Appointment Scheduling System for a Primary Hospital

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Many primary hospitals in developing countries face serious shortages of equipment and skilled personnel to handle cases reporting to them. This article focuses on a primary hospital constructed in the 1970s, with 29 facilities reporting to it. Patients referred to the hospital are usually ferried in ambulances if they are exhibiting critical conditions. Patients deemed uncritical are given referral letters. However, patients are exposed to long waiting times that put their lives at risk or worsen their conditions. The research aims to establish improved ways in which the patient waiting times can be reduced. An appointment scheduling framework for the primary hospital is conceived as a better approach. This is an SMS based queue management system. The system reduces the waiting time of patients in the hospital's outpatient department. A patient registration device that contains a GSM module and a microcontroller which sends messages to and from the patient when booking an appointment for consultation are developed. This queue management system has the potential to reduce patient waiting times by more than 95%.
*Keywords: Queuing System, Queue Management, GSM, Outpatient, Healthcare, Patient Appointment, Scheduling*

1 Introduction

The waiting times for receiving treatment in hospitals are high in many public hospitals, particularly in developing countries. Patients waiting too long before being attended to may acquire some infections, or their current situation may become worse. There is a possibility of some patients going undiagnosed. A triage system is used, patients who seem to be in a critical condition may have some underlying problems, and the extension of their waiting time may lead to their problem growing. Prolonged waiting times are a result of overcrowding in hospitals. Overcrowding is not good, as it leads to doctors having many patients to attend to. Medical errors may also arise because of the pressure on doctors to try to help as many people as possible.

Scheduling too many patients on the same day is one of the causes of long waiting times in queues for health treatment. Referral scheduling is necessary to fill in the gap of long waiting periods for medical treatment. [1] Observes current trends where modern life is becoming too busy to make medical appointments in person and maintain proper health care. This prompted the researchers to provide ease and comfort to patients through an online appointment system. Queuing is a general problem in many service industries. The service provider industries must meet the needs of both the customer and the service provider, hence scheduling appointments can be difficult [2]. Customers resent long waits, whereas service providers are pressed to minimize the idle time of their resources and the use of overtime [3]. The research conducted by [4] implements four appointment scheduling policies, i.e., constant arrival, mixed patient arrival, three-section pattern arrival, and irregular arrival, in an ultrasound department of a hospital in Taiwan. The study helps hospital managers seeking to improve key performance indicators (KPIs) on the patient appointment scheduling system to focus more on searching for optimal solutions or developing better appointment scheduling policies. The current process flow of the outpatient department in the case study hospital is shown in **Fig. 1**.
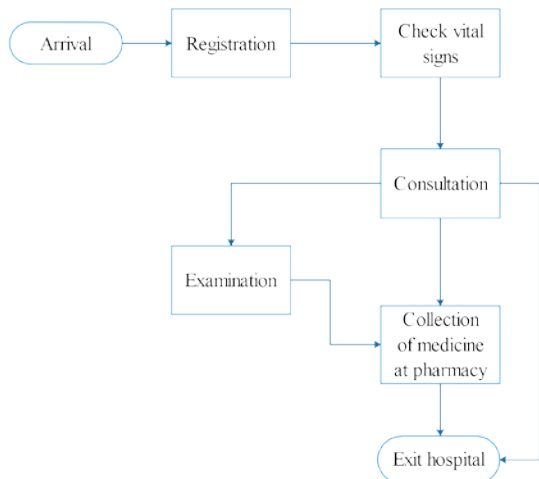
Fig. 1. Process flow for the hospital Out-Patient Department

2. Objectives

Research aims to reduce patients' waiting time in a primary hospital by developing a queue management system. The authors undertake the following steps to come up with the most feasible solution;

- Evaluate the current queue management system used by the hospital;
- Benchmark the existing system against that of successful hospitals;
- Determine where most of the patients' time is spent waiting for assistance;
- Design a more efficient and effective queue management system.

The study uses statistics for patients attended to within a three (3) months period. A framework will be produced to help guide the hospital in the most efficient operational methods to minimize waiting times. Minimizing waiting times in a hospital setup is a critical part of the process, as saving lives is the ultimate goal. The envisaged platform is accessible to patients and hospital staff. It aims to solve the challenges faced by patients while taking appointments and keeping medical files. The advanced system features allow doctors to access and update a patient's medical record after every check-up. Some of the features are as follows: Online follow-up with doctors for distant patients, and linking laboratories and the pharmacy in order to allow the medical administrator to view suggested prescriptions, whilst laboratories can view clinical tests recommended by the Doctor. The system is implemented for all the individuals who seek treatment with the primary hospital. Only registered users can participate. Potential users must create an account through the registration form and should provide their medical history. Patients' records would be updated automatically after each doctor's visit.

