Accelerating the Delivery Process of Clinical Diagnostic Laboratory Results

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Abstract: - Faster Delivery of laboratory test results is one of the most noticeable signs of good laboratory service and is often used as a key performance indicator of laboratory performance. Despite the availability of technology, The Delivery time of clinical laboratory test results continues to be a cause of customer dissatisfaction which make patients feel frustrated and they became careless to get their laboratory test results. The Medical Clinical Laboratory test results are highly sensitive and could harm patients especially with severe case if they deliver in wrong time. Such results affect the treatment done by physicians if arrived at correct time. Efforts should therefore be made to ensure faster delivery of lab test results by utilizing new trusted, Robust and fast system. The proposed system provides quick response rate and the decision is faster than the manual methods. This will save patients life. A multi-agent system is formed by a community of agents that exchange information and proactively help one another to achieve the goals set by the system designer. We show how agents can collaborate to accelerate the delivery process of clinical diagnostic laboratory results using GSM technology.

Key-Words: - Multi-Agent, GSM, SMS, Laboratory, JADE, Delivery

1 Introduction

In this paper we proposed a distributed Multi-Agent System to enhance and faster the process of laboratory test results delivery using SMS. The developed system relies on SMS messages because of the wide availability of GSM network comparing to other network. The software provides the capability of knowledge sharing between different units and different laboratory medical centers. The system was built using java programming. To implement the proposed system we had many possible techniques. One of these is to use the peer-to-peer (P2P) model, where all the peers are treated equally and the service is distributed among all the peers of the network. However, for the pure P2P model, it is difficult to maintain the coherence of the network, discover new peers and ensure security. Also security is a quite important issue since each node is allowed to join the network without any control mechanism. We thus take the hybrid P2P model, a model between the Client/Server model and the pure P2P model using GSM technology through SMS messages. This model satisfies our need. A GUI has been developed to provide the laboratory staff with simple and easy way to interact with the system. This system provides quick response rate and the decision is faster than the manual methods. This will save patients life.

Rural areas in Jordan suffers from absence of electronic system to save laboratory results. Medical centers in rural areas uses classical laboratory results record book (Figure 1). The current system relies on direct visit of the patient to the laboratory centers or hospitals to get result slip (Figure 2) in order to take it to his/her physician. Absent of smart distributed medical network makes patient in rural areas travel long distances to take consultation from specialist doctor. This becomes an obstacles to the patient that could prevent them from going to the specialist especially when they think that there case is not that sever.

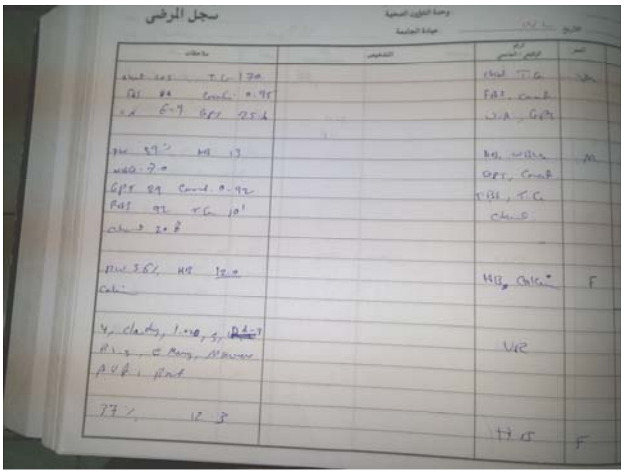
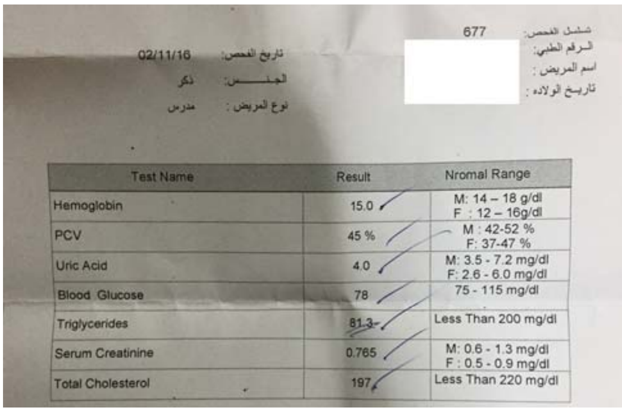


