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IOT-based and Auto Firmware System for Transmitting Notifications and Advertisements via GSM/GPRS Modems

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Abstract

Recently, it has been a kind of trend that many applications adopt IOT-based SMS services for delivering notifications and advertisements (i.e. ads) to their users. As a result, we are mobilized to design and develop a GSM-based system within this paper to send alerts and ads in our faculty community as SMS messages. This system is called "NATEGA" as an abbreviation of "Naïve and Auto firmware for Transmitting Exam Grades and Advertisement via SMS messages". The Hardware part of NATEGA system consists of three main modules; GSM/GPRS Module (GGM), USB-to-TTL bridge Module (UTM), and DC-to-DC Converter Module (DDC). Any PC or laptop can be employed for execution of the NATEGA program (i.e. software part) which is developed in C# programming language. The efforts, that have taken place intentionally during design of NATEGA system, led to support both Push paradigm and Pull paradigm concepts in sending notifications and ads. Four performance metrics are used to validate and verify the feasibility of NATEGA system. They are Message Construction Time (MCT), Message-to-Modem Delivering Time (MMDT), SMS Delivery Report Time (SDRT), and Success in Delivering SMS Ratio (SDSR). Time-based metrics (MCT, MMDT, and SDRT) are chosen for evaluation because the provision of timely information is imperative for applications of delivering notifications and ads.

Keywords: IOT-based GSM Network ; SMS-based notifications ; M-Educational Services; ATCommand ; Result Alerts system;.

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1. Introduction

Nowadays, we are living in the realm of information and technology. Continuous and ever-increasing development, in such realm, lead to a plethora of electronic devices and services that can be used to exchange information with users such as computers, mobile phones, Internet, and so on. One of these services is delivering notifications and advertisements into personal devices of real or prospective users or customers about a specific product(s) or service(s). When notifications pertain to emergency, warning, or security contexts, they should be delivered without any delay and personally to its dedicated users. There are many ways for delivering notifications and ads to users, which depend on technological medium for transferring and displaying them such as:

- Notifications and ads over voice calls or messages on wired or wireless phones.
- Displaying such notifications and ads on websites.
- Hotline services.
- Notifications and ads over TV channels, Radio stations, big LED Screens.
- Notifications and ads over Short Message Service (SMS) or Multimedia Message Service (MMC) via GSM operators.
- Notifications and ads via emails.
- Notifications and ads via android apps or IOS apps.

Generally, There are two main paradigms that regulate delivering notifications and ads systems [1]: Push paradigm and Pull paradigm. Push paradigm related to send notifications or ads in a unidirectional manner from a service provider or a brand to users. The role of the user, in this case, is only receiving notifications or ads with or without his permission. Typically, push paradigm is better for companies who have an established relationship with users who have granted permissions to receive such notifications or ads. This is referred to as permission-based marketing [2]. All seven ways of delivering notifications and ads, that are listed previously, can be considered a push paradigm.

In pull paradigm, the role of the user is completely different from his role in push paradigm. Firstly, a user should send a formatted request for a specific notification or feedback information from its related provider or company. After that, this provider or company prepares the required response notification and resend it to this user. For example, a student can get his grades if he firstly sends a request including some information such as his academic ID, name, or etc. sending request from the user implies his agreement to receive such notifications. Pull paradigm is most suitable for merchants with simple time-limited and location-related notifications or ads.

In the last ten years, we are witnessing an outstanding pervasion of using mobile phones. As a result, mobile phones become unavoidable and close-fitting part of any user. This adhesion, between users and mobile phones, is the main incentive for preferring to send notifications and ads via websites, emails, or SMS (or MMS). The aforementioned three technologies (i.e. websites, emails, and SMS) are beneficial to support the concept of push

paradigm in the dissemination of notifications, ads, promotions, news, monitoring status of sensor-based systems.

