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THE PERFORMANCE ANALYSIS OF RFID POLLING SYSTEM ON LESSON LEARNING IN UNIVERSITY

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ABSTRACT

Radio frequency identification (RFID) is an increasingly important technology in the modern world. The first major applications of RFID focused on supply chain management. The first institutes on campus to introduce RFID technology were university libraries, to organize and manage books. Additionally, RFID enhances inventory tracking and reduces shrinkage, ensuring that systems can be operated in real-time. Some selected and related critical factors should be addressed when discussing each chosen application. This work considers the feasibility of new RFID applications in education. The unique characteristics of RFID, such as accurate personnel's tracking, authentication, responsibility and recall, mean that the attendance by students of classes can be automatically monitored. Cheating can be discovered at the beginning of an examination. Therefore, RFID technology has a good potential contribution in education by active RFID tags for unique identification. Additionally, an RFID network is built accelerate the widespread adoption of RFID technology.

KEYWORDS: RFID, education, examination, WEB-based platform, intelligent image, system.

1. INTRODUCTION

In traditional university education, an education institute focuses on promoting strong relationships between students and teachers [1]. However, a long delay time in making a roll call is taken by a teacher to switch and poll all students in a classroom individually. Therefore, the learning time of each student due to the roll call is reduced, affecting student's learning. To overcome the problem, RFID technology is implemented on campus [2-5]. The basic architecture of RFID technology comprises a tag, a reader and a database. A reader allows multiple tags to access the channel simultaneously, and sends the information on tags to a database. The RFID system supports innovative service offerings, meets legislative requirements, and is flexible and responsive. Most information about a desired component or product can be obtained in real time by linking computer networks to sensors and identification technologies.

In general, the seats in a classroom are in an irregular arrangement, and are randomly chosen among these students after them entering the classroom. Therefore, the issue of automatically tracking the location of a specific tag or every student's seats has to be resolved first when we performing the tracking of the attending rate of lesson learning among students in a classroom. The most adopted method is that each student's seat has a RFID reader individually. Each student has a tag with an independent and different serial number. When a student is on the chosen seat, it put his/her passive tag on the RFID reader to identify his/her seat's location. However, the cost to install all RFID readers to all students' seats is very expensive.

Some additional issues also need to be considered. One issue is how to know who want to leave the room, with a good reason, during a class as well as who leaves the room without permission during an examination. Another issue is that "ghost students" should be detected. These intricate processes can be resolved by RFID technology. By scanning the RFID tags, these miscellaneous procedures for managing the entrance and exit of students can be resolved and simplified.

To achieve these functions which are described as above, in this work, we place a RFID reader on the entrance of a classroom. However, the selection of frequencies, tag configuration, types and shape of the antenna and reader in RFID technology influences the capability of the whole RFID system [1-10]. The antenna of the reader can

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either emit radio signals to a tag, or receive radio signals from it. Antennae with high frequencies, in the microwave band, allow higher data rates for transferring or exchanging data, and control information between reader and tag along a line of sight. A high-frequency system can provide easy access to tags and data transmission rates. Therefore, this study adopts an RFID reader with frequencies in the microwave band. The RFID reader controls the multiple accesses among active tags, and automatically accumulates data from these tags simultaneously. The RFID reader reads and records the unique tag number when a student entered the classroom. Therefore, the presence and absence of students can be determined by logical deduction from information obtained from readers. In addition, an auxiliary hardware circuit is designed to achieve the function to identify the chosen seat of a student. The procedure of our RFID system is described in section 2 in detailed.

This study considers some critical issues, which can be resolved when the proposed system is implemented. The rest of this paper is organized as follows. Section 2 establishes the queueing model of the system. Section 3 analyzes the system performance to poll all students which are in the classroom to find which seat is chosen by the polled student. Section 4 presents the numerical results and, finally, concluding remarks are made in Section 5.

2. SYETEM ARCHITECTURE AND OPERATIONS

In our RFID system, the database stores the information the classes taken by students. This information can be applied to determine the "legal" status of each student or not. The tracking of the attendance and learning status of each student are also stored in the database. The database also records the relationship between the number of tag and the seat for tracking examination papers.

2.1 The design of entrance controller

A reader can read a tag at each door to confirm whether the door is locked. That information could be sent to a control center from the RFID reader. In addition to determining whether the tag is legal, the system should be able to locate the visiting tag in front of the entrance to an accuracy of ten millimeters, to ensure that strangers and illegal tags cannot enter the room. Hence, the RFID reader captures the signal strength from the active tag to compare it with the predefined threshold value. Notably, database stores the information that determines a student who is allowed to enter the classroom or not, i.e. the door of class will be opened or not. Therefore, the signal strength from an active tag will not make the erroneous action of door.

However, for the traditional processes, if the receiving signal strength from the active tag is more than that of predefined threshold value A, and the tag is legal, then the entrance controller automatically opens the door, and allows the student with the legal tag to enter the classroom. If the student enters the classroom, and is far away from the entrance door such that the received signal strength from the student is below the predefined threshold value B, then the entrance controller locks the door automatically again. However, this method has the following problems.

