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A Smart Mobile System for the Real-Time Tracking and Management of Service Queues

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Abstract: This paper proposes a solution to the problem of client dissatisfaction with long waiting times associated with some services. This solution is a smart queue management system that provides real-time visual and audio updates to service requests via a smartphone app. Users receive digital tickets and are free to leave the waiting area until it is their turn to be served. If they choose to remain in the area, they have the option of listening to the signal of the television set that is typically muted for a better experience. The system comprises connected units forming a web of things. There are units for ticket registration and verification, audio capturing and streaming, queue management, and user units as smartphone applications. We have tested this system to ensure its functionality and report our results and possible improvements.

Keywords: Queuing Management Systems; Near Field Communication; Internet of Things; Mobile Computing.

1. Introduction

As the world's population grows, more people find themselves waiting in queues to receive service. Research states that their satisfaction with the service depends on the waiting period. Davis and Heineke [1] studied the effect of several parameters on customer satisfaction. These include awareness of the duration of the wait, the level of comfort while waiting, and whether the clients were occupied or not during the wait. Therefore, it is important to create an efficient queuing system that allows the client to anticipate how long they are going to wait and improves their experience while waiting. We address these issues in our solution by providing the client with dynamically-updated service time prediction, the choice to briefly exit the area, and entertainment options.

Another paper [2] studies the effect of offering a time guarantee (i.e. making sure the client is served within a certain time-frame and compensating them if they are not) on customer satisfaction. Customer satisfaction affects both the private and public sectors. For example, the UAE has applied a star rating system for government departments to encourage better service [3]. Two of the criteria for this system are reduction of waiting time and use of technology. In that vein, the UAE government has created online platforms to allow users to receive government services through their smartphones. However, waiting at service venues remains a frustrating experience.

Queue management systems with time prediction algorithms have been set up in hospitals, banks, and other institutions. Unfortunately, they are misused by users who draw more than one ticket as a precaution against losing their turn. The system considers the extra tickets clients and overestimates the waiting period; discouraging future clients as a result. To combat this, service providers appoint a security guard to ensure clients draw only one ticket. This cancels out any benefits of automation. Clients also ignore the suggestion to leave and return at the specified time due to their fear of missing a turn.

A mobile ticket dispenser system (MTDS) allows the customer to remotely place a request and updates the expected waiting time [4], but it faces two problems: clients are unable to cancel their requests, and might abuse the system by requesting multiple tickets as with the non-mobile systems causing the service to be unavailable. To answer the largest possible number of requests, researchers in [5] studied how emergency vehicles are routed using mathematical models. Two studies, [6] and [7] show systems that allows users to remotely request

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hospital appointments and receive a notification that tells them when they should leave their current location. Although this MTDS depends on variables such as distance, time of day, queue length, and the physician's speed for its prediction; it does not take into account patients who are late, miss their appointments, and the variability of each appointment's duration. The MTDS need not be restricted to apps. Arun and Priyesh [8] describe a system where Short Message Service (SMS) is used for requests and notifications. A specially formatted message is sent by the client. Then, the system creates a request and responds with a message containing a ticket number. The client is notified 30 minutes before their turn comes up. However, that timeframe might not suit all users with different locations. Another system created by researchers is Queuesense, an android app used with multi-modal sensors to detect queues and monitor their progress [9]. Among the issues that prevent smart queue management systems from becoming more prevalent are accessibility to a varied client base, the cost of setting up the system, usability, and overhead costs (e.g. maintenance).

Our smart queue management solution is a Internet of Things (IoT) that exploits the existing infrastructure of smartphones to assign tickets to clients. Arduino platform is our choice as it is both affordable and open source [10]. The client opens the application, scans the registering slave unit Near Field Communication (NFC) shield [11-13] using their NFC-enabled smartphone, and then either leaves the waiting area until they are notified to return with a visual and audio alert, or remain and use the entertainment options in the app. The app screen is designed to resemble a real status board to make it more intuitive for the user. We specify a radius near the desired service where the app may be used to reduce false service requests, which also makes the dynamic time prediction algorithm more accurate. The users are also offered a swapping functionality of their tickets for convenience.

The rest of the paper is organized as follows: Section 2 presents the proposed solution, followed by the results in Section 3 and the conclusion in Section 4.