Fig.1: Laboratory Results Record Book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Test Name	Result	Nromal Range
Hemoglobin	15.0	M: 14 – 18 g/dl F : 12 – 16g/dl
PCV	45 %	M : 42-52 % F: 37-47 %
Uric Acid	4.0	M: 3.5 - 7.2 mg/dl F: 2.6 - 6.0 mg/dl
Blood Glucose	78	75 - 115 mg/dl
Triglycerides	81.3	Less Than 200 mg/dl
Serum Creatinine	0.765	M: 0.6 - 1.3 mg/dl F : 0.5 - 0.9 mg/dl
Total Cholesterol	197	Less Than 220 mg/dl

Fig. 2: Laboratory Result Slip

Having intelligent software that can accelerate the delivery process of clinical diagnostic laboratory results is very beneficial in the medical world. Such intelligent systems can also be used to analyze patient data and human response and hence guide the implementation and management of therapies and future treatments.

In this research, we propose a multi-agent intelligent system that will be used in accelerate the delivery process of clinical diagnostic laboratory results. Multi-agent system has been a hot topic in recent years [1,2,3,4,7]. And it's still be researched and developed because it will have an important effect once it comes to our life. Such monitoring must have autonomous interactions between these medical units in order to be effective. The proposed system which will use multi-agent system is formed by a community of agents that exchange information and proactively help one another to achieve the goal of delivering the clinical diagnostic laboratory results.

Having intelligent communication system will faster and improve the communication between different units in the health system of Jordan. This will help physicians in hospitals by faster the access to the clinical laboratory results data and enhance the diagnostic stage in real time. The proposed system will connect patients and the laboratory centers regarding their geographical area. Patients will be able to seamlessly and from anywhere track their laboratory results.

2 The Developed System Architecture

Multi-agent system has been a hot topic in recent years. And it's still be researched and developed because it will have an important effect once it comes to our life. Multi-agent system methodology offers an implementation that fits the design needs [5,6,7]. The agent is a special software working for its human client/clients to perform certain tasks that imitate human agents or systems and it has the ability to be autonomous in its action. From that definition we can conclude that an agent is autonomous because it has control over its actions and it pursuit them without direct involvement of its human agent or others. The agent is also social because it can cooperates and communicate with other agents and hence their humans in order to complete the required task. An agent is reactive since it is conscious about the updating of available data and changes in circumstances and responds based on in that in a timely manner. This entire make the agent rational in achieving its goals.

Agents work with each other in a cooperative way to complete certain task that cannot be done with single agent. A set of agents that help one another in solving problems by using cooperation, coordination and negotiation techniques is called a multi-agent system [6].

The multi-agent system is a complex system since the agents must be supported with interaction strategies that make them capable to select the appropriate activity at the appropriate time [2]. Agent learning focuses on learning how to communicate with other agent, learning how to coordinate different activities, learning how to manage a given task until completion, and learning from other agents.

Multi-agent systems have been widely adopted in many application domains because of its offered advantages [5,6]. In multi agent system the complex task may be divided to different part and each part can be handled concurrently by specific agent. Different tasks or services can be distributed among the agents based on their complexity so each agent will deal with certain number of task rather than dealing with all tasks.

Agent talk with each other using special communication language called agent communication language (ACL). This language relies on speech act theory [6,7]. An ACL support the agents with a variety of resources needed for exchanging information and knowledge.