(1). If a student with a legal tag remains by the door, so that the received signal strength from the tag remains above the threshold value B, then the system is unable to judge whether the student has already entered the classroom or the examination hall.

(2). The battery power gradually decays with the passage of time. If the tag does not store the amount of energy remaining in the battery, then the intensity of the absolute signal does not accurately locate of the student. Therefore, the system needs alternative ways of determining whether a student should be permitted to enter the classroom or the examination hall, and whether the student has already entered the room.

A predefined threshold is used to resolve these problems, while also considering the safety of entrance. The modified procedures for processing entrance control are as follows.

Step 1 – If an RFID reader receives the signal from a specific tag, then it opens the entrance door, and let student enter the classroom, and a timer counter starts.

Step 2 - If the student enters the classroom or examination hall before the timer counter reaches the predefined time, then the procedure of Step 4 is performed. Otherwise, if the timer counter reaches the predefined time, then the entrance door closes automatically whether or not the student enters the classroom or examination hall. The RFID reader then automatically tells each active tag to enter the receiving (idle) state.

Step 3 - If the student is still outside the entrance door when the entrance door is closed, then he/she has to push the button on the tag. The procedure of Step 1 is then performed.

Step 4 - Step 3 of the operation algorithm for classroom management in Section 2 is performed.

This algorithm reduces the error rate of judging whether a student is inside or outside the entrance door to almost zero. This approach eliminates mistakes caused by variations in the intensity of the tag's signal due to decay of the battery power, and saves battery power.

2.2 The polling procedure to find the student's seat

In our system, see Figure 1, we use active tag. The tag of an active RFID tag system derives its power from an onboard battery to power the chip unit, and communicates with the RFID reader by using peer-to-peer communication. Therefore, an active tag has a limited lifetime due to the heavy use of battery power. Hence, the active tag must be placed in a power saving status by receiving the broadcast from the corresponding reader when a student enters the specific classroom. About the polling procedure to find the student's seat, the operation algorithm of classroom management is as follows.

Step 1 – A student wishing to attend an education course should submit a registration request with his/her unique tag serial number to the RFID system. Any student with a legal tag is allowed to enter the classroom for the registered course. If the reader senses the correct tag number of tag recorded in the database server and approves this request, giving by first come first served, and the door automatically opens. The server also records all corresponding information of service histories about this tag, such as time which the student enter the classroom. If an illegal tag is detected, then an alarm is displayed on the screen to alert the responsible students, and the door remains closed.

Step 2 - The classroom door is closed after a student enters the classroom. The corresponding RFID reader sends a Tag_off message to the corresponding active tag, placing the active tag in the power saving status.

Step 3 - To ensure that each student is in his correct place in the classroom, RFID system sends a Poll_request to poll tags, which are recorded in the database when they enter. If a tag is polled by the RFID system, then the LED installing on the wall in front of students' seats will display the polled student's name. The student with the polled tag has to respond to the RFID system by pushing the button on the desk where he/she sits. When the button is pushed, the system can access the pre-defined number of the seat and records the relationship between the seat and the student.

Step 4a - A student wishing to leave the classroom during the lesson learning has to push the button on the tag, sending a Tag_on_request to the system via the RFID reader. After receiving the Tag_on_request message, the system returns a Tag_on_response so that the tag status is active.

Step 4b - A student wishing to ask a question during a class has to push the button on the desk, to send a Question_request to the system through the reader. The yellow LED on the corresponding desk turns on, and glimmers for a fixed time. The voice system is then initiated, and becomes active after the tag receives the Question_response.

Step 5 - At the end of the class, the RFID system broadcasts a TAG_active message through the RFID reader to announce that all tags are active again.

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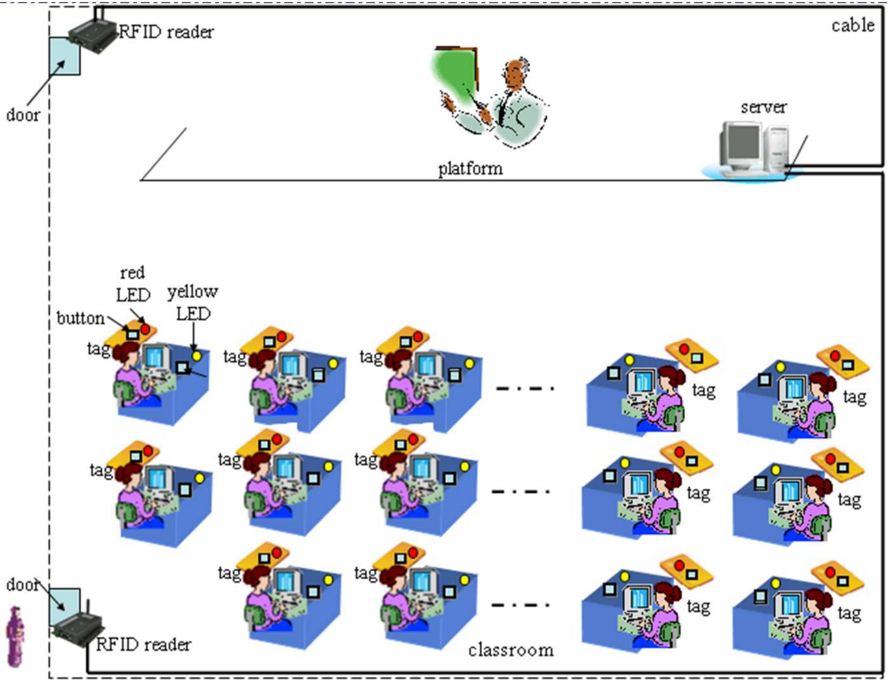