3. Queuing in healthcare

The scheduling approaches for healthcare providers are hampered by the challenge of determining how to schedule the number of patient appointments using special time slots based on fluctuations in patients and stochastic patient treatment time [5]. A typical appointment scheduling problem can consist of one or more objective functions, such as minimizing patients' average waiting time, machines'/doctors' average idle time, overtime, and cost [4]. Most healthcare facilities use queueing systems where patients arrive, wait for a healthcare service in a queue, obtain a service, and then depart from a healthcare facility [6]. Queuing theory is used to define analytical techniques, which are closed mathematical formulas, which describe a sequence of dealing with situations where there are congestions and blockages. The services of a healthcare outpatient department involve patients who seek service, wait in a queue before service, and depart the system after being served; an out-patient department is regarded as a queueing system [7,8]. Many countries experience long waiting times. Excessive waiting for treatments may cause deterioration in patient's health, reduce treatment effectiveness, resulting in a barrier in the access to health care services [8]. Patient's waiting is defined as the time between the patient's arrival time and the actual service start time of the patient's service or appointment. Patients' waiting time is affected by;

- Tardiness of earlier patients, causing a delay in the scheduled treatment time;
- Patients having different treatment times, creating a stochastic environment [4];
- Efficiency of the server or personnel providing the service sought by the patient's socioeconomic status [8].

Factors considered in analyzing queuing problems are line or queue length, number of lines, and the queue discipline. Services are mostly offered on a first-come-first-served basis although other services use reservations first and the triage system. The basic queuing model is a single-server, implying that service is provided at a single point from a single line or queue of patients. Queues are classified as finite or infinite by looking at the maximum possible number of patients that a queue can contain. Queue discipline refers to the way in which members of the queue are selected for service. Most healthcare facilities use the First-In-First–Out (FIFO) queue discipline or they categorise patients into sets according to their priorities. However, the priority discipline reduces waiting time for more critical patients, while the average waiting time for lower priority or stable patients increases [9]. Patient flow represents the movement of patients in a healthcare facility. It also shows the ability of a healthcare facility to provide services to patients from arrival to departure by making use of the available resources and ensuring that the quality of the services provided is not compromised [10]. The flow of patients should be quicker to avoid a blockage in the flow which may lead to longer waiting times and throughput time, hence a negative effect on the delivery of services. Short waiting times in all phases of a healthcare system are signs that the patient flow is well managed and that generally improves healthcare services [11]. Factors which have an influence on the operational efficiency based on patient flow include daily patients volume, health care facility policies such as how often patients visit, the type of the healthcare provider attending to patients, the size and the combination of the service providers, and the type of staffing used [12]. Ineffectiveness and inefficiency of appointment systems is one of the factors that lead to prolonged waiting times for patients in the outpatient department [13]. Some of the ways which may be used to reduce waiting times in healthcare facilities are as outlined below:

- Demand Management: Developing a partnership between primary and secondary care with the aim to manage and deliver reduced waiting times is important, since waiting starts in the primary care hospitals. Patients may also be scheduled by matching the demand for medical care with the resources available at the healthcare facility [13].
- Queue Management: Managing queues may ease patient flow in a hospital, as well as reduce the patients' waiting times before they can receive a healthcare service. [14] Suggests the use of an SMS system which notifies patients of their predicted service time as one of the tools that can reduce overcrowding in hospitals, hence reduce waiting times.
- Queue Index System: Index numbers are used to show the position of the patient in a queue. The patient may leave to attend to other issues once they get their index number. Some index cards show the number of people waiting to get the service ahead of the current index number. The system does not indicate the time a patient may have to wait before being attended to.

Patients depart through numerous routes once they are served. Some of the exit fates are listed below:

- Patient is admitted to specialized hospital units;
- Patient may receive the service as expected;
- Patient may be delayed and choose to get the service elsewhere;

- Patient was advised by a health worker to seek services elsewhere if they are unable to provide it.

4. Online outpatient scheduling systems

Online outpatient scheduling systems have been designed to curb problems of high patient no-show rates and long waiting times experienced when using traditional approaches [15]. A study on the effects of an Online Appointment Scheduling System on Evaluation Metrics revealed a significant positive effect on the improvement of the three metrics means, including Patient waiting time, No-show rate, and Physician punctuality [15]. Online systems offer benefits such as scheduling an appointment at the right time and date with the intended physician and 24-hour access to the system, which increase patient satisfaction [16–18]. They also reduce the patients waiting time and permit adjusting healthcare facility capacity through reducing the number of phone calls. Online systems improve the quality of care and the accessibility of patients to outpatient services [19–22]. Other metrics used to evaluate online outpatient scheduling systems are listed below:

- Patient punctuality: The difference between a patient's appointment time and the actual arrival time; [23]
- Clinic size: The number of patients scheduled per clinic session [23]
- Walk-in rate: The number of patients who walk in without appointments as a percentage of all appointments; [23]
- Service times: The amount of time the physician spends with the patient; [24]
- Panel size: The number of patients covered by the physician. [25]

Real-time appointment scheduling systems have been explored, whereby a patient only fixes a time and date, and the system allocates a doctor available at that particular time and date and also handles the rescheduling of patients with doctors [26]. The object-oriented analysis and design approach were used for development, whilst the android studio was chosen for mobile implementation. [27] Designed a patient appointment and scheduling system, using Angular JS for the frontend, Ajax framework for handling client-server request and Sqlite3 and MYSQL for the backend.

[28] Propose an online patient appointment scheduling system based on the Web Services architecture. The results show that the Web Services architecture provides an ideal design paradigm for the development of an integrated health care information system in the primary care setting.