Agents are communicating between each other using certain communication protocols. The communication protocols used between agents have to be fixed. Agents interact through speech acts language. For example query, inform, request, offer, accept, withdraw, and reject speech acts has been used in the developed system .Interaction between agents occurs within a scene. The developed system composed several scenes which are basically group meeting composed of a set of agents playing different roles and communicating with a well-defined communication protocol. To specify a scene, the first step is to identify which are the agents that will participate in the scene. Agents with different roles can enter and exit a scene to go to another one. The second step is to define the communication protocol [5,7]. JADE provides messaging system that follows FIPA_ACL (Foundation for Intelligent Physical Agents - Agent Communication Language) standers. The messaging system manages message traffics and monitors the resulted queues provided to agents. FIPA_ACL incorporates a lot of predefined interaction protocols that manage conversations between agents. The Knowledge Query and Manipulation Language (KQML) was the first agent communication language. Nowadays FIPA–ACL is the most usable agent communication language and it uses almost all the aspect of KQML [2,3,6]. FIPA-ACL has 22 performative (or communicative acts) that specify the excepted flow of messages (either sent or received) from agents, and type of messages (inform, request, propose, failure, confirm, disconfirm, agree, accept, propose, cancel, refuse, query, etc.). FIPA-ACL makes sure that the sent message will be understood in the same way the sender needs [5] .

There are five agents in the preliminary proposed MAS system. Figure 1 gives the general organization model of the proposed system. Within each health organization, there would be a unique Health organization Agent (HOA) that have many Department Agents (DAs) and many Physician Agents (PAs). Different HOAs and PAs can communicate with each other and not necessarily from the same medical network.

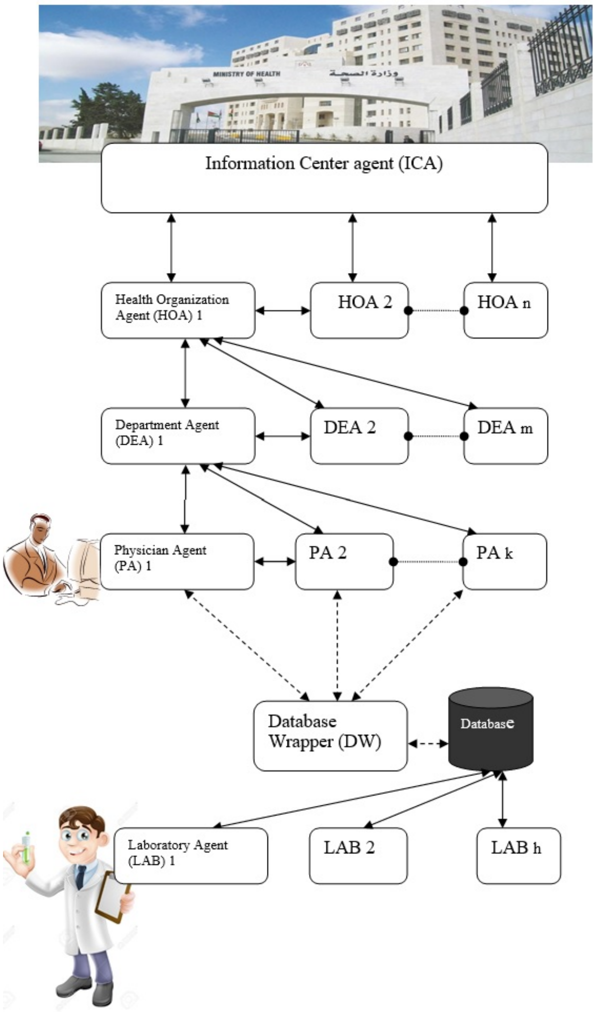

Fig.3: The proposed Multi-Agent system for Accelerating the Delivery Process of Clinical Diagnostic Laboratory Results using GSM Technology

Interaction between agents occurs within a scene. Our system is composed by several scenes [1]. We consider the protocol of a scene to be the specification of the possible dialogues the participating agents have. A scene can be described as a graph, which can be regarded as a state diagram. The nodes represent different states of a conversation. The graph has a single initial state and a set of final states representing different endings of the conversation. Fig. 3 shows the state diagram of a scene how agents, have a conversation. where

$Q = \{X0 - X4\}$ – a set of states of the automaton:

X0 – initial state;
X1 – waiting for a response to the request;
X2 – checking the data;
X3 – lack of communication;
X4 – data processing,