2. THE PROPOSED SYSTEM

The system presented in Figure 1 aims to reduce waiting times and make them more tolerable. It also allows clients to increase their productivity by allowing them to wait outside the waiting area. In addition, it allows clients the leisure of swapping tickets with each other as to not miss their turns as they run their errands offsite the waiting area. On the other hand, onsite clients may then reach their turns faster through the exchange. This increases the overall effectiveness and performance of the system.

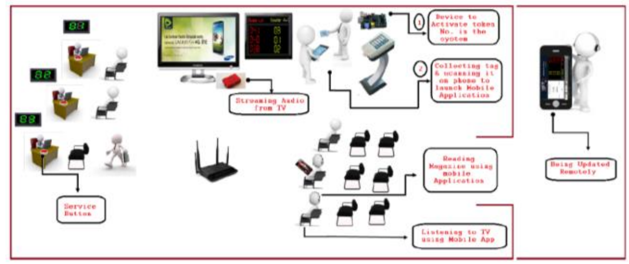

Figure 1. Overall System Diagram [14].

The process of the system begins when the client scans the ticket registration unit. If the user does not have an NFC-enabled smartphone, they can scan the QR code on it to create a ticket. The app then launches and displays the digital ticket besides the queue status. The ticket and status board resemble their real-world counterparts to make the user interface (UI) intuitive and accessible to the user, as shown in Figure 2 below. Subsection A discusses the registration and verification unit and the system's workflow, while subsection B expands on the streaming and queue management unit.

Figure 2. Main View of the smartphone application [14].

A. *The Registration and Verification Unit*

Until a scan occurs, the system is in an idle state. The algorithm in [15] is applied to the system. The system contains two cycles: an enqueueing cycle and a dequeueing cycle. The enqueueing cycle is entered when the users approaches and scans the registration unit for a QR code or using an NFC enabled smartphone, the embedded Linux board receives identifying information about the user; for instance, the IMEI number, and manages the queue status utilizing a web server and database management system. Additionally, the user receives the URLs for the server and the TV audio stream. These exchanges of information are in the JavaScript Object Notation format (JSON). Tickets cannot be created when the smartphone is not within a certain distance of the NFC antenna of the registration unit. One alternative to the system proposed here is to allow users to make ticket requests remotely and calculate when they should