[29] Developed an Online Doctor's Appointment and Medical Database Management System. The purpose of the application was to enable patients to easily compare, choose, and make an online appointment for a doctor just by sitting at home. The development tools used are HTML, CSS, and JavaScript for the client side, while PHP and MySQL for the server side.

Introducing an appointment schedule reduced the maximum waiting time for all patients by 42% [30].

5. Research method

A stratified sampling method was used to select subjects for the research. The staff in the Out-Patient Department (OPD) were divided according to the nature of their work and then a few were chosen from these small groups to participate in the research. The OPD has patients coming in and out of the hospital, so it was easy to keep track of the time that they waited to get assistance. The data collection methods used for this research are a questionnaire, an oral interview, and observation. A set of questions was prepared prior to visiting the hospital and a total of twelve (12) questionnaires were distributed among the OPD staff. The first part of the questionnaire addressed the first objective of evaluating the current scheduling system used by the hospital. The next point then made a comparison to what other hospitals are doing

with regard to addressing the schedule and managing patients' times. The third set of questions looked into statistics to get average times taken before patients get assistance.

An oral interview was used to personally understand the hospital operations from the management of the facility as a follow-up to the questionnaire. A set of questions prepared before the meeting was directed towards the hospital manager to get a clear view of how they deal with long queues using their scheduling program. These questions were to clarify how they deal with patients' flow in terms of staffing, as well as how they cater for shift changes to ensure there are not many delays in helping patients caused by change of personnel on duty.

Observation of patient movement within the hospital was made from the time a patient arrives until they get assistance and leave the hospital. The waiting times at each service station were recorded. From registration, temperature check, consultation, to pharmacy, patients' movements were observed. This method is effective since the information is first-hand and has no distortions.

The data collected from the healthcare facility is presented in graphs and charts for easier interpretation. Trends in patient movement can be easily identified through these representations, thus easing the work towards a solution. **Table 1**. shows the waiting times for 10 patients at each service point. The waiting times and averages are plotted on a graph in **Fig. 2.** On average, patients spend 217 mins waiting for consultation. The proportion of waiting time is 2% for registration, 21% checking vital signs, and 72% consultation as shown in **Fig. 3.**

Table 1. Waiting times at each service point

Patient No.	Waiting Time Before Registration (Mins)	Waiting Time Before Checking of Vital Signs (Mins)	Waiting Time Before Consultation (Mins)
1	8	58	222
2	10	60	213
3	4	63	224
4	5	61	211
5	5	59	229
6	6	60	214
7	5	61	209
8	5	57	218
9	6	59	216
10	4	63	214
Average	**5.8**	**60.1**	**217**

Waiting Time (mins)

Fig. 2. Waiting times at each service point
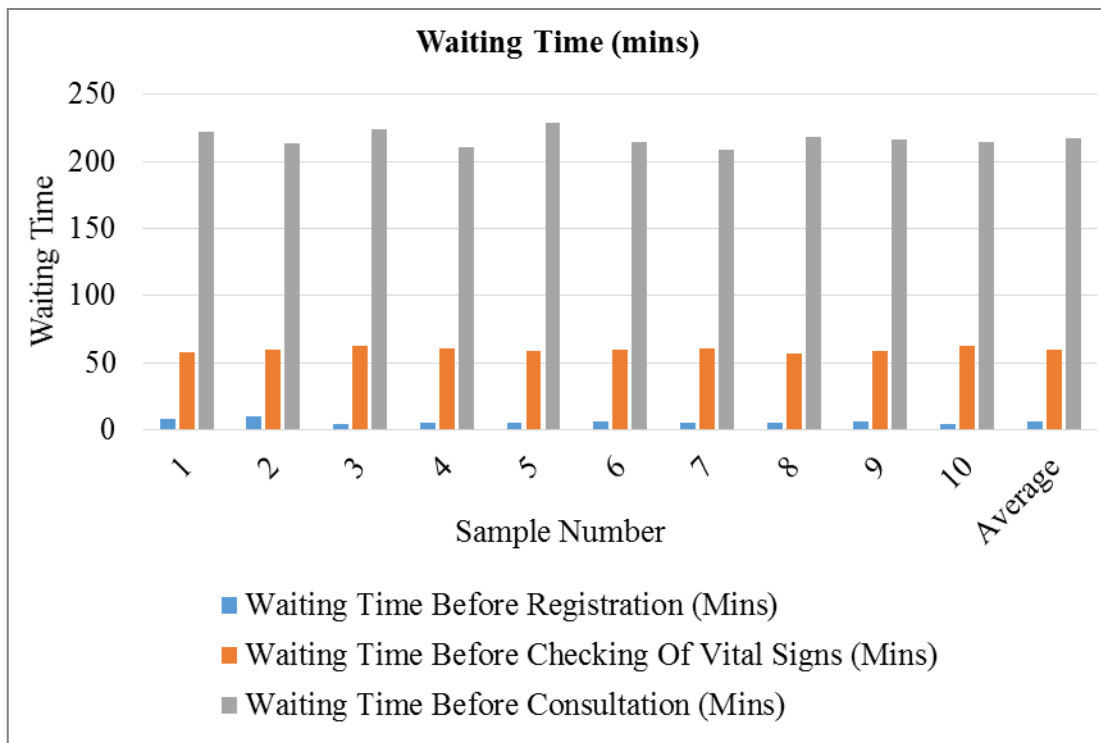
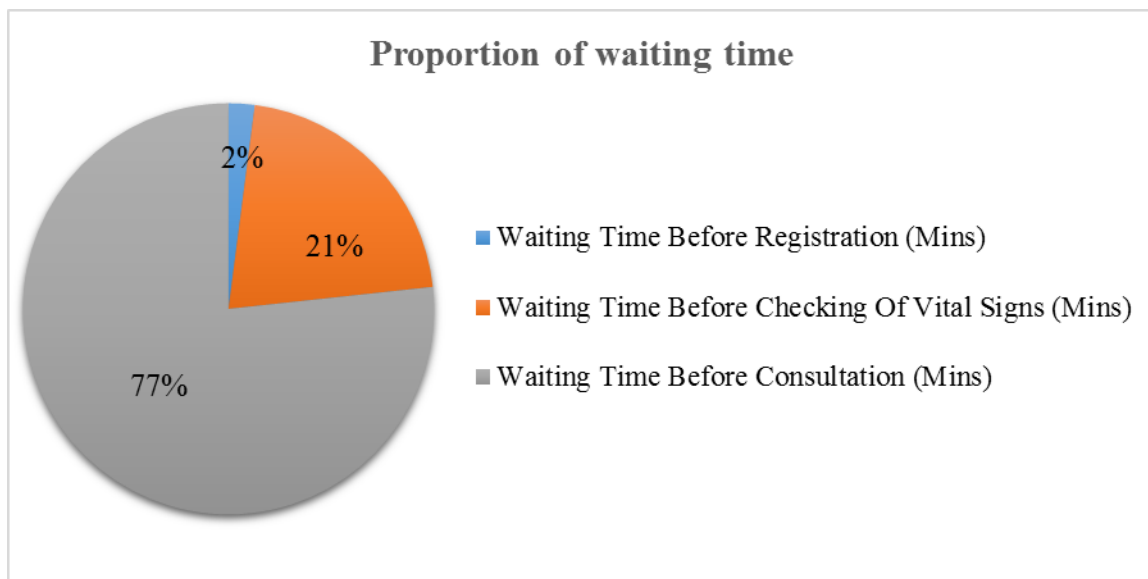**Proportion of waiting time**