Figure 1: System structure

3. SYSTEM QUEUEING MODEL

To obtain the desired properties of systems and performance metrics such as throughput and mean delay time, modeling of system is necessary to made quantitative analysis. In general, throughput and average delay time largely justify a system's robustness. Assume that n_i tags at the beginning of an initiated renewal. Let t_{over} be the overhead time is sum of the time to generate the packet, the time to poll a student to fine his/her chosen seat by the RFID system. Denote t_s to be the response mean time of a tag, and τ to be the maximum propagation delay. In the other words, it means that $t_s + \tau < t_{\max}$. Let λ be the arrivals rate which the arrivals to the polling system is from outside. Denote λ_2 be the arrivals rate of node 2 which the arrivals to the polling system is from these students without responding to the polling requests up to the maximum waiting time. Then the total arrival rate to the polling system, i.e. node 1, is

$$\lambda_1 = \lambda + \lambda_2 \tag{1}$$

Since this network includes one or more sources of incoming tags and one or more sinks that absorb departing tags, the model of the system can be expressed as a open network with two nodes. In this example, the open queueing network is illustrated as Figure 2 [11].

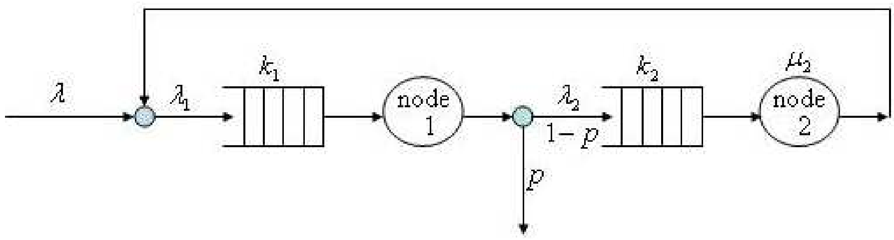

Figure 2: system queueing model

In Figure 2, the probability that system can receive a response from the polled student within a maximum response waiting time t_{max} is denoted to be p. Therefore,

$$\lambda_2 = \lambda_1 (1 - p) \tag{2}$$

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Subtracting equation (2) into equation (1), we obtain

$$\lambda_1 = \frac{\lambda \mu_1}{p} \quad (3)$$

and

$$\lambda_2 = \frac{\lambda(1-p)}{p} \quad (4)$$

Based on the fact of $M/M/1$ queue, if μ_i, $i \in \{1,2\}$, is the service rate of the i th node, the server utilization, ρ_i, of the i th node is given as

$$\rho_1 = \frac{\lambda}{p\mu_1} \text{ and } \rho_2 = \frac{(1-p)\lambda}{p\mu_2} \quad (5)$$

If k_1 and k_2 is the number of finding students at node 1 and node 2, respectively, using Jackson's result, the probability to find k_1 students at node 1 and k_2 students at node 2 is can be expressed as the product form and is given as

$$P_r(k_1, k_2) = (1-\rho_1)\rho_1^{k_1}(1-\rho_2)\rho_2^{k_2} \quad (6)$$

4. PERFORMANCE ANALYSIS

According to the descriptions in section 3, we allow there are only k_1-k_2 students respond the polling requests among the k_1 students.

$$T(k_1, k_2) = k_1 t_{over} + (k_1 - k_2)(t_s + \tau) + k_2 t_{\max} \quad (7)$$