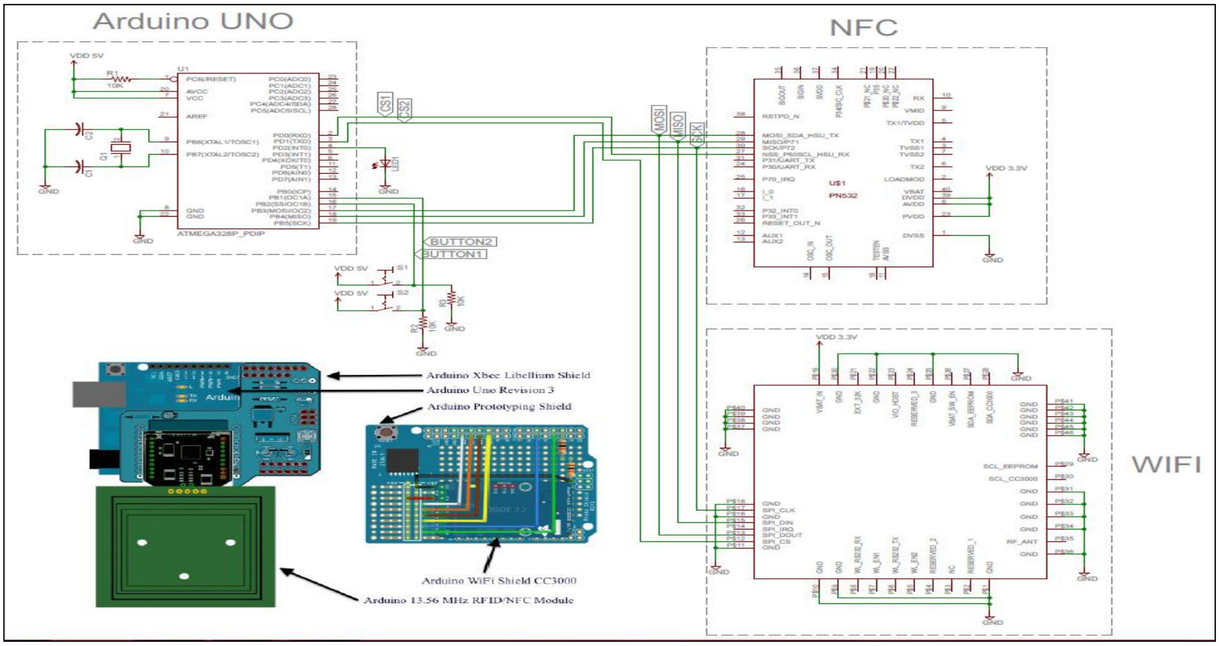

Figure 3. Proposed slave schematic and realization [14].

arrive using the Global Positioning System (GPS) and their current location. As mentioned in the introduction, this makes the system susceptible to false requests and can create false demand that leads to denial of service. The next step occurs when the user reaches the service counter. Ticket validation units are used to check the scanned ticket information against the information stored in the database. The human servers press a dequeueing button to remove the ticket from the queue after the client is served. This button sends an update request to the server and the registration and validation units' hardware schematic is shown below in Figure 3.

To conserve the user's battery, we could deliver server-sent events to their smartphone using push notifications rather than polling the server repeatedly or creating a delay in notifications due to the long polling periods [16]. The proposed workflow for the system is shown below in Figure 4.

The audio alerts mentioned previously are made possible by the use of a text-to-speech engine that converts the information on the status board to audio.

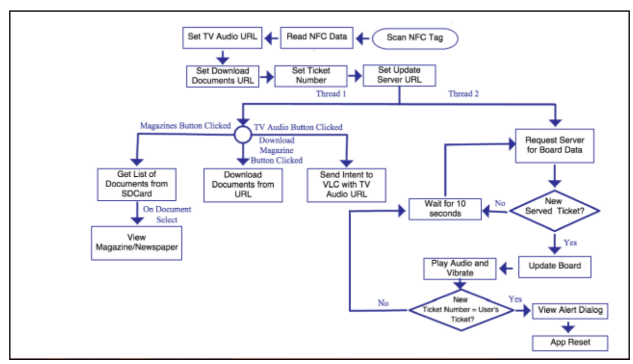

Figure 4. Proposed system's workflow [14].

B. *Streaming and Queue Management Unit*

Our cost-effective entertainment solution utilizes the TV screens that are already available at the waiting area. The current progress of the queue is displayed on the screen, and the audio output of the TV is available for users to listen to using the smartphone application and the audio capturing and streaming unit made up of an embedded Linux target board connected to the audio jack of the TV. Usually, places such as banks, hospitals, and other venues do not want those who are not watching the TV to be disturbed by the sound, and do not want to disturb the ambiance of the place. Our solution allows the user to employ Web Real-Time Communication (WebRTC) technology to better utilize the television set. WebRTC is an effective new technology for mobile applications such as ours [17], as well as web communication systems [18-20].

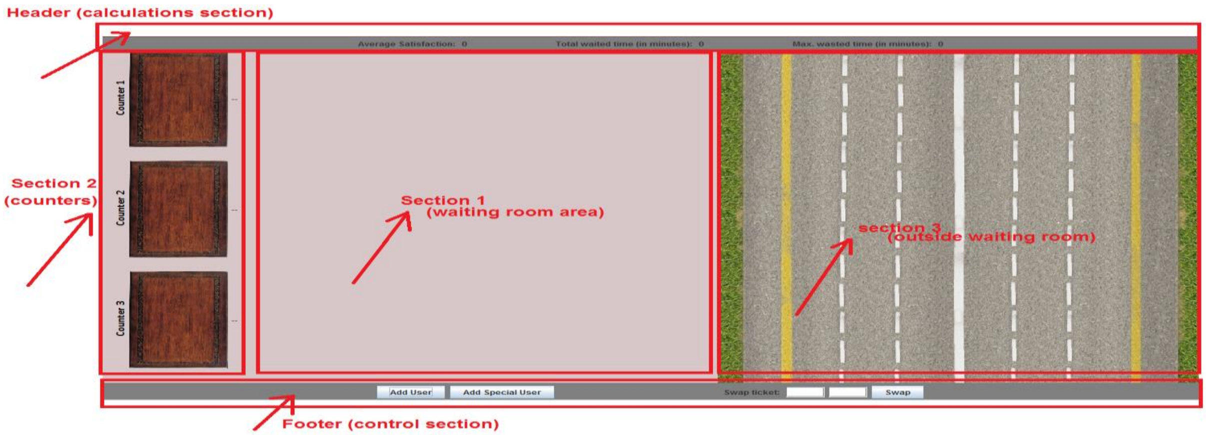

Figure 5. Simulation platform's visual interface.