Fig. 3. Proportion of waiting time

6. System modeling and design

Three categories of queue management systems were identified from the literature as the traditional queueing method, online system with tokens, and the SMS-based appointment. These were compared using the weighted matrix method. After the selection of the best solution, the subsequent modeling of the proposed solution was followed through the database design methodologies, conceptual modelling, and logical and physical design [31].

The following attributes were considered in the ranking of the systems:

- User Friendliness: The proposed solution

should be easier to understand both for the hospital personnel and the patients.

- Response Time: the solution should give a quick response to the user.
- Flexibility: the solution should give patient freedom to run personal errands while waiting for their time.
- Schedule Visibility: the scheduled times should be visible to the patient and hospital personnel to keep them both in sync.
- Delay Reduction: the solution should

reduce the patient's waiting time.
Using a ranking scale of 1 to 5 as outlined below, an SMS based system was selected for further development, as shown from results in **Table 2.**

Rating scale:
5- Very Satisfactory
4-Slightly Satisfactory
3-Fair
2-Dissatisfactory
1-Very Dissatisfactory

Table 2. Waited scoring matrix

Feature	Weight (%)	EQMS with tokens		SMS		Traditional	
		Score	Total	Score	Total	Score	Total
User friendliness	20	4	80	4	80	2	40
Response time	10	5	50	4	40	3	30
Flexibility	10	3	30	4	40	2	20
Schedule visibility	25	2	50	5	125	1	25
Delay Reduction	35	1	35	5	175	2	70
TOTAL	**100**		**245**		**460**		**185**