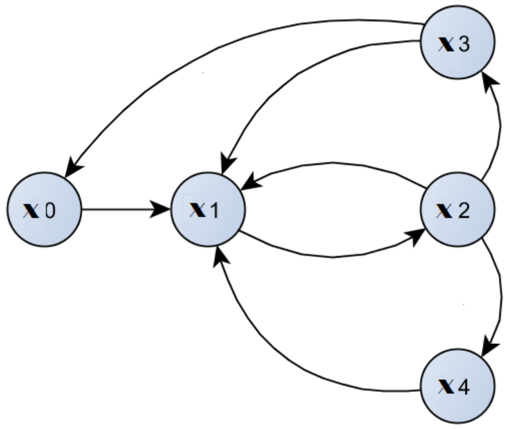

Fig. 4: The state diagram of a scene in multi agent environment.

B) Architectures of the Agents

1) Information Center agent (ICA): It has the highest authority and is responsible for necessary management and information collection. It provides a gateway among the agents in the system. It controls the access to the system and it also checks the identities of the users. There is only one ICA in the system. It stores information about the elderly peoples and their unique IDs. Thus agents need to communicate with the ICA agent to find out which hospital organization is available in the system at any given time.

2) Health Organization Agent (HOA): The HOA continuously monitors incoming and outgoing information through this HOA.

3) Department Agent (DEA): it models each department within each Health Organization. It is similar in its architecture with health organization agent.

4) Physician Agent (PA): PAs helps a physician acquire useful information of the elderly people and make initial decisions about the medical situation of the patients. The PA will perform according its knowledge. The PA could also ask other agents about the rules they are using in evaluating a medical condition of an elderly person so that the agent can updates rules. The PA has the ability to track the further development of the suspected cases under the help of other agent available in the system. The PA will keep all the cases seen by or forwarded to its physician in electronic records and such records will be updated when new information is being available. The PA can decide to take any of the following actions depending on the decision reached, i.e.:

- To order some extra clinical tests.
- To continue the same medical treatment or to modify it.
- To schedule another visit for the future.
- To transfer the patient, for example, hospitalize him if his health has deteriorated too much. Patients can also be transferred from one of the health centers to another according to the patient needs.

4) Laboratory Agent (LAB): LABs gathers certain medical information of the patient such as Blood pressure Levels, Blood Glucose Levels, Cholesterol levels, Temperature, Heart rate, Oxygen level in blood, and other laboratory tests such as Creatinine Laboratory Test and Potassium Laboratory Test. Creatinine Phosphokinase (CPK) Laboratory Test and Transaminases Laboratory Test (either ALT or AST).

3 Implementation

For system construction and execution, JADE 3.7 agent platform (Java Agent DEvelopment Framework) is adopted. JADE is an open-source software framework. JADE is a widely used package in multi agent system implantation [6]. JADE is following the specifications laid by The Foundation for Intelligent Physical Agents (FIPA) for multi agent system implementations. It provides a set of Java classes that makes it easy to implement the systems. JADE can run on a variety of operating systems including Windows and Linux. The JADE platform includes most of agent's specifications. Each agent is implemented in JADE as a single thread. JADE provide a multi thread environment that allows the agents to execute parallel tasks. Different cooperative behaviors can effectively schedules in JADE. JADE incorporates some ready to use behaviors that commonly used by agents during performing certain task. Among the others, JADE offers a behavior that allows full integration with JESS which is a rule based engine that performs all the necessary reasoning.

In brief, JADE runtime environment consists of two essential built-in agents namely Agent Management Service (AMS) and Directory Facilitator (DF). The AMS is responsible for managing the interactions of the agents in the system. The Directory Facilitator agent maintains a description of the services that the agents are ready to provide to the others. Any registered agent can use the DF agent to search for specific services or help that can be handled by other agents.