In equation (7), the first item represents the time to display the name of these n_i students on the LED. The second item is the time to successfully respond these d responses from all polling requests. The third item is the time which must be wasted to ensure that any response is not detected when these students do not respond their responses to these polling requests. The random time variable to successfully transmit these ID packets is

$$U(k_1 - k_2) = (k_1 - k_2)t_s \quad (8)$$

4.1 Throughput

To derive the system performance, initially assume that the number of total students is N within the classroom. Under a steady state, the average time ratio of the periods which has response to polling requests in a mean round cycle is called the throughput. The random variable epoch $\overline{T}$ is defined herein as the mean interval between the instant that the interrogator initiates a polling among these tags in node 1. Allow $\overline{U}$ to be a random time variable to successfully transmit these ID packets. Then, the busy period can be obtained as follows:

$$\begin{aligned} \overline{T} &= \sum_{k_1=0}^{N}\sum_{k_2=0}^{k_1}\left[k_1 t_{over} + (k_1 - k_2)(t_s + \tau) + k_2 t_{\max}\right]P_r(k_1, k_2) \\ &= \sum_{k_1=0}^{N}\sum_{k_2=0}^{k_1}\left[k_1 t_{over} + (k_1 - k_2)(t_s + \tau) + k_2 t_{\max}\right](1-\rho_1)\rho_1^{k_1}(1-\rho_2)\rho_2^{k_2} \end{aligned} \quad (9)$$

In addition, the expected time to successfully transmit all generated packets in busy time duration is

$$\begin{aligned} \overline{U} &= \sum_{k_1=0}^{N}\sum_{k_2}^{k_1}(k_1 - k_2)t_s P_r(k_1, k_2) \\ &= \sum_{k_1=0}^{N}\sum_{k_2}^{k_1}(k_1 - k_2)t_s(1-\rho_1)\rho_1^{k_1}(1-\rho_2)\rho_2^{k_2} \end{aligned} \quad (10)$$

Therefore, the system throughput is given as

$$throughput = \frac{\overline{U}}{\overline{T}} \quad (11)$$

4.2 Mean delay time performance

Restated that one of these tags may have one packet to be transmitted when it is polled. While considering n students in a classroom, i.e., there are n students at node 1, the delay time suffered by this polling procedure has three components: (1) the time between the instant that this packet is generated and the instant that it is allowed to enjoin the channel contention; and (2) the packet transmission time itself. Herein, define the delay $D(n)=W(n)+X(n)$ as the average time which a polling request is generated until it has been successfully transmitted. The average delay $\overline{D}$ can be separated into $\overline{W}$ (i.e. the average time that the polling is executed until the current round cycle is over) and $\overline{X}$ (i.e. the average time that the system initiates the new round cycle until the response to a polling request is successfully transmitted).

Allow $X(k_1,k_2)$ to be the delay time to serve these k_1 students with maximally available detected responses. For k_1-k_2 successful responses [12], we have

$$X(k_1,k_2)=k_1 t_{over}+\frac{(k_1-k_2)(k_1-k_2-1)}{2}(t_s+\tau)+\frac{(k_1-k_2)k_2}{2}t_{\max} \tag{12}$$

According to the renewal theory [13], $\overline{W}$ can be expressed as

$$\overline{W}=\frac{E_{k_1,k_2}\left[T^2(k_1,k_2)\right]}{2E_{k_1,k_2}\left[T(k_1,k_2)\right]} \tag{13}$$

Similar to [14], the delay average time $\overline{X}$ is

$$\overline{X}=E_{k_1,k_2}\left[\frac{X(k_1,k_2)t_s}{U(k_1,k_2)}\middle| k_1,k_2\right] \tag{14}$$

Therefore, the mean delay time of a packet can be expressed as

$$\overline{D}=E_{k_1,k_2}\left[\frac{X(k_1,k_2)t_s}{U(k_1,k_2)}\middle| k_1,k_2\right]+\frac{E_{k_1,k_2}\left[T^2(k_1,k_2)\right]}{2E_{k_1,k_2}\left[T(k_1,k_2)\right]} \tag{15}$$

5. NUMERICAL RESULTS

This chapter evaluates the performance of our system. Subsequent impacts on the performance of our system among a variety of the number of polled students and the system are examined by considering different response probabilities. According to our results, we change the polling schemes or only one parameter and maintain the others unchanged to clarify the effect of the changed parameter as much as possible for each comparison. Based on the condition of equations (3) and (4), we have

$$\frac{\mu_2}{(1-p)\mu_1}=\frac{\rho_1}{\rho_2} \tag{16}$$

Denote $k=\frac{\mu_2}{\mu_1}$ be the ratio of the service rate of node 2 to that of node 1. In general, $k<1$. If the values of p, ρ_1, and k are given, then the value of ρ_2 can be determined. Therefore, from the result of equation (16), we have

$$\rho_2=\frac{1-p}{k}\rho_1 \tag{17}$$

Subsequent impact on the performance of our system among the varieties of the ρ_1 value, k, p, and t_{max} are examined.

