receive Sensitivity	-82 dBm
Min Return Loss	10 dB
Management Console	RS-232 using a standard Cisco-style management cable (DB-9 to RJ-45) Baud rate: 115200, Data: 8 bit, Parity: none, Stop: 1 bit, Flow control: none
Power Sources	Power over Ethernet (PoE) IEEE 802.3af +24 VDC @ 800mA via external universal power supply with locking connector—sold separately
Operating Temperature	-20 °c to +50 °c
Dimensions (H x W x D)	7.5 x 6.9 x 1.2 in (19 x 17.5 x 3 cm)
Weight	1.5 lbs (24.5 oz)

An antenna is initially designed for boundary/threshold crossing applications, the threshold of an Impinj RFID antenna (as shown in Figure 9) has a very wide beam width to maximize zone coverage. Threshold antennas provide a consistent and continuous read zone when linearly distributed head-to-tail. At 46 x 9 x 2 cm, the threshold antenna's planar form factor fits readily onto fencing or other borders. Electrical specifications of the RFID antenna are shown in Figure 8

Regarding the error checking of the data transmitted from the chip, we used the first four bits of data to check for our specified condition. If the values of those four bits match the conditions, the transmitted data will be processed. Otherwise, the data will be ignored.

To reduce ESD effect to a human body, we have designed a method to install the chips in shoes to minimize contact between a chip with a human.

Parameter	Typical	Units	Conditions/Notes
Frequency Range	865 to 868	MHz	
Far-field Gain	5.0	dBi	
HPBW (x-z plane)	50°±3°	Deg	3 dB beam width
HPBW (y-z plane)	100°±3°	Deg	3 dB beam width
Pattern Variation (x-y plane)	14	dBi	Between max and min
Polarization	Linear		Parallel to short axis
VSWR[1]	1.5:1		
Input Impedance	50	Ω	
Input Power	30	dBm	33dBm absolute max
ESD	2	KV	Human Body Model

Figure 8 RFID Antenna Electrical Specifications

Figure 9 An RFID Antenna

Figure 10 An RFID Controller Station

The controller and antenna are arranged on the ground, for the performance of the data read from the chip RFID. The antenna is placed under the plastic panels as shown in Figure 10.

Table 2 shows RFID components in the 11th Khon Kaen International Marathon. We use the Wi-Fi router instead of 3G at the start and finish points because we can access Wi-Fi that is available for free in that area.

Table 2 RFID components at different station points

Station point	Component	Number of uses
Check in	RFID Controller	1
	RFID Reader	4
	3G Router	1
Start and Finish (same location)	RFID Controller	4
	RFID Reader	16
	Wi-Fi Router	1
Checkpoint 1	RFID Controller	1
	RFID Reader	4
	3G Router	1
Checkpoint 2	RFID Controller	1
	RFID Reader	4
	3G Router	1

2.2.2.2 RFID tags

An RFID tag is used to store data. Before the race event, the chip data is programmed and checked for confirming the rights of data and checking chip performance. The appearance of the chip RFID will put them on the line, which can prevent wet from water. Chips are placed in the shoes on both sides by inserting under a shoe lace. The chip is shown in Figure 11. When sending RFID chip tag data from the controller to the web service, we protected data by using two methods 1) implementing a secret KEY on the web service and requiring an RFID controller to send a secret KEY. Each data transmission needs to have its own secret key. 2) configuring prefix of data on a programmable chip. The prefix is the randomization of data specific for each marathon event.

Figure 11 RFID tags attached to a shoe rope

3. Results

We have used our system in many events, including the 11^{th} Khon Kaen international marathon. In this section, we describe the registered runners, the web application result, and the statistics of the 11^{th} Khon Kaen international marathon.

3.1 Registration runner

There were 7,725 registered and 5,608 runners who participated in these three types in the 11^{th} Khon Kaen international marathon as shown in Table 3.

Table 3 List of runners divided by category

Type	Registered Runners	Actual Runners
Marathon	712	667
Half Marathon	948	876
Mini Marathon	6,065	4,065

3.2 Race result report

The 11^{th} Khon Kaen international marathon event had 53 categories of race types. The awards were bestowed to the top 5 and the top 10 runners of each category. The runner can check the results online at http://timetrack.kku.ac.th. The result shows two types of runner time. finish time and net time. Finish time is the time between the start time of the first runner and each runner's finish time. On the other hand, the net time is the difference between the time recorded at the finish minus the time recorded at the start.

Staff can monitor the statistics of runners from the beginning of the race. It shows the information of the runner when running through checkpoints. The system keeps the logs and statistics. The search from the numbers run, or the name of a runner is shown in Figure 12.

Figure 12 Real-time Result, Monitoring System and Search Support of the Web Application

From Figure 12, a left-handed side picture shows a monitor that displays status reports in real time. When the runners run through a RFID controller, the system will update the information of the runners on that monitor. After the race ends, runners can check the results through a website as shown in the right-handed side picture of Figure 12.

3.3 RFID chip tag data

The 11^{th} Khon Kaen international marathon 11th event has data from RFID chip tag 161,551 records of input from the controller. The data was retrieved from the web service and stored to the database.

3.4 Experimental result analysis

We compared the existing system which was used in the 10th Khon Kaen international marathon event and the system that we developed which was used in the 11th Khon Kaen international marathon event. We summarize the main points of the comparison in Table 4.

From Table 4, the operation time of our proposed system is greatly reduced. The chip cost is much cheaper than the existing method because the chip that we use is made in Thailand. We need to speed up the process because several runners are from other provinces or from other countries. Many of them plan to go back their homes or attend other next events right after they know the current race results.

4. Conclusions

We have designed and developed the real-time marathon processing and reporting system for many marathons, including the 11th Khon Kaen international marathon. The developed system uses RFID data processing technique to compute the processing time of running at the check in point, the start point, the checkpoints, and the finish point. It can also calculate the net time (the elapsed time which is the difference between the finish point and the start point). The net time is used to order the ranking of the runners and reporting race results in 53 categories on the web application.

In the future, we would like to handle many simultaneous reads and writes to a single server. By using a MySQL Server replication to distribute information from master to slave and processed separately from each other. We would like to detect duplicates which may be due to multiple tags are attached to the same runner. In addition, we would like to speed up the processing system by storing data using memory instead of using a relational database. We are also interested in using data mining to find interesting information about runners and their running times at different points of the race.

Table 4 The result comparison between the existing system and our proposed system

Particular	Existing	Proposed
Cost		
Hardware cost	Bought the hardware of approximately two million Baht.	The project was a collaboration between universities and the company with no cost.
Software cost	Included in the purchased price of the hardware but used only two years under the software license.	custom development
chip cost	210,000 Baht (30 x 7,000 pcs)	182,000 Baht (13 x 14,000 pcs)
Operation time		
Installation time	1.5 hours	30 minutes
Monitor time	It was not a real-time PC-based processing. Staff needed to retrieve data from the controller according to a preset time.	real-time on the check in point, the start point, the checkpoints and the finish point.
Merging data before process	30 minutes	None
Processing time	1 hour	5 minutes
Competition result announcement time	Cannot be announced within 24 hours due to chip quality.	4 hours
Competition results for all runners	Unavailable	12 ours

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