Since agent are normally distributed at different location. Each location will have a runtime environment that hosts the agents, which is called a "Container". Each container has AMS and DF agents. The containers will communicate with each other using a pre-defined protocol. One container needs to be assign as main container which represents the bootstrap point of a platform. It is the first container to be launched and all the other containers must join it by registering with it. For my system, the main container hosts four PAAs (I choose four because it is representative enough while computing time is still reasonable).JADE also provides tools that manage both locally and remotely agent life cycles including create, suspend, resume, freeze, thaw, migrate, clone and kill.

In this proposed system This information will be gathered from the patients using regular medical instruments and the result will be input to the system through graphical user interface in order to be sent to the database and to his/her physician. The Graphical User Interface (GUI) was done by VB.NET (Figure 5).

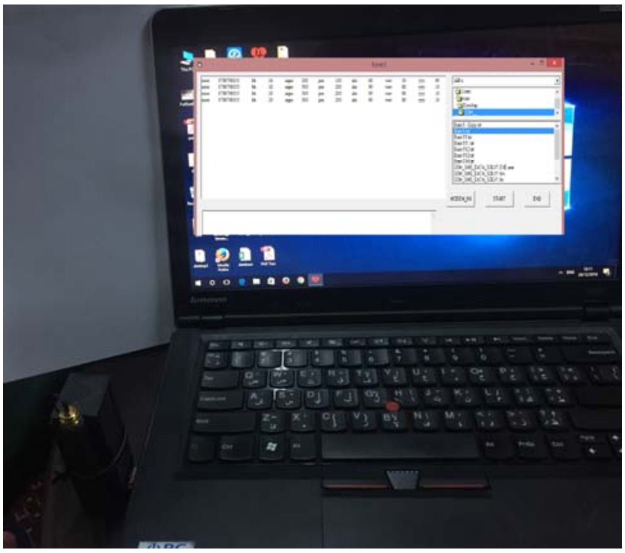

Fig.5: The Implemented GUI System

The proposed way of sending the data to the database is not only using regular internet networks but also using GSM technology through SMS messages. Using SMS messages is very helpful in rural areas where the internet connection is not available. This was done using GSM modems (Figure 6) by AT commands. AT commands is used to collect information by controlling GSM Modems. A GSM modem is a special device that uses a SIM card, and it operates like mobile phones. AT is the abbreviation of ATtention.

Fig.6: SIM800L module

GSM module requires one SIM card. This module is capable to accept any network SIM card. The GSM module has a unique identity number like mobile phones have. The GSM module is used to send an SMS to the user‘s cell phone number. When the patient data has been entered and the send order has been given, a signal to the GSM module which then sends a message to the physician user that is predefined by the programmer. GSM SIM 900 Quad-band GSM/GPRS engine, works on frequencies 850MHz, 900MHz, 1800MHz. It is very compact in size and designed with RS 232 level converter circuitry, which allows you to directly interface PC Serial port. GSM uses a combination of Time Division Multiplexing and Frequency Division Multiplexing. The baud rate can be configurable from 9600-115200 through AT command. This GSM/GPRS RS232 Module is having internal TCP/IP stack to enable you to connect with internet via GPRS. Using this module, we will be able to send & read SMS, Connect to internet via GPRS through simple AT commands. The suitable operating voltage level is 5V-12V DC.

The SMS architecture is shown in Figure 7. The SMS message will be transmitted from the agent GSM module to nearest Base Transceiver Station (BTS) through a wireless Channel [8,9,10]. The SMS will be received and passed to Base Station Controller (BSC). The BSC handles the operation of the BTS. The message will leave BSC and move to the Mobile Switching Center (MSC). The Mobile Switching Center acts like a switching device which switch data between users on the network based on routing information provided by the Home Location Register (HLR). The HLR contains relevant data about network subscribers: their status, location and thus its routing information. The message will be stored within Short Message Service Center (SMSC) which will forward the message when the receiving Agent becomes available. The SMSC is software that manages the processes of queuing the messages, billing the sender and returning receipts if necessary. The Subscriber details will be validated by Visitor Location Register (VLR) and Equipment Identity Register (EIR). VLR will verify that the message transfer does not violate the supplementary services invoked or the restrictions imposed. The visitor location register is a database that contains temporary information about subscribers homed in one Home Location Register (HLR) who are roaming into another HLR. EIR is a database to determine if the service of a GSM mobile Subscriber is authorized, unauthorized, or if it should be monitored. It uses International Mobile Equipment Identity (IMEI) to identify each Subscriber device. An IMEI is considered as invalid if it has been reported stolen or is not type approved.

