Monitoring Working Hours of Nurses at Azra Hospital Using Smartphone Based Geofencing

Anesa Noor Aulia Putri, Asep Id Hadiana
Department of Informatics
Universitas Jenderal Achmad Yani
West Java, Cimahi, Indonesia
aneesanoorap18@if.unjani.ac.id, asep.hadiana@lecture.unjani.ac.id

Sigit Anggoro, Faiza Renaldi
Universitas Jenderal Achmad Yani
West Java, Cimahi, Indonesia
sigit.anggoro@lecture.unjani.ac.id, faiza.renaldi@unjani.ac.id

Abstract

Position of nurses in hospitals has a vital role in providing medical services to patients. Still, these nurses often cannot offer high-quality work due to the enormous workload, and this is in line with previous research that conducted questionnaires on 364 nurses who stated that most nurses had 2.875 working hours/week excess. Because of these problems, in this study, a geofencing system was created which is used to monitor the presence of nurses in hospitals using the pull service technique so that nurses get the feature to be able to turn on geofence when starting work and entering the hospital, and also turning off geofence when finished working and leaving the hospital. Geofencing in this study is set at a radius of 200m or equivalent to the area of Azra Hospital, which is 20,323m^2. Based on the geofencing accuracy test, the system can produce native real-time positioning with an error rate of 1.4 to 3.7 m and has a time delay of 4.45 to 15.30 seconds for user position switching, depending on the device used.

Keywords
Geofencing, GPS, Nurse, Monitoring System, Hospital

1. Introduction
Location-based information services are now widely used on many platforms, especially mobile applications. One of the technologies behind based services is geofencing. Geofencing is a virtual fence used to delimit a geographic area. Geofence can detect when someone enters or leaves a specific area (Maiouak and Taleb). The new position is calculated intermittently from various sources as the user moves, depending on internet connectivity, whether via Wi-Fi, RFID signals, cellular data, or GPS (Global Positioning System). It can produce real-time native positioning with an accuracy of 20-50 meters from the original location. However, if a geofence wants a better accuracy, it can use Bluetooth beacons with proximity accuracy of up to three meters from the original location (Mackey et al.). Currently, geofence has been widely applied in various sectors, including the health sector, to track the Covid-19 area (Anto Arockia Rosaline R, Lalitha R, Hariharan G) and find the nearest hospital for patients (Nguyen et al.). In this study, geofencing will be used as a technology to monitor the effective working hours of nurses in the hospital area.

Monitoring in the world of work is essential because every company or agency management has its own set of hours and work schedules, including health service agencies such as hospitals. The hospital has a 24-hour work system consisting of three shifts with a high workload, according to Kepmenakertrans No. Kep-233/Men/2003 of 2003 concerning the type and nature of work, nurses on duty in hospitals have five working days with a limit of eight hours per day and 40 hours per week (Latief and Lestari). Because it plays a vital role in health services, nurses should have regular working hours accompanied by high work efficiency. However, due to the high workload, nurses often work more than the predetermined working hours, causing a decrease in the quality of service quality to patients. The questionnaire conducted by previous research on 364 nurses stated that the average nurse was always over 2.875 working hours/week (Rodriguez Santana et al.). This condition causes many nurses to complain of fatigue, especially night shift nurses.

Previously, research by Alvin Syarifudin Shabah on the present application on Android using face recognition and geofencing has been carried out, resulting in the conclusion that facial recognition photo data sent to the server using k-NN produces 90% accuracy and 1.5 seconds processing, using geofencing as well. Staff does not need to wait to fill in the absences on the attendance machine. The fastest time in the attendance process on this system is 3.4 seconds which includes geofencing authentication and face recognition processes (Shahab and Sarno). Subsequent research conducted by Lily Owei on "Smartphone-Based Hospitalization Geofencing: A Novel Approach to Monitoring Clinical Work Hours in Surgery Residency" used geofence for hospitals in the United States. In this study, semi-structured interviews conducting to find out how effective it is. The monitoring application for nurses' working hours build, 26 residents became the object of research, and 23 of them had used the monitoring application. This study indicates that the presence of an application for monitoring working hours using geofencing can make it easier for nurses to see accurate data on their daily working hours. Also, the number of violations of working hours committed by nurses has decreased significantly because of this application. However, this study states that one nurse lives in an area near a hospital whose geofence has to create so that the application continuously records working hours even when the nurse is at home (Owei et al.).