C. Simulation Platform

In order to simulate our proposed solution and compare the results of different scenarios, a simulation Java platform has been designed and implemented with a visual interface to facilitate features for the various scenarios' generation and comparison. As shown in Figure 5, the visual interface is divided into sections.

Section 1 represents the waiting room, section 2 shows the counters that serve the clients in the waiting room, and section 3 refers to any location outside the waiting room. The footer of the platform provides the controls used to create different scenarios. The 'Add User' button is used to simulate the entrance of a user to the waiting room section, while the 'Add Special User' button is used to simulate the entrance of a special user. A special user in real world could be, for example, a pregnant woman, an old man, a user with special need, or any other user that is difficult for him/her to wait for service. Figure 6 is used to simulate a user waiting in the waiting room, whereas; Figure 7 is used to simulate a special user waiting in the waiting room.

Figure 6. Normal user.

Figure 7. Special user.

As a user is added to the system, if no one is being served at any of the counters, the user is assigned directly to any of the available counters without having to wait in section 1. Clicking on any of the users waiting in section 1 will move the selected user to section 3 to simulate that the user has left the waiting room area. Clicking on a user that is in section 3 will move the user back to section 1; i.e. the waiting room section. Moreover, to simulate swapping of two ticket numbers, the control section provides two text fields as to enter the two ticket numbers that need to be swapped, and then a click on the 'Swap' button is required for confirmation. Each counter is set to serve a user in 3 minutes and then ask for the next ticket number owner to approach. If the user is in the waiting room, he/she gets served; otherwise, he/she loses the turn and the counter waits for 10 seconds as a penalty before requesting the next ticket.

In the header section, calculations of the system and the applied scenario are done in the background, while displaying three main numbers, the average satisfaction, the total waited time (in minutes), and the maximum wasted time (in minutes). The user's wasted time is calculated from the waited time inside the room and in case a user loses his/her turn, a random number in the range of 20 minutes is used to reflect the wasted time in the road trip. When the user leaves the room, the counter that calculates the waiting time pauses, as this time is not considered wasted because the user is being productive somewhere else. The user's satisfaction is measured on a scale of 0 to 5 and is based on the user's wasted time. Wasting less than 5 minutes corresponds to satisfaction equals 5, between 5 and 10 minutes corresponds to 4, between 10 and 15 minutes corresponds to 3, between 15 and 20 minutes corresponds to 2, and more than 20 minutes corresponds to 1. User's satisfaction is considered 0 if the user loses his/her turn. In the simulation platform's header, the average satisfaction is displayed which is the sum of satisfaction of all users divided by the number of users. The total waited time displayed in the header is the sum of the waited time of all the users. Finally, the maximum wasted time is evaluated as the maximum wasted time per user compared with the other users.

Figure 8. Twenty four users are added to the waiting room.

D. *Simulated Scenarios*

1) Scenario 1:

Twenty four users enter the room, out of which 8 are in special condition (ratio 3:1). The 24th user leaves the room as he/she notice that many other users are waiting ahead. This repeats with other 4 users coming into the room and finding it full of other waiting clients.

2) Scenario 2:

Twenty four users enter the room, out of which 8 are in special condition (ratio 3:1). Fifty percent of the users decide to leave the room, while only 50 percent of those who left manage to return to the room before missing their turn. In the simulation platform adopted, Figure 14 shows that the 24 users entered the room, while Figure 15 shows that about 50 percent of them left the room (5, 7, 9, 11, 13, 15, 17, 19, 21, 23). Users with ticket numbers 5, 11, 17, 19, and 23 were able to return to the room, while users with ticket numbers 7, 9, 13, 15, and 21 lost their turn while being away.