The SMS-based appointment system is used to help patients book their doctor's appointment from the comfort of their homes. The main objective of this system is to reduce congestion in hospitals, consequently reducing patients' waiting times. The system architecture is made up of two parts, the client side (patient) and the server side (hospital). The client-side interaction is through the SMS application of the patient's mobile phone, whereas the server side is the combination of the desktop application and the hospital database. The desktop application consists of written SQL queries that make access to the database possible. A patient sends their details, purpose of their visit, and brief description of their condition through hospital hash tags designed to access the central patient registration platform. The system then schedules the patient to come through at a time when they would not have to wait in queues. The patient receives confirmation of their appointment via a text message. This arrangement allows for the patient to carry out their daily chores and only make their way to the hospital at a time of their appointment. **Fig. 4.** shows the system overview.
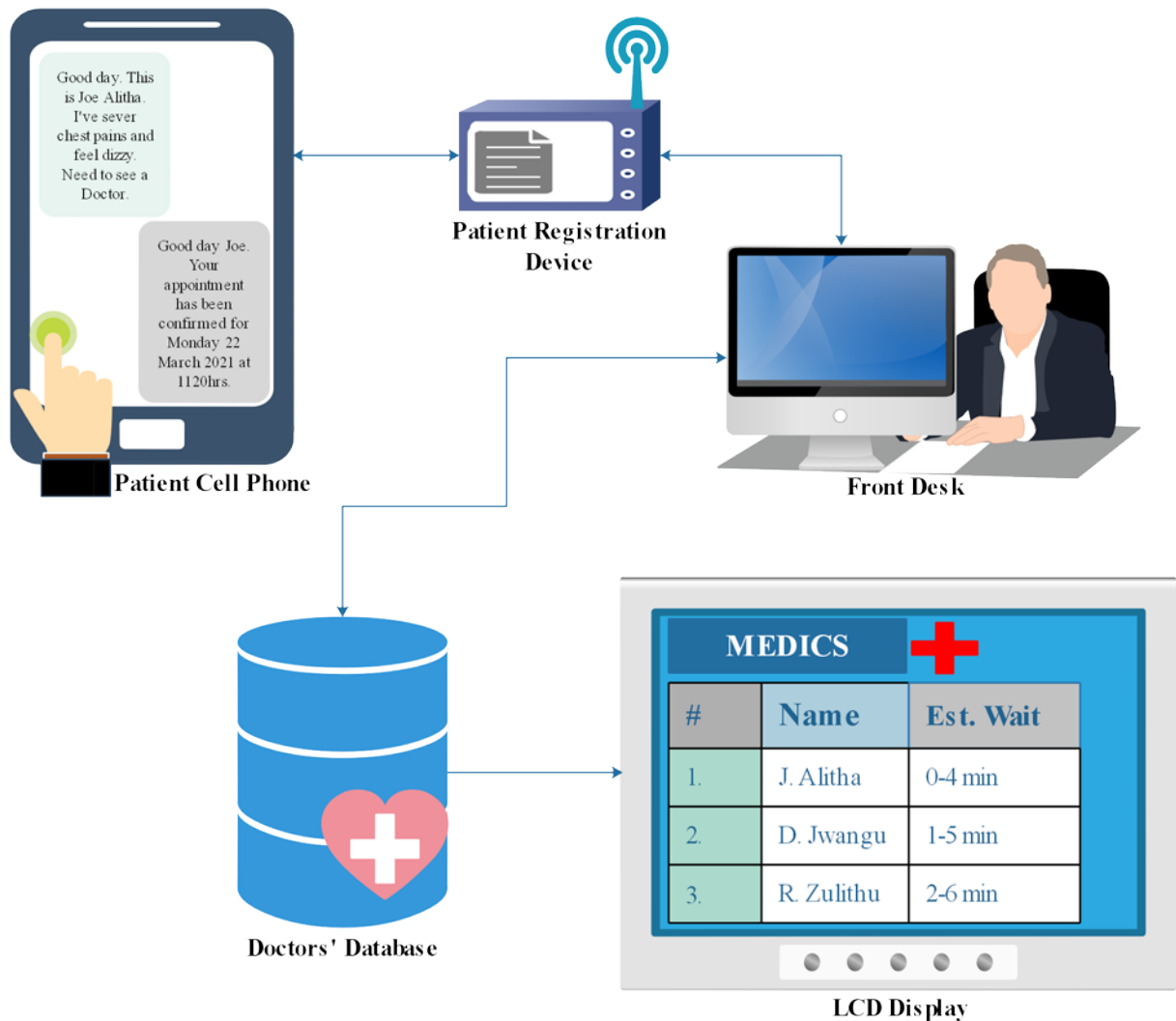
Fig. 4. Proportion of waiting time