Because of these shortcomings, the location-based service built in this study uses the pull service type. Users will get the feature to turn on the geofence when starting work, walking in the hospital, and turning off the geofence when they finish working and leaving the hospital. This study aims to determine the effectiveness of the geofencing method in monitoring how long nurses are in Azra Bogor Hospital through a system installed on the nurse's android smartphone by utilizing GPS technology. This monitoring of working hours can simultaneously monitor the presence of nurses in the hospital, either absent or late nurses, to encourage nurses always to come and do their work at the right time. Researchers expected that this system would reduce the number of working hours violations and protect nurses from fatigue to provide safer and high-quality care to patients.

2. Related Work

Service systems to delimit an area. For example, in the research conducted by Ranajoy Mallik in 2020 to limit the Covid-19 zone and detect violators who enter the area using Geofencing and Firebase, researchers categorize the Covid-19 area with red, orange, and green colors, when users enter the Covid-19 area. 19, which is red, the user will get a warning notification that he must leave the area (Mallik et al.). Furthermore, geofencing can also use in marketing for advertising strategies; geofencing is used to notify buyers of offers and promos when they pass through the store location area (Stefan F. Bernritter, Paul E. Ketelaar). There are several geofencing, namely, Application-Based Geofencing, Network-Based Geofencing, and Hybrid geofencing. Geofencing-based applications require applications to access GPS data. Smartphone users will automatically provide the latitude, longitude, and radius used to mark the area of the desired virtual site. The user must have a GPS receiver device to track, and GPS data from the receiver is used to determine the user's location relative to the Geofence. Network-Based Geofence is categorized into micro and macro. Macro geofencing will use cell towers, while micro geofencing uses Wi-Fi hotspots. Hybrid geofencing combines the two previous geofencing technologies, such as GPS + Bluetooth, GPS + Wi-Fi, Wi-Fi + Bluetooth, and others (Zuva et al.). Apart from being used for outdoor areas, geofencing can also use for indoor position tracking. However, indoor GPS accuracy is very low, and its usually combined with other technologies, such as Pseudolite GPS, Cell tower, Wi-Fi, Bluetooth, Infrared, UWB, etc. The comparison of indoor positioning system technology in Table 1 illustrates its accuracy and advantages and disadvantages.

Table I. Overview Indoor Positioning System

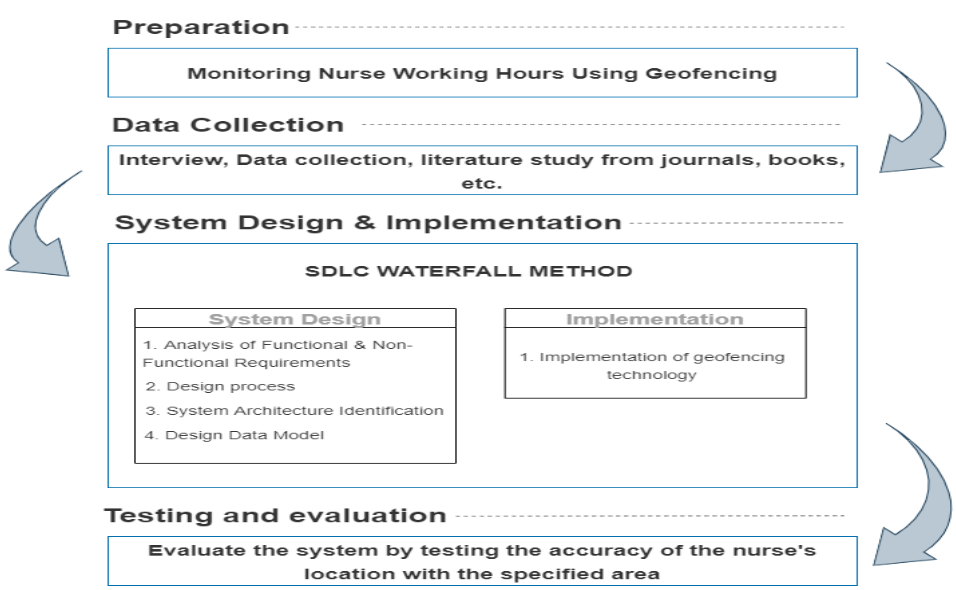
Technology	**Indoor Accuracy**			**Pros**	**Cons**
	Low	**Medium**	**High**		
GPS	√			Easy to get availability	Accuracy for indoors is very low
A-GPS	√			High Accuracy for outdoor	Low accuracy for indoor
Pseudolite GPS			√	High accuracy for indoor and outdoor	Equipment costs are very expensive
Cell tower	√			Long distance range	Low accuracy for indoor and outdoor