3) Scenario3:

Twenty four users enter the room, out of which 8 are in special condition (ratio 3:1). Fifty percent of the users decide to leave the room, while all who left manage to return to the room before missing their turn for being able to switch their turn and save their turn. In the simulation platform adopted, Figure 8 shows that the 24 users entered the room, while Figure 9 shows that about 50 percent of them left the room (5, 7, 9, 11, 13, 15, 17, 19, 21, 23). All users who left were able to get their turn as they used the swap functionality to swap their ticket with someone in the waiting room until they return and become available in the waiting room.

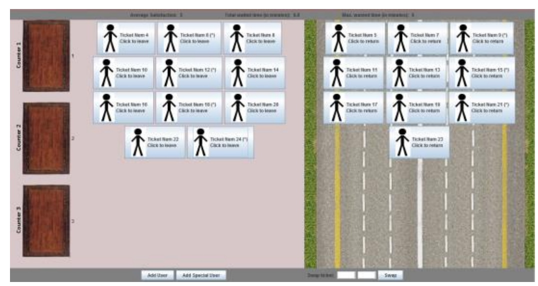

Figure 9. About fifty percent of the users left the waiting room.

3. RESULTS

A. *Smartphone application*

This section showcases the results of deploying the system presented in this paper. The user unit is represented by an android smartphone application, NFC antennas are used for the registration and verification units, and an embedded Linux target board is used for audio capturing and streaming. The server responsible for processing requests is an Apache Hypertext Transfer Protocol (HTTP) server, and the database manager that stores and updates requests is MySQL Relational Database Management System (RDMS). QR codes were available for smartphones without NFC-enabled smartphone.

When the user launches the application, the user's ticket and the counter board are displayed onscreen, as shown in Figure 2. The user can also press the download button to download the magazines and newspapers available at their waiting location, and then presses the magazines button to view them; as shown in Figures 10, 11, and 12 respectively.

Figure 10. Download button page view [14].

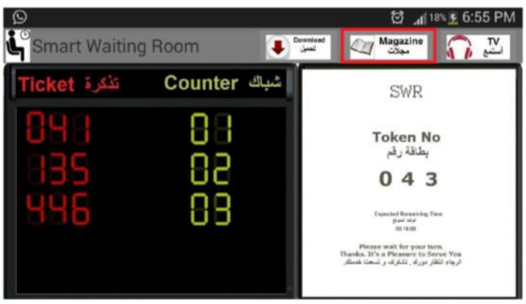

Figure 11. Magazines button page view [14].

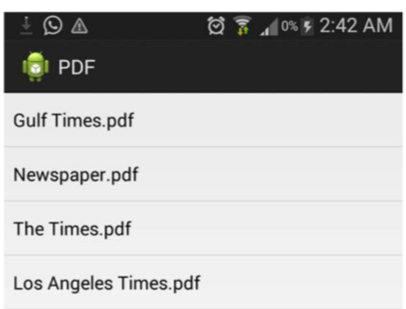

Figure 12. Available reading material list [14].

If the user presses the title of a publication, it is opened in a PDF viewer, as shown in Figure 13. If the waiting room contains a television, the user can press the television button. This allows them to listen to the TV audio delivered by the embedded Linux target board connected to the audio jack of the set through their headphones, as shown in Figure 14.

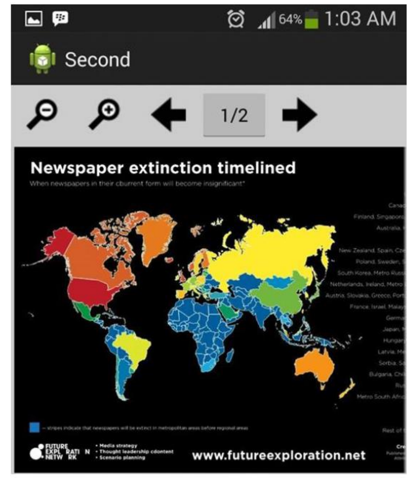

Figure 13. magazine displayed in the smartphone application [14].

Figure 14. TV Button for listening to the audio signal from the TV set [14].

If the user wishes to leave the waiting area, then the application will retain its notification functionality. It vibrates, plays an audio alert of the current ticket number, and displays it in Arabic and English on the status board. Additionally, the application displays a dialog box when the user's turn arrives as shown in Figure 15 below.