Patients book appointments by sending an SMS to the hospital and receive immediate feedback confirming receipt of their appointment details. An internal system scans through the relevant doctor's schedule and the front desk operator confirms the appointment. The system then sends a confirmation SMS to the patient containing the date and time of their appointment. After confirmation of the appointment, the patient details are stored in a database. These details are accessed on the patient's appointment date and displayed on the LCD screen when it is their turn to get consultation. A use case diagram for making an appointment is shown in **Fig. 5.** whilst **Fig. 6.** shows the activity diagram. The primary actor is the patient. The other actor is the front-desk administrator. First-user patients do not necessarily need prior registration in the system. Any patient can dial the hash tags to submit their first intention. Full registration details will be submitted upon visiting the hospital, and records can be retrieved on recurring visits or interaction with the system. The front-desk administrators are registered in the system, search for the doctor, and book an appointment. Other hospital staff – doctor/ physician, pharmacists, can log in to the system with a username and password, accept patient's appointment requests, and update medical record after each visit. Checking the doctor's schedule is done automatically through keyword search based on the patient's inquiry, as illustrated in the activity diagram in **Fig. 7.** The process is
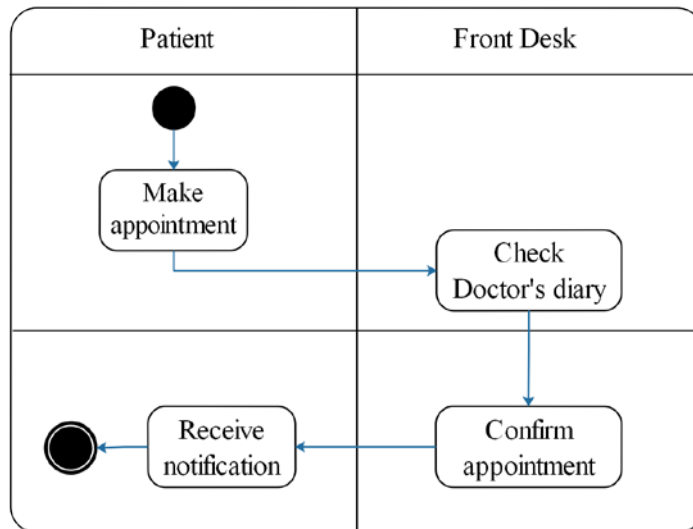
executed through retrieving the patient messages from the patient registration device by the hospital application system.
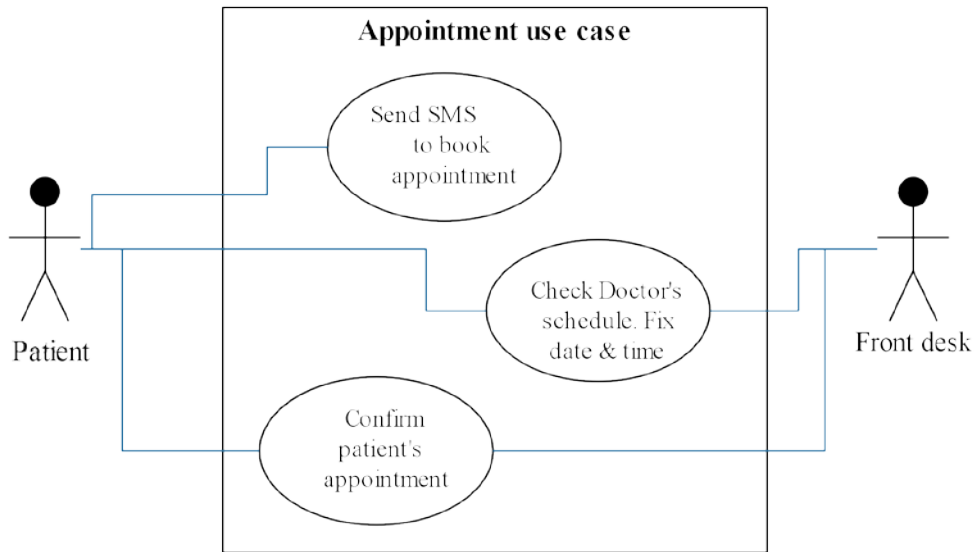
Fig. 5. Use-case diagram for making an appointment

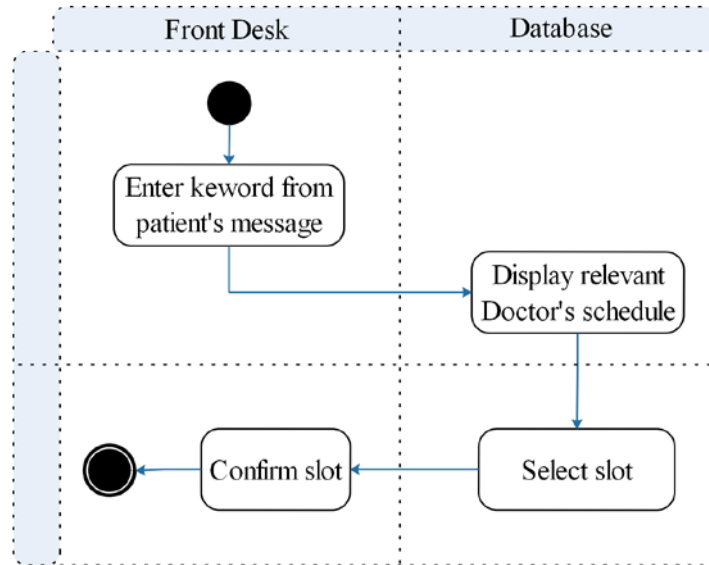**Fig. 6.** Activity diagram for making an appointment