Technology	Indoor Accuracy			Pros	Cons
	Low	Medium	High		
Wi-Fi		√		Already available for many buildings, low cost implementation	Network strength may very due to multipath propagation
Bluetooth			√	Low power and cost for implementation	Expensive implementation costs
Infrarred			√	High accuracy for indoor	Expensive implementation costs, sunlight can affect accuracy, short range
UWB			√	Low power density, wide bandwidth	Expensive implementation cost, rarely used

Previous studies have compared indoor positioning technologies via smartphones that have been developed over the last few years. In this study, each architecture and working principle of IPS is discussed, and its advantages, disadvantages, complexity, accuracy, and costs are described. In its implementation, the most influential parameters are accuracy and complexity. Accuracy down to sub-meters has been achieved through ultrasound, UWB, and Bluetooth technologies, but these technologies are not suitable for everyday use due to their high cost and are too complex to implement indoors. Therefore, the researcher also suggests that the IPS technology that has been described in the Table can be combined to become a hybrid technology; besides that, modern smartphones now provide various sensors needed for location determination (Batistic Luka).

3. Method

The first phase of this research is problem identification. In this phase, researchers describe the problems they encounter when monitoring working hours at Azra Hospital. Hospital. After identifying the problem, the researcher then carried out the stages of collecting data through interviews and observations. Interviews are used because they can be a means of collecting industrial research projects (Potter) considering that direct reports from hospital practice may vary. Next is the Needs Analysis; this stage is making a workflow analysis of the ongoing system adjusted with the Geofencing method. Next is the system design stage; the researcher designs a software system model at the system design stage. Then the last is the stage of developing working hours monitoring software by applying the geofencing method. The research method diagram is shown in Figure 1



1.

Figure 1. Research Method Diagram

As shown in Figure 1, the researcher uses the SDLC waterfall method in the system design and implementation stages. The advantage of using this method is that researchers can systematically determine the steps in developing the system (Rizkya et al.). The waterfall method is also suitable for generic systems or software, meaning that the system can identify all requirements starting with general specifications (Heriyanti and Ishak).

4. Result and Discussion

4.1 System Requirement Analysis

Based on the interviews, Azra Bogor Hospital has a nursing management system; one of its functions is to monitor nurses' working hours to match the predetermined time. Currently, Azra Hospital Bogor has many nurses, namely 365 nurses, consisting of 29 nurses with a Nurse degree and 336 non-Nurse nurses. The current system for monitoring working hours at the Azra Hospital Bogor occurs between the Head of Nursing, Head of Nursing Section, Head of Room, and implementing nurses. The Head of the Nursing Midwife is in charge of organizing, distributing, and coordinating tasks for subordinates. The Head of the Nursing Section is in charge of coordinating the preparation and supervising of the Nursing Staff implementation. The Head of the Room is tasked with providing Nurse Care documents to the implementing nurse and checking the documentation. The implementing nurse is tasked with carrying out nursing care according to standards, writing team reports on patient conditions, making monthly logbooks, and helping the head of the room guide nurses. Meanwhile, the calculation of working hours at the Azra Hospital Bogor is divided into three shifts that are not the same between treatment rooms, but the average number of days in each shift is the same each month, namely:

1. Night shift: 6 – 8 days, from 09.00 PM – 06.30 AM
2. Afternoon Shift: 7 – 8 days, from 01.00 PM – 09.00 PM
3. Morning shift: 6-7 days, from 06.00 AM - 02.00 PM

The proposed solution for monitoring the working hours of nurses at the Azra Hospital Bogor is to build mobile-based software to unify the location. The system to be built has one access right for nurses. The system's database will use Google Firebase, which is the base platform. One of the reasons why the database was chosen is because Google Firebase has a technology database that is updated in real-time and is effective for location-based applications. The access rights granted to nurses are that nurses can log in, clock in, and clock out. The flow chart for the system is shown in Figure 2

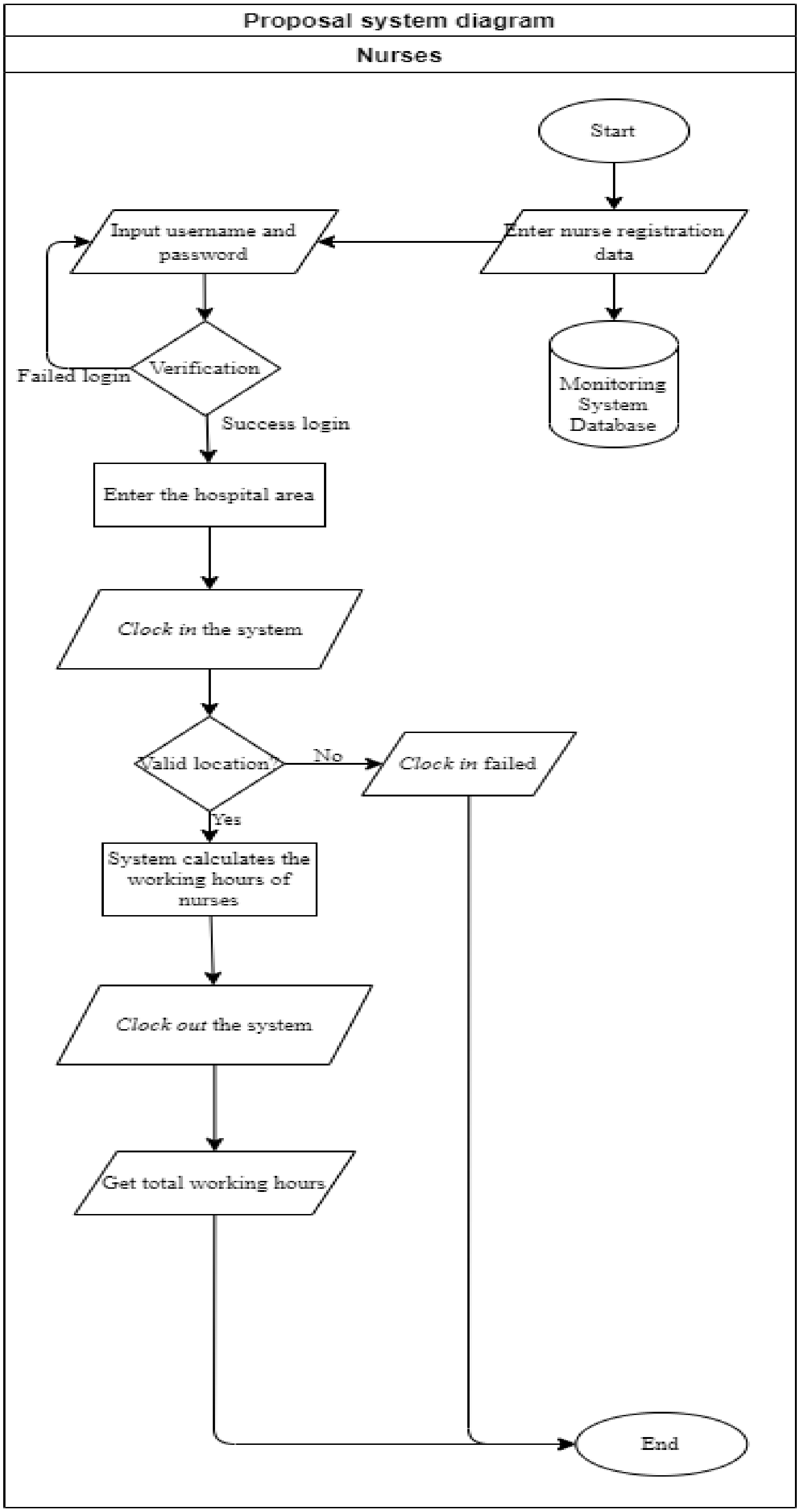


Figure 2. Proposed System Flow Chart

4.2 Service Architecture