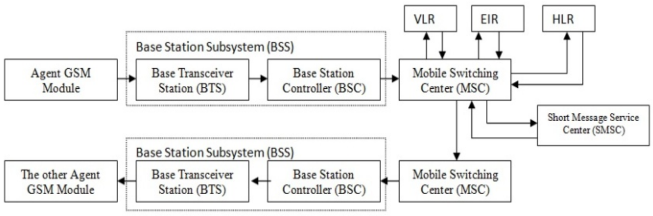

Fig.7: SMS Architecture.

MSC asks HLR for reception location. The MSC will deliver the message to the specific mobile subscriber through the proper base station. The message will be released and moved to the appropriate MSC and then forwarded to nearest Base Station Subsystem (BSS) and it will be received to its destination agent.

The used GSM Module is Mini GSM / GPRS breakout board is based on SIM800L module, supports quad-band GSM/GPRS network, available for GPRS and SMS message data remote transmission. The board features compact size and low current consumption. With power saving technique, the current consumption is as low as 1mA in sleep mode.

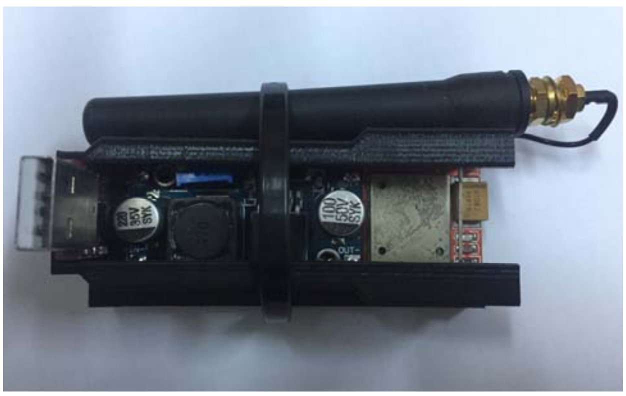

Fig.8: The developed GSM Transmitter Unit

Fig.9: The developed GSM Transmitter Unit (Side View)

The process starts by opening an Excel sheet and fill it with patient laboratory results. Then using the developed system, the file will be loaded.

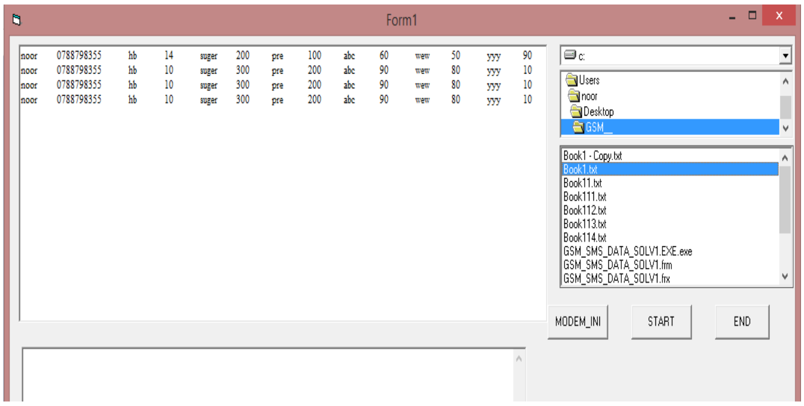

Fig.10 The Implemented GUI System – Computer GUI

And by Clicking "START" bottom the data will be delivered to patients and their physicians

Fig.11: The Implemented GUI System (Transmission view box)

The data can be also entered to the system using mobile application. The process starts by slecting PATIENTS putton and enter the predefined password in order to getin to the system