Fig. 7. Activity diagram for checking the doctor's schedule

Appointment confirmation is made prior to the patient's visit to the hospital. The front desk administrator confirms the booking through liaison with the doctor. A confirmation SMS is automatically sent to the patient through the patient registry device. The patient may reject an appointment, and the search process for a suitable booking continues until a favourable slot is found. The activity diagram is illustrated in **Fig. 8.** whilst **Fig. 9.** illustrates the sequence diagram for booking an appointment.
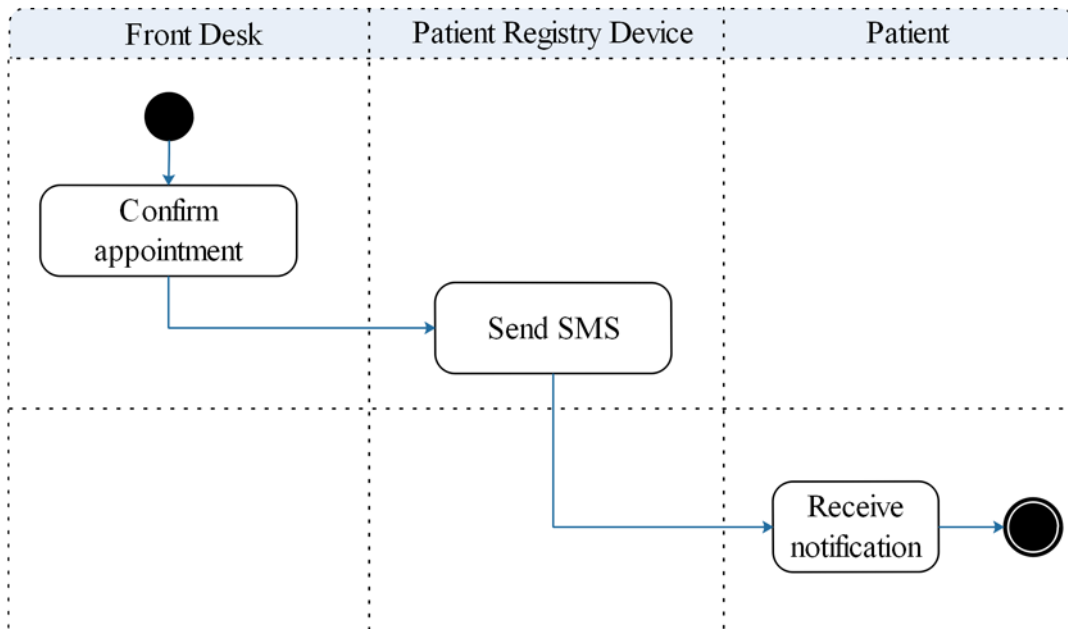

Fig. 8. Activity diagram for appointment confirmation

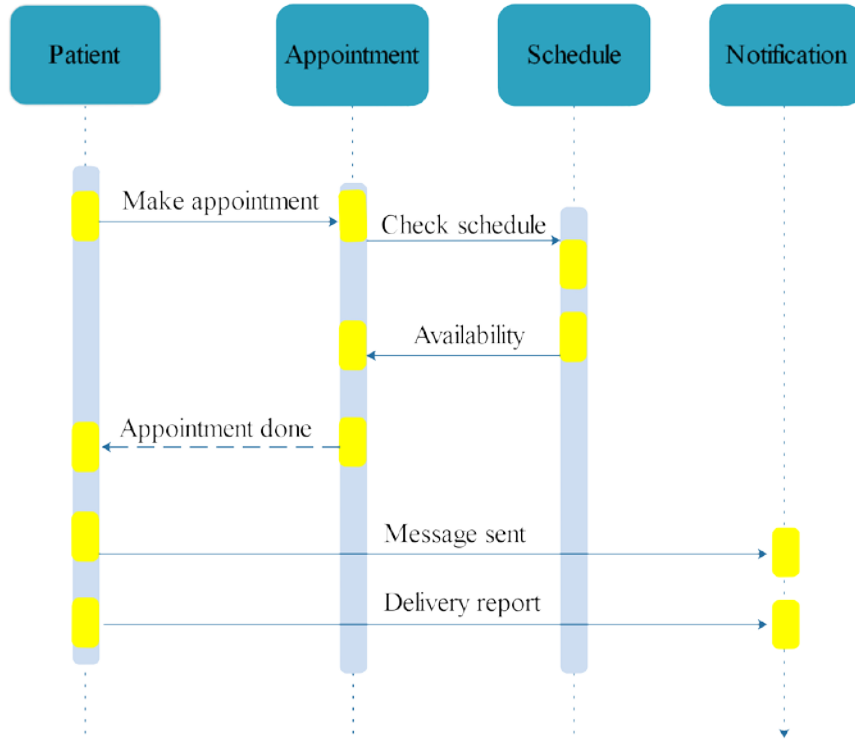**Fig. 9.** Sequence diagram for making an appointment