The architecture of this service uses a client and server system. The basic concept of this architecture is to connect two objects in the form of a client system and a server system that communicate with each other through a computer network or the same computer. The server will provide application management, data, and client data security (Sallow et al., 2020). The architectural details for the system in this study are shown in Figure 3.

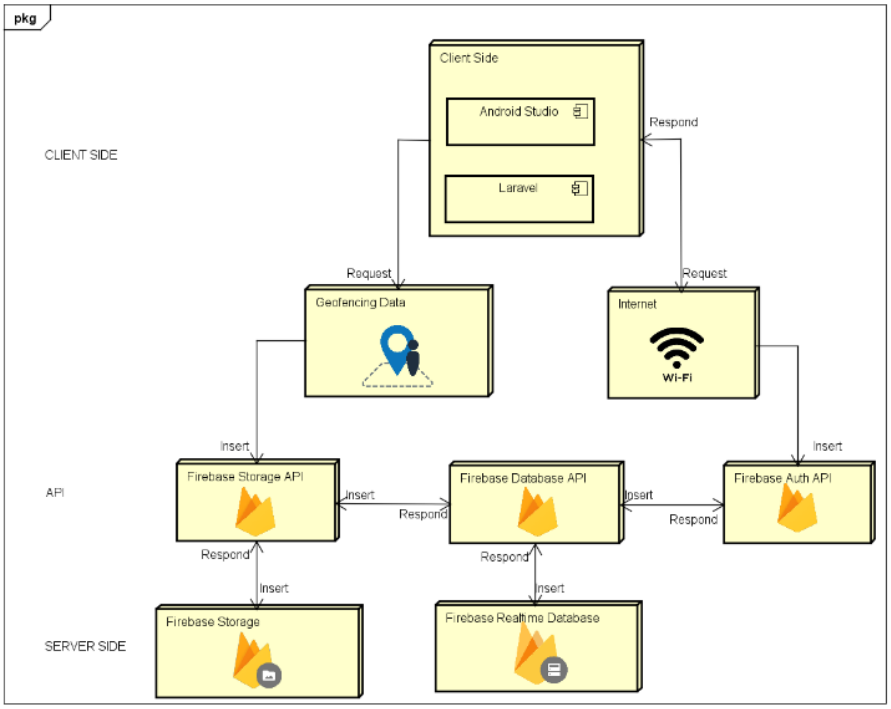


Figure 3. Service Architecture

4.3 Geofencing Implementation and Testing

The depiction of the geofencing area on the map has several forms, such as circles, squares, and polygons. Drawing shapes represent objects on a map bound to latitude and longitude coordinates. The geofencing area in this system is determined to be the same as the Azra Hospital area, which is 20,323 m^2, as shown in Figure 4.