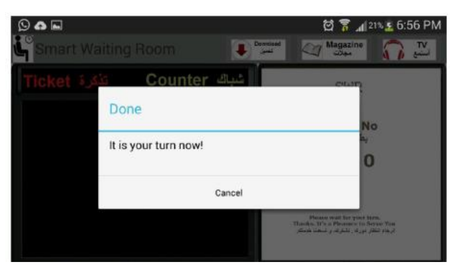

Figure 15. The user's ticket is currently served [14].

B. Simulation Results

The results achieved from scenario 1 are shown in Figure 16. The results show that the total time wasted by all users is 227.3 minutes; hence an average of 9.5 minutes per user.

Ticket Number	Waited time	waisted roadtrip time
1	0	0
2	0	0
3	0	0
4	0.75	0
5	0.75	0
6	1.5	0
7	1.75	0
8	1.75	0
9	3.5	0
10	2.75	0
11	2.75	0
12	5.5	0
13	3.75	0
14	3.75	0
15	7.5	0
16	4.75	0
17	4.75	0
18	9.5	0
19	5.75	0
20	5.75	0
21	11.5	0
22	6.5	0
23	6.75	0
24	0	27
25	0	28
26	0	26
27	0	26
28	0	29

Total waisted time	Average waited Time
227.3	9.5

Figure 16. Scenario 1 simulation result.

The results achieved from scenario 2 are shown in Figure 17. The results show that the total time wasted by all users is 188.3 minutes; hence an average of 7.8 minutes per user.

Ticket Number	Waited time	Wasted road trip time
1	0	0
2	0	0
3	0	0
4	0.75	0
5	0.5	0
6	1.5	0
7	0.25	28
8	1.75	0
9	0.5	26
10	2	0
11	0.25	0
12	5.5	0
13	0.25	27
14	3	0
15	0.5	27
16	3.25	0
17	0.75	0
18	8	0
19	0.25	0
20	4.75	0
21	0.5	29
22	5	0
23	0.5	0
24	11.5	0

Total waisted time	Average waited Time
188.3	7.8

Figure 17. Scenario 2 simulation result.

The results achieved from scenario 3 are shown in Figure 18. The results show that the total time wasted by all users is 58.8 minutes; hence an average of 2.4 minutes per user.

Ticket number	Waited time	Wasted road trip time
1	0	0
2	0	0
3	0	0
4	0.75	0
5	0.5	0
6	1.5	0
7	1.75	0
8	1.75	0
9	3.5	0
10	1	0
11	2.75	0
12	1	0
13	3.75	0
14	7.5	0
15	3.75	0
16	1	0
17	1	0
18	2	0
19	11.5	0
20	2	0
21	1.5	0
22	6.75	0
23	1.75	0
24	1.75	0

Total waisted time	Average waited Time
58.8	2.4

Figure 18. Scenario 3 simulation results.

As a result, by comparing the results from the three scenarios, scenario 3, that represents our proposed solution, reduces the wasted time by user significantly as shown in Figure 19 and Figure 20.

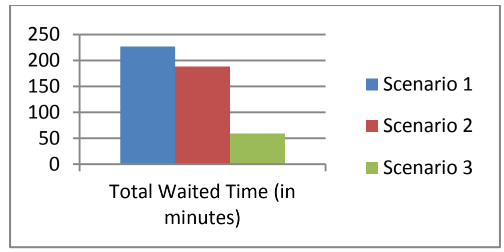

Figure 19. Comparing total waited time for the three scenarios.

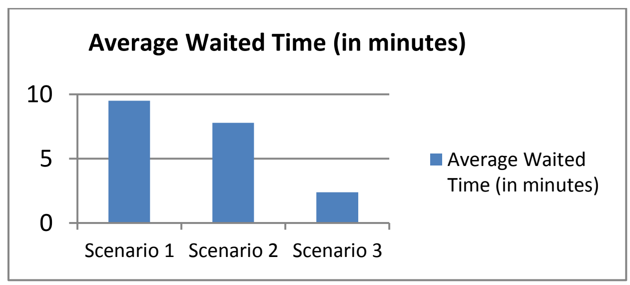

Figure 20. Comparing average waited time for the three scenarios.

4. CONCLUSION

To conclude, the smart queue management system has the potential to improve client satisfaction and productivity, and to solve the problem of improving waiting time for services. It delivers audio visual updates to smartphones, and entertains clients with reading material and a TV audio stream.

5. ACKNOWLEDGMENT

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