This first comparison is made by altering the value of ρ_1. Equation (5) also verifies that if the value of ρ_1 increases based on the fixed service rate and the probability p, the arrival rate which the arrivals to the polling system is from outside increases. Figures 3 and 4 summarize the results of the relationship among throughput performance, delay performance and various values of the number of students that are allowed to enter the classroom, denoted as N, with different parameters ρ_1. According to Figures 3 and 4, we set that the smaller the value of ρ_1 is, the better the system performance is. It is intuitive that if the number of polled students increase, the mean polling time to completely poll all students in the classroom increases. Figure 5 presents that if the value of *N* surpasses a level of the number of students, then the amounts to enhance the performance is not obvious even through optimal value of *p* and *k* are applied. However, if the value of ρ_1 does exceed this level, the performance is largely enhanced when optimal *k* is applied. Otherwise, if the value of ρ_1 does not exceed this level, the amount to enhance the performance is not obvious. In addition, the larger value of *k* means that the service ability of node 2 is lack. It also represents that the tendency of the node 2 is lengthy such that the total arrivals to node 1 decreases. Because the smaller the value of *k* is, the more the feedback arrivals are. This phenomenon also lengthens the mean delay time of our system. Figures 5 and 6 confirm this notation.

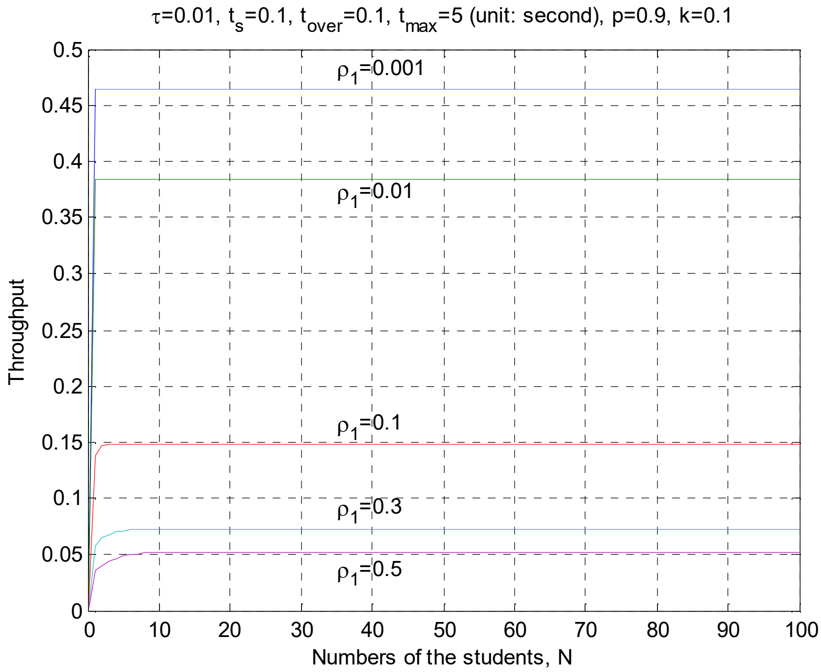

Figure 3: The relationship between throughput performance and N with various parameters ρ_1 under the conditions p=0.9 and k=0.1.

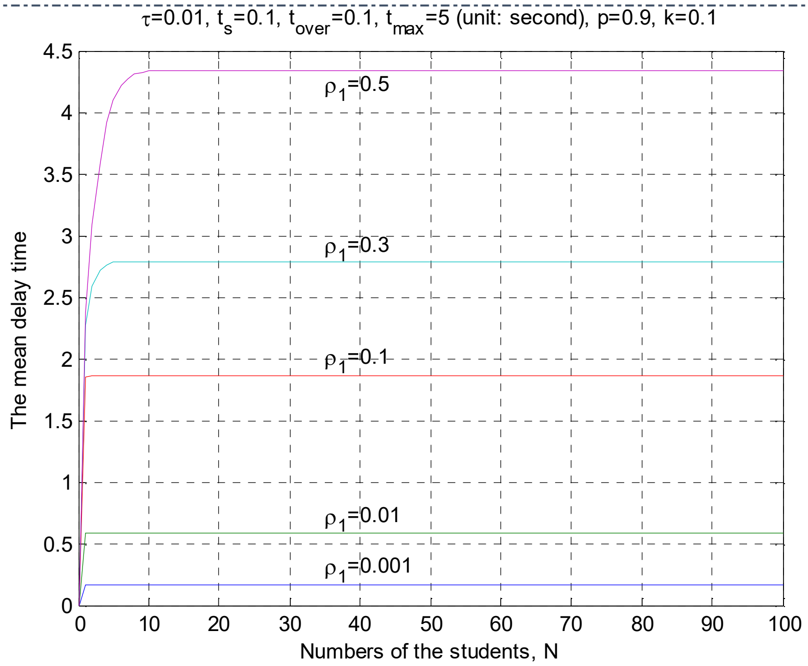

Figure 4: The relationship between delay performance and N with various parameters ρ_1 under the conditions p=0.9 and k=0.1.