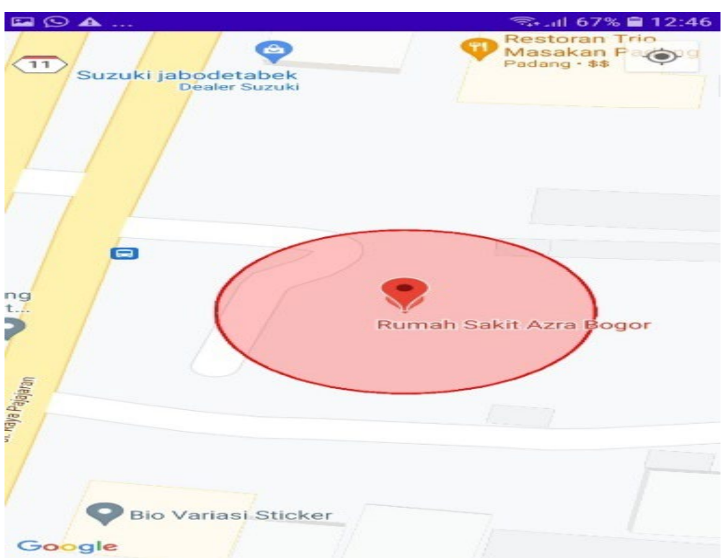


Figure 4. Geofence Area

A geofencing detection analysis was carried out to detect the presence of nurses in the geofencing area, as shown in Figure 5.

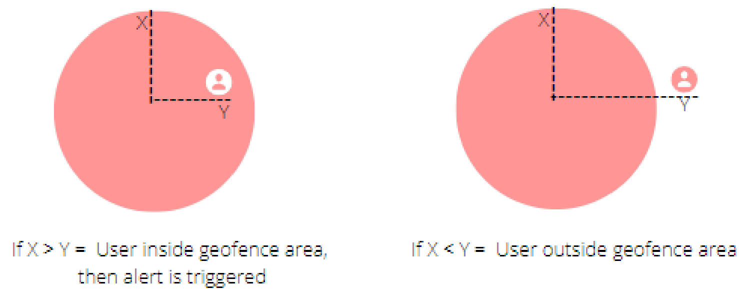


Figure 5. Geofencing Detection Analysis

Next, the researchers tested the detection of geofencing in the system by placing the nurse's smartphone at coordinate points outside and inside the geofence area. Figure 5 shows the user (marked with a blue dot) who is outside the geofence area, namely RS Azra, cannot press the "Clock in" button to be able to calculate its working hours. While Figure 6 & 7 shows that the user is in the geofence area and can press the "Clock in" button to be able to start counting his working hours.

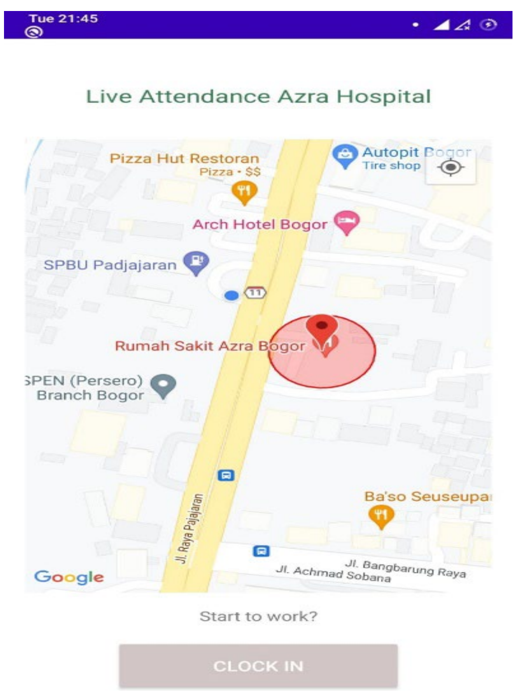


Figure 6. Geofencing detection Test

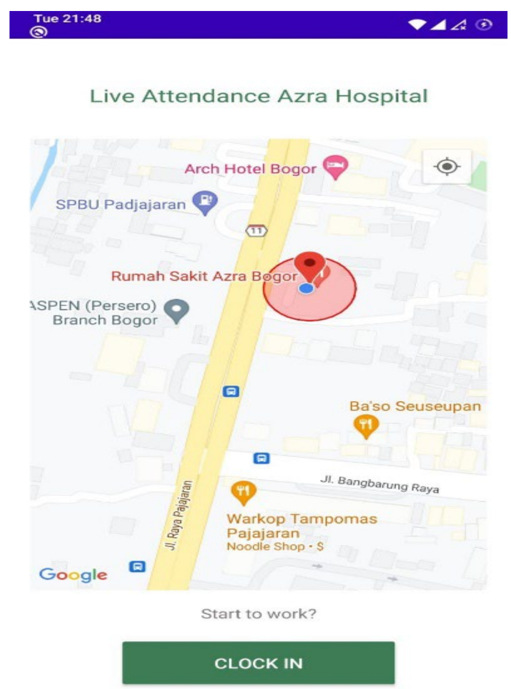


Figure 7. Geofencing Detection Test (2)