Fig. 10. shows the physical database model for the system. The main entities are the patient, the front desk administrator, the doctor/physician, appointment/booking, the specialty, and the notification. The hardware configuration for the SMS based system is shown in **Fig. 11.**
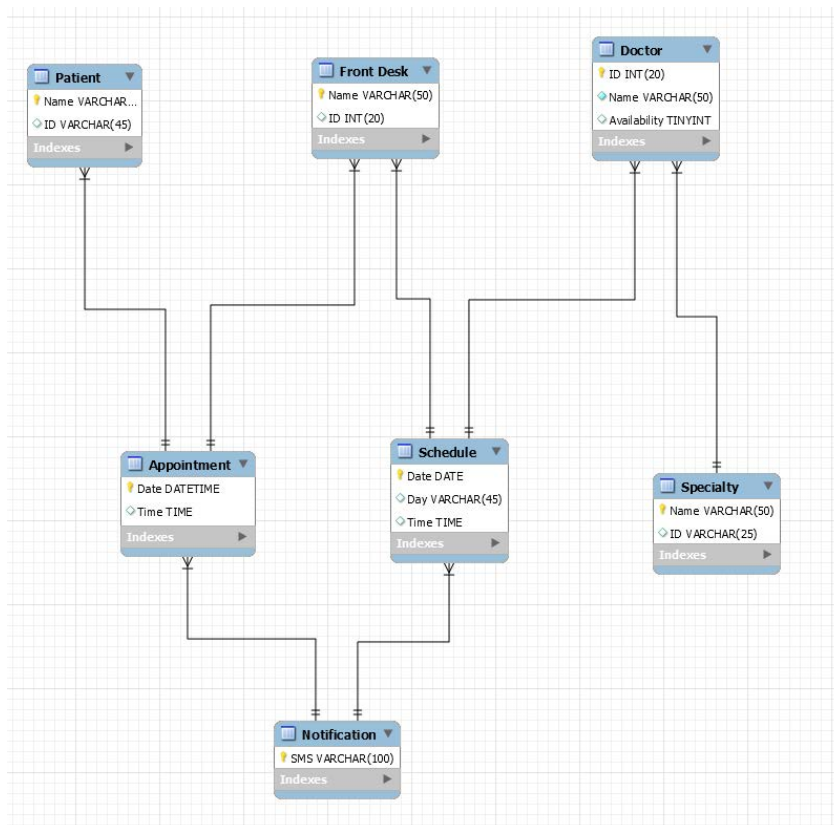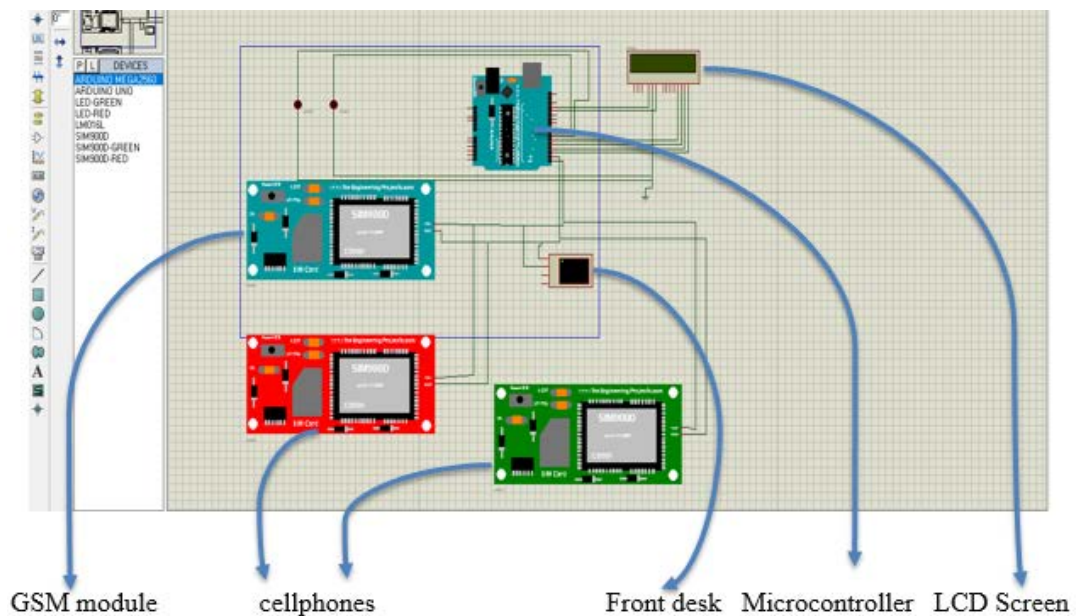

Fig. 10. Physical model for SMS based appointment system

Fig. 11. System hardware configuration

7. Conclusions

The proposed system has the capability to drastically reduce waiting times. This is possible through the slotting of patients at their specific times. Patients only go to the hospital at their allocated time slot without having to wait for a longer time before being attended to. The SMS appointment system is the most optimal and effective system that can be used in remote areas and patients of all classes because it does not need an Internet connection or the use of smartphones. The benefits of implementing this technology cut across a wide spectrum of patients and staff involved in the scheduling process, such as administrators and doctors who will be able to conduct their tasks more efficiently and accurately. Patients have the ability to book their appointments and reservations quickly and more conveniently.

There is a wide range of improvements to the proposed system, as outlined below:

- Accommodate patients cancelling appointments;
- Integrate and customize it to allow patients to choose their own time slots. This will increase the flexibility of the system,
- Allow for rescheduling of appointments. Rescheduling will enable the hospital to give the available slots to the next patient in line if a patient is unable to come on their scheduled time and wishes to reschedule to another date or time;
- Adding sound to the announcement system. The use of a sound to announce the next patient in line will ensure that the patient is aware that it is their time to get a service. Patients may not pay much attention to the LCD screen, which might lead to a minor delay and increase idle time.

8. Acknowledgment

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Appendices

1. Which days are the busiest?

Mondays ☐   Tuesdays ☐

Wednesdays ☐   Thursdays ☐

Fridays ☐

2. What time of the day do you experience a higher number of patients?

Morning ☐   Afternoon ☐   Evening ☐

3. What is the average time taken by a patient to get health care?

Less than 15 minutes ☐

16-30 minutes ☐

31-45 minutes ☐

46 mins – 60 mins ☐

More than 60 mins ☐

4. Which criteria is followed in attending to patients?

_____

_____

_____

5. Is there any communication made with patients in a queue?

Yes ☐

No ☐

If yes, how is the communication made?

_____

PATIENT TIMES RECORDING SHEET

PATIENT NO.	ARRIVAL TIME	REGISTRATION		CONSULTATION		PHARMACY	
		IN	OUT	IN	OUT	IN	OUT