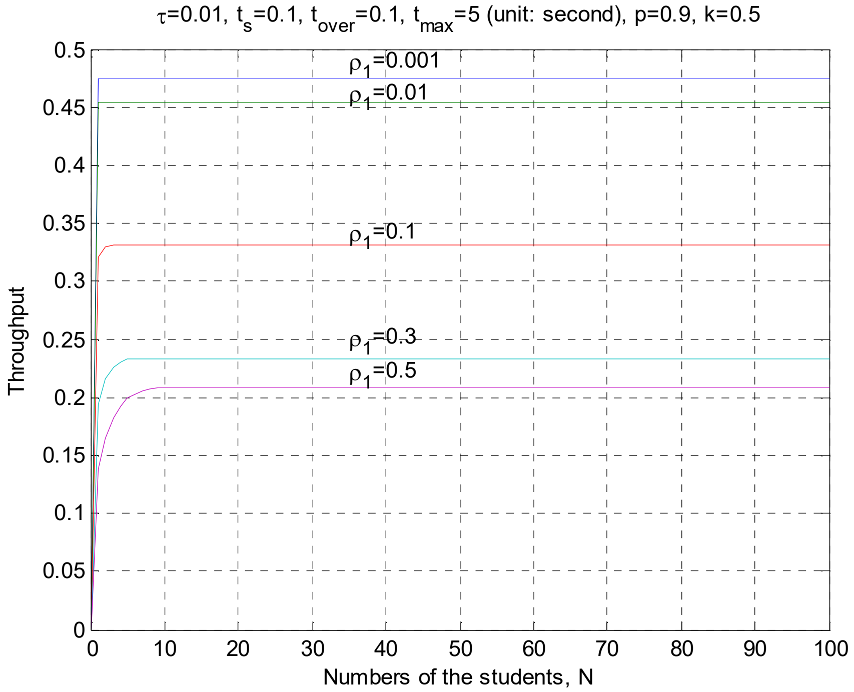

Figure 5: The relationship between throughput performance and N with various parameters ρ_1 under the conditions p=0.9 and k=0.5.

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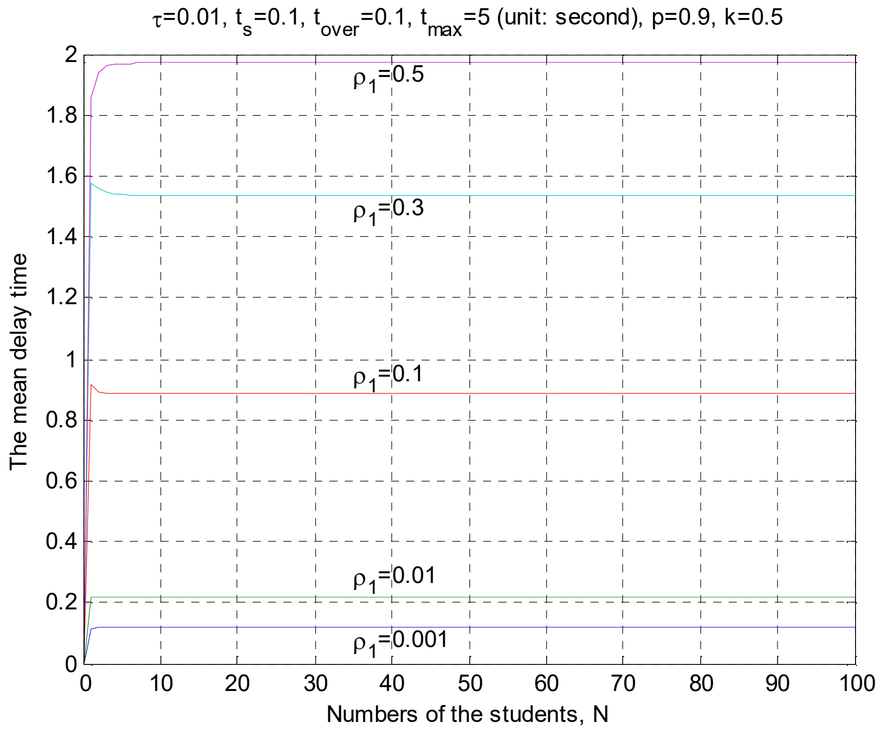

Figure 6: The relationship between delay performance and N with various parameters ρ_1 under the conditions p=0.9 and k=0.5.

Varying value of parameter ***k*** makes second comparison. It also obviously reveal that the curve with a larger value of ***k*** obtain the correspondingly throughput performance and minimum delay performance at the same ρ_1 and ***p***. The third comparison is made by varying the value of parameter *p*. We summarize the performance of the system at various value of *p*. It is intuitive that the larger value of *p* represents that a polled student can respond the polling request from RFID reader within the time duration t_{max}. It also decreases the feedback arrivals to node 1. It reveals that the throughput performance increases with the increment of the value of *p*. It also presents that the mean delay time increases with the decrement of the value of *p*.

From Figure 3 to Figure 10, we can infer no obvious change in the throughput performance and delay performance. While considering the impact of *p*, *k*, and ρ_1, all figures reveal that the system performance experiences a significant change. From the perspective of the model, our analyses seem to indicate the relationship among these dominant factors such as *p*, *k*, and ρ_1. Therefore, the forth comparison is made by altering the value of ρ_1. We first derive the relationship between throughput performance and ρ_1 to obtain the minimum throughput performance based on a specific values of *p* and *k*. From equation (11), we set

$$\frac{\partial(throughput)}{\partial\rho_1} \equiv 0 \tag{18}$$

Therefore, we have

$$\overline{T}\frac{\partial\overline{U}}{\partial\rho_1} = \overline{U}\frac{\partial\overline{T}}{\partial\rho_1} \tag{19}$$

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fter some mathematical operations, we know that the value of ρ_1 to obtain the minimum throughput performance must satisfy following equation.