If the user has successfully “Clocked in” in the hospital area, the user will be directed to a page as shown in Figure 8 to calculate his working hours. Working hours will continue to be counted as long as the user is connected to the Celullar data; if the user leaves the hospital area or the Celullar data network is disconnected, the system will notify the user that he is out of the geofencing area.

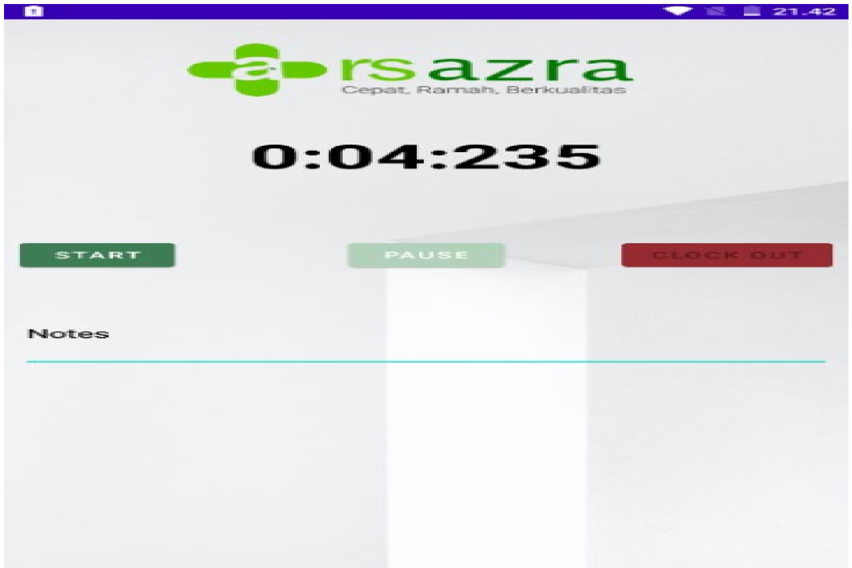


Figure 8. Calculation of Working Hours

Then testing the accuracy of the geofencing method in detecting moving objects, either inside or outside the area. The test area is set in a field with the longitude and latitude angles are -6.916167 and 107.497942, and the radius of the geofencing area is set at 21m with an area of 346.185m2. This test was carried out on three mobile devices, namely:

1) Oppo A5s, android version 8.1.0
2) Samsung J510fn, android version 7.1.1
3) Redmi 4, android version 6.0.1

The test scenario to test the accuracy of geofencing is to walk to the geofencing area and count the time per second until the user can press the "Clock in" button, which means geofencing has detected the presence of the device in the area. Tests were performed per 40° geofencing circle area to produce nine trials on each device. The test is carried out 2 times to test when the device enters the geofencing area ("Geofencing In" column) and exits the geofencing area ("Geofencing Out" column). Geofencing experiments on each machine are shown in Table 2 to Table 4.

Table 2. Geofencing Performance Test (1)

Android 8.1.0	Geofencing In		Geofencing Out	
	Delay Time (Seconds)	Location Distance (Meter)	Delay Time (Seconds)	Location Distance (Meter)
Test-1	2.35	2.5	1.32	4.3
Test-2	12.63	0.96	11.76	3.0
Test-3	2.13	0.94	1.72	0.5
Test-4	8.95	3.0	3.68	2.0
Test-5	10.31	3.1	10.31	2.4
Test-6	3.47	0.6	6.03	0.72
Test-7	5.41	1.0	2.15	0.47
Test-8	6.27	1.2	2.73	0.5
Test-9	4.38	2.9	4.18	2.4

Table 2 shows the results of the experiments on Android 8.1.0 showed that the system could detect the user's movement with a time delay of 7.12 seconds and the user's location accuracy error of 1.8 meters.