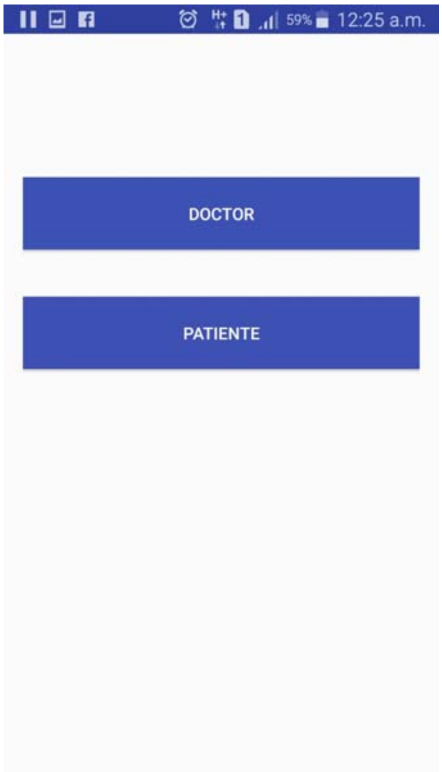

Fig.12: The Implemented GUI System- Mobile Application

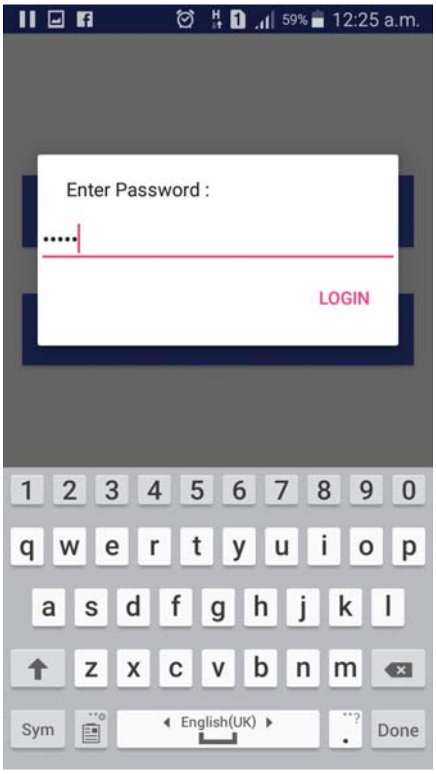

Fig.13: Password entry

The application has an option setup patient's number and doctors.