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$$\frac{\sum_{k_1=0}^{N}\sum_{k_2=0}^{k_1}\left[k_1 t_{over} + (k_1 - k_2)(t_s + \tau) + k_2 t_{\max}\right](1-\rho_1)\rho_1^{k_1}(1-\rho_2)\rho_2^{k_2} f(\rho_1, k_1, k_2)}{\sum_{k_1=0}^{N}\sum_{k_2=0}^{k_1}(k_1 - k_2)t_s(1-\rho_1)\rho_1^{k_1}(1-\rho_2)\rho_2^{k_2} f(\rho_1, k_1, k_2)} = \frac{\overline{T}}{\overline{U}} \tag{20}$$

where

$$f(\rho_1, k_1, k_2) = \frac{k_1(1-\rho_2)-\rho_1}{\rho_1(1-\rho_1)} + \frac{1-p}{k\rho_2(1-\rho_2)}\left[k_2(1-\rho_2)-\rho_2\right] \tag{21}$$

and

$$\rho_2 = \frac{1-p}{k}\rho_1 \tag{22}$$

According to Figure 7 and Figure 9, the system is more likely to yield a maximum performance about the position of *1/N*. These figures also indicate the minimum performance incurred when the value of ρ_1 is 0.5 roughly. Based on the same value of *p* and *k*, the performance is enhanced according to the increment of ρ_1 value when the value of ρ_1 exceeds 0.5. Under this condition in which the new arrival students are allowed to join the system before a new polling is created. This phenomenon reflects a situation in which the arrivals to node 1 from outside is more than that from node 2. Equation (17) also verifies this result. However, because *p* is less than one, the probability that the number of students from node 2 to node 1 increases. This makes the mean delay time for each student increases. Figures 8 and 10 confirm this notation.

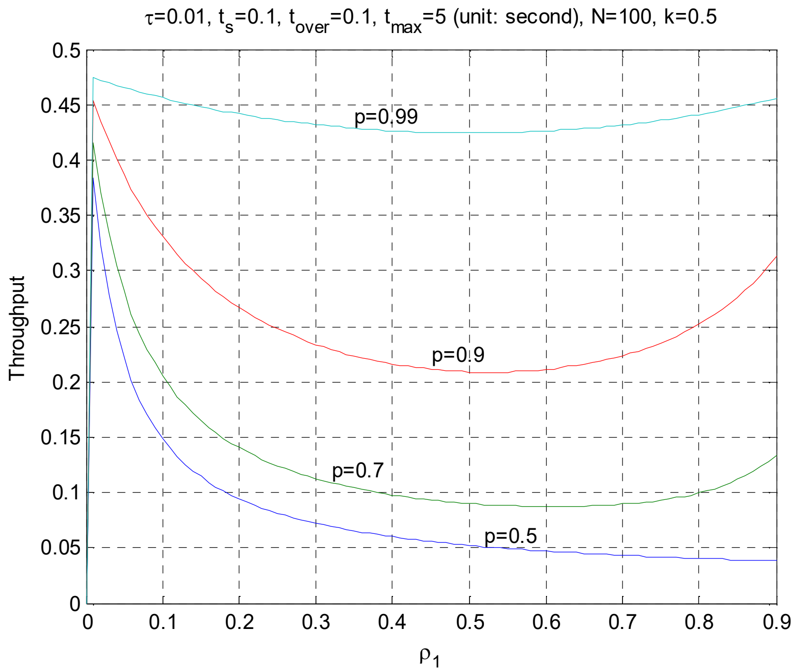

Figure 7: The relationship between throughput performance and ρ_1 with various parameters p under the conditions N=100 and k=0.5

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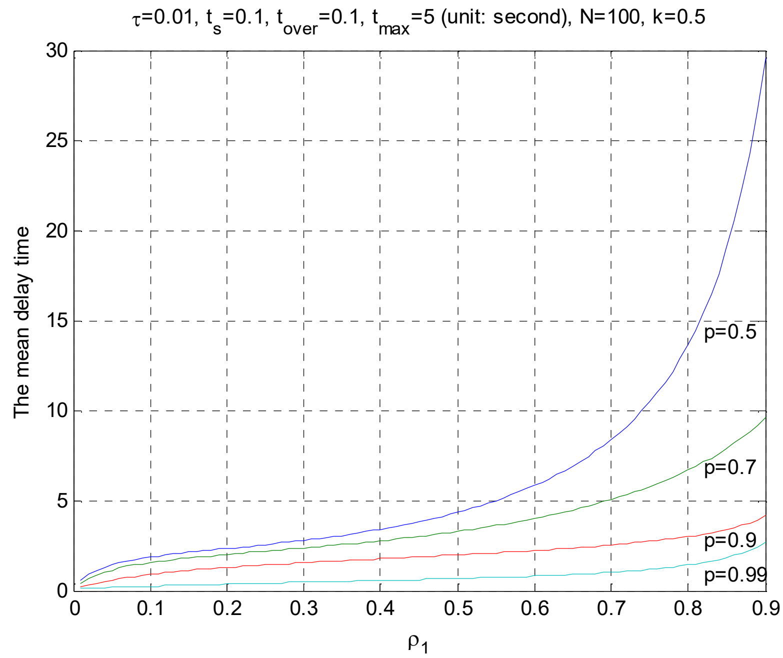