Coupling, between the pull paradigm and each one of website technology or email technology, entails difficulties and constraints, especially when using these technologies for controlling and management of distributed measurements and control systems (DMCS). DMCS is a system that consists of sensors and actuator, so the user of such systems needs to be notified with sensor measurements immediately and to have the ability to send commands (i.e. requests) to control actuators in such systems. Difficulties and constraints of coupling pull paradigm with websites or emails are listed below:

1) Using websites or emails entails the need for internet access.
2) Users should have to be present physically on the spot in many application scenarios.
3) Skimming of user commands or requests, from text in such structured documents (i.e. websites or emails), requires employing special and complicated parsing algorithms

Currently, it is a kind of trend that systems of delivering notifications and ads adopt SMS or MMS technology as an alternative from websites or emails. SMS service has been proven very popular among the users of mobile phones whether they are smartphones or not. In addition, mobile operators still support SMS or MMS services up to now. There are many reasons for preferring to employ SMS technology rather than websites and emails. They are listed as follows:-

1) SMS or MMS offers a straight forward and efficient way for delivering notification, ads, or commands to any user while on the move at any time and any where without the need to access internet.
2) SMS is a text message with maximum characters length which equals only to 160 characters. As a result, commands, in case of DMCS, can be skimmed by using a simple parser or by dividing SMS text (i.e. 160 characters) to words.
3) SMS is often characterized as a "Killer-Application". This means that SMS messages can penetrate mobile phone of user and stop immediately application to notify him with its contents.
4) SMS-based notifications and ads supports both push and pull paradigms.
5) Availability of many mobile operators in each country with a tailored infrastructure that provide wireless coverage area for distances of kilometers.

Recently, SMS-based notifications and ads system can be applied in many applications such as healthcare, information technology, schools and universities, financial institutions like banks, and/or customer services. The main purpose of this paper is designing and developing a GSM gateway appliance to be employed as SMS-based notifications and ads system in m-Educational institutions such as schools and universities which is named "NATEGA". NATEGA is a HW/SW solution that employed to send student results as SMS Messages. This system allows a user to send all student results within a specific result excel sheet (RES) file in a push manner. Also, it has the ability to receive an only SMS request from any student and then prepare his private result and re-send it only to him which refers to support pull manner.

In addition, the NATEGA system can be used as an SMS-based advertisement solution by sending only one SMS-based content to one or multiple recipients in the realm of Mobile Educational (i.e. m-Educational).

2. Structure

The outline of this paper is as follows: Section 3 presents briefly the related work and some of commonly proposed prototypes about SMS-based Notifications and Ads systems within different applications. A detailed description, about components of our proposed NATEGA system, is presented in section 4 including HW/SW solutions of such our system. The practical experiment setup and performance evaluation of such proposed NATEGA system are shown in section 5. Finally, a conclusion is briefly described in section .6

3. Related work

This section is devoted to give a survey about commonly proposed prototypes and frameworks of SMS-based notifications and ads systems (SMS-NAS).

O. Olamide et al [3], presented a pull-based Result Alert System (RAS) with emails and SMS. Firstly, a student sends an SMS to a specific number of the SIM card which embedded into a GSM modem. Student should send required information within SMS message such as full name, metric number department, semester and session, to meet regulations of Bells University of technology. Paper does not mention how this information are formatted. After that, RAS validate student's information according to a pre-saved database which is designed using MYSQL server. If the student is found in the database, RAS prepares a feedback SMS message to the student including his required result. In addition, RAS sends an email to the student as another notification. Performance feasibility of RAS is not included in this paper, such as efficiency, accuracy of delivering results, time consumed to deliver such results, and so on. In addition, many development information about RAS system is missed such as type of GSM modem, parsing algorithms used to divide SMS text that received from student, design of database, algorithms that used to compose both feedback SMS and email messages.

L. Boukas et al. [4] designed an SMS-oriented m-informational system for educational realm and they called it "Pandora" system. The salient goal of pandora system is enhancing the quality and the diversity of services of pandora are classified into three main categories: administrative, informative, and academic services of Pandora. These services are classified into three main categories; administrative, informative, and academic. In order to benefit of pandora services, candidate users must subscribe to pandora via its website which means that this user gives permission to pandora to send SMS notifications. Pandora system can be viewed that it supports both pull and push paradigms. It allows candidate users to send SMS-based and simple structured command. Each command has its own syntax and each user must follow this syntax. Any command syntax consists of three letters code and its arguments to reduce complexity and to obey the law of maximum length of any SMS message (i.e. 160 English characters). for example, when the student registers for a specific course, he should send SMS with syntax "REG username password List(course codes)". Username and

password are the stored ones in pandora system for such user. List contains one or more courses codes. Many other commands syntaxes are included in L. Boukas et al [4]. Although, formatted commands syntax, in pandora, facilitates parsing process to extract them from received SMS text, users are forced to remember and comply with syntax of each command when writing it and this is a tedious process. Also, pandora supports push paradigm when it sends informative SMS-based notifications about weather, news