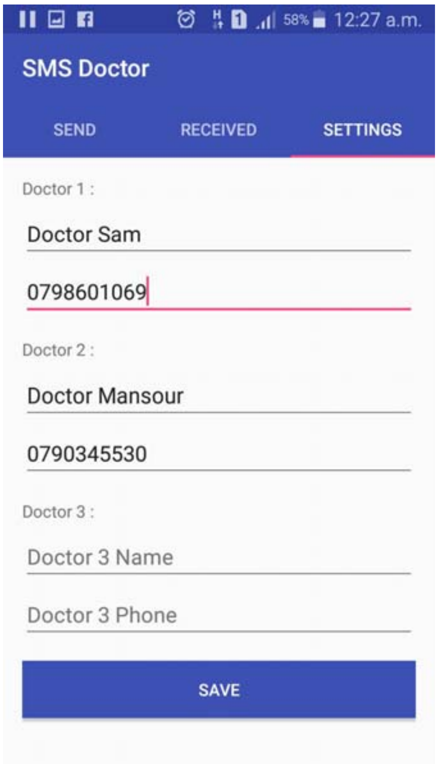

Fig.14: Doctors and patients phone number setup

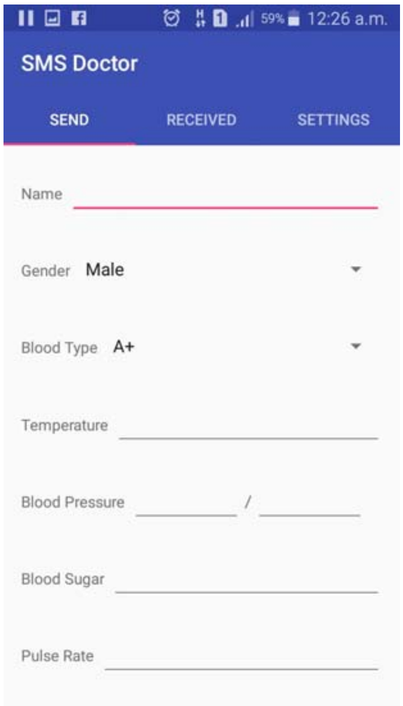

Fig.15: Patient information

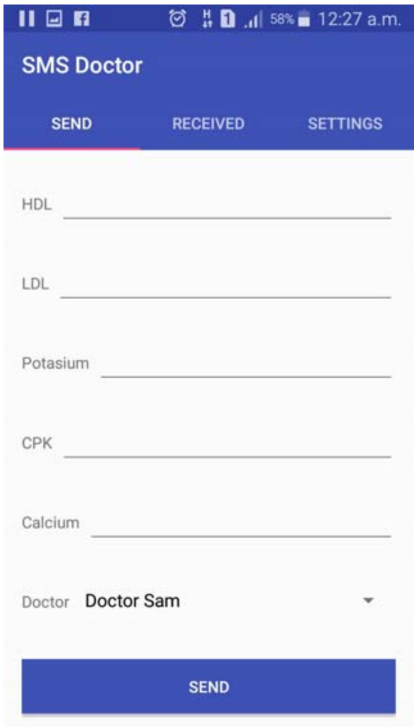

Fig.16: The Laboratory results

The physician can be accessed from personal computer unit or Mobile phone or through Medical Kit. The physician has the ability to analyze patient information and comment on the individual results in the same GUI. The diagnoses of patient case with any taken action will be entered by interacting with GUI and sent back to the patient and/or his family members. All received data will be stored in Access database.

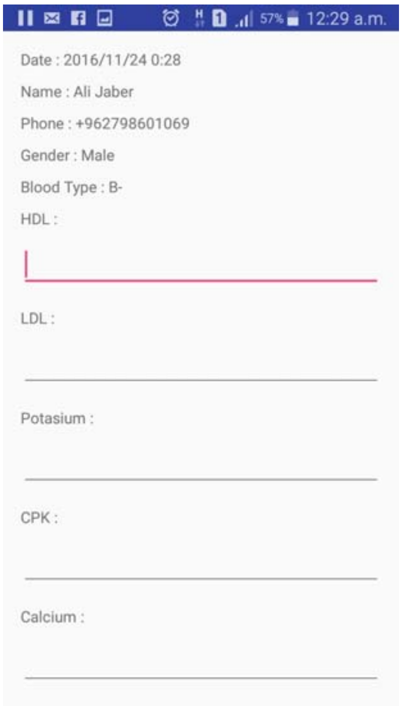

Fig.17: The Implemented GUI System- Doctor Side

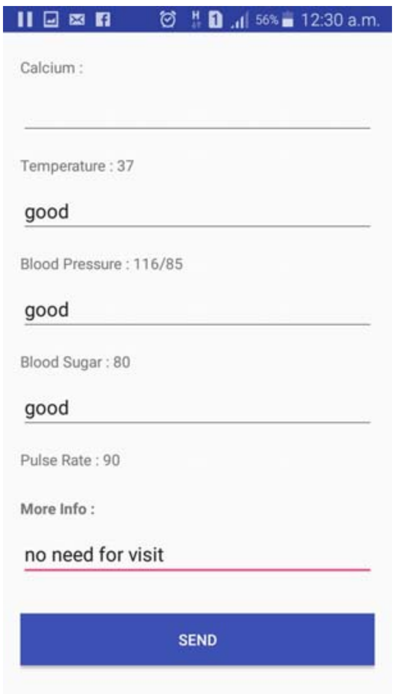

Fig.18: Comments written by doctor to patients

Fig.19: Received information from doctor

5 Conclusion

In this paper, a system is designed and developed to accelerating the delivery process of clinical diagnostic laboratory results using GSM technology. The electronics and software of the prototype were developed using multi-agent. The system has be designed using JADE. We have also preliminarily assessed its detection performance.

Acknowledgment

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