Table 3. Geofencing Performance Test (2)

Android 7.1.1	Geofencing In		Geofencing Out	
	Delay Time (Seconds)	Location Distance (Meter)	Delay Time (Seconds)	Location Distance (Meter)
Test-1	13.66	3.3	13.66	5.17
Test-2	18.96	3.29	10.38	3.97
Test-3	16.48	3.28	16.73	3.79
Test-4	17.79	4.7	15.38	4.63
Test-5	19.12	3.72	16.38	4.27
Test-6	15.28	5.78	14.23	2.89
Test-7	16.76	3.67	17.76	3.90
Test-8	13.55	3.12	14.86	2.97
Test-9	12.85	2.95	11.87	2.45

Table 3 shows the results of the experiments on Android 7.1.1 showed that the system could detect the user's movement with a time delay of 15.30 seconds and the user's location accuracy error of 3.76 meters.

Table 4. Geofencing Performance Test (3)

Android 6.0.1	Geofencing In		Geofencing Out	
	Delay Time (Seconds)	Location Distance (Meter)	Delay Time (Seconds)	Location Distance (Meter)
Test-1	2.38	0.4	2.47	0.5
Test-2	4.20	1.2	4.78	1.4
Test-3	9.46	3.4	10.46	3.9
Test-4	4.72	1.0	5.00	1.2
Test-5	3.00	0.4	2.41	0.5
Test-6	3.68	1.3	3.89	1.4
Test-7	4.10	1.5	2.48	1.2
Test-8	2.63	0.6	4.13	1.2
Test-9	5.39	2.9	4.99	2.8

Table 2 shows the results of the experiments on Android 6.0.1 showed that the system could detect the user's movement with a time delay of 4.45 seconds and the user's location accuracy error of 1.48 meters.

Based on the geofencing performance testing that has been done, the system can produce native real-time positioning with an error rate of 1.4 to 3.7 m and has a time delay of 4.45 to 15.30 seconds for user positioning, depending on the device used.

5. Conclusion

This study's working hours monitoring system consists of several components, namely Android smartphones, and GPS. The function of this system is simple. Namely, the system will access the GPS on the smartphone user to get the user's location and automate the user so that they can "Clock in" and "Clock out" within the limits of the hospital area. This monitoring system is expected to be an option that makes it easier to replace the manual attendance method that still exists on the running system. The system can calculate the adequate time of nurses in the hospital area from the implementation results. Based on geofencing performance testing, the system can produce real-time positioning with an error rate of 1.4 to 3.7 m and has a delay of 4.45 to 15.30 seconds of user positioning, depending on the device used. Expectations for research are to develop this application for other operating systems besides Android, such as Blackberry and Ios. Besides that, it is also hoped that future research can track the presence of nurses in hospitals so that they can record nurse activities automatically.

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Biographies

Anesa Noor Aulia Putri is a final year undergraduate student in the department of informatics, Universitas Jenderal Achmad Yani, Indonesia. Her primary interests are systems analysis, web service technology, data and software engineering.

Asep Id Hadiana received his Master's degree in Enterprise Information Systems from Indonesian Computer University and a Doctor of Philosophy from Techinal University of Malaysia Melaka. He is a lecturer in the Informatics Department, Faculty of Science and Informatics, Jendral Achmad Yani University. Amongst his research interest are Cyber Security, Data Mining, Spatial Analysis, Location Based Services and Geographic Information Systems.

Sigit Anggoro received a Bachelor's degree in Electrical and Communication Engineering from Gadjah Mada University and Master's degree in Electrical Engineering from Bandung Institute of Technology. He is a lecturer in the Informatics Department, Faculty of Science and Informatics, Jendral Achmad Yani University. His interest is related network engineering and health informatics.

Faiza Renaldi received his Master of Business Informatics at Universiteit Utrecht, The Netherlands, in 2006 and now serves his time as an assistant professor in the department of informatics, Universitas Jenderal Achmad Yani

Indonesia. Amongst his research interests are health informatics, information systems/information technology management, e-government, agile project management, and IT entrepreneurship.