Figure 8: The relationship between delay performance and ρ_1 with various parameters p under the conditions N=100 and k=0.5

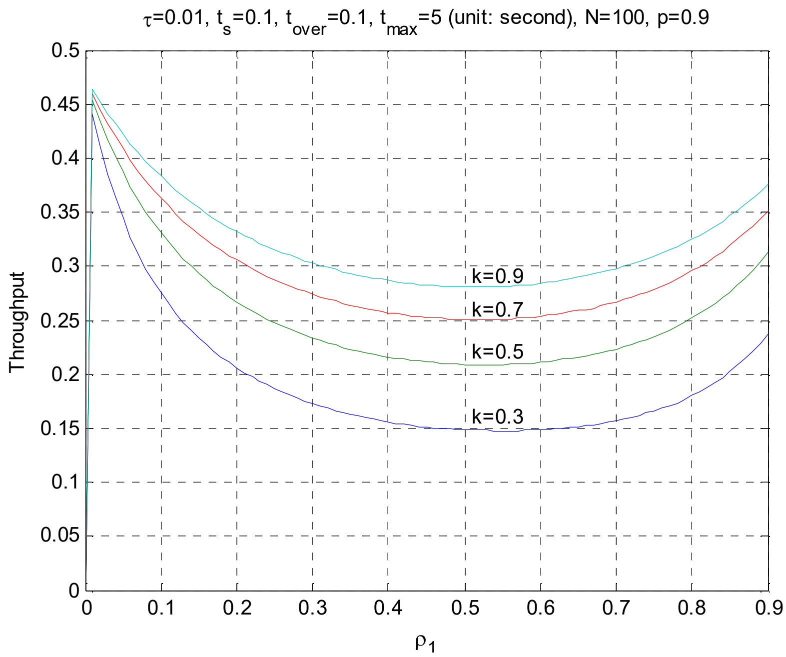

Figure 9: The relationship between throughput performance and ρ_1 with various parameters k under the conditions N=100 and p=0.9.

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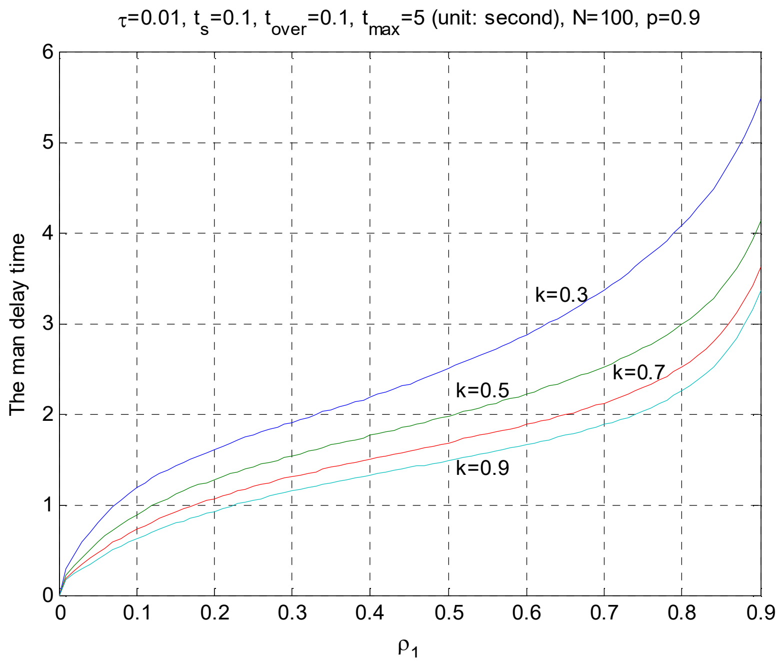

Figure 10: The relationship between delay performance and ρ_1 with various parameters k under the conditions N=100 and p=0.9

5. CONCLUSION

This study considers the real-life issue and challenges of implementing RFID in university learning. Therefore, the proposed system integrates the possible networks without increasing the cost and delay time in helping educational communities by resolving the problem of identify fraud. Simultaneously, the proposed RFID system can be strengthened and deployed in a variety of settings, and improves the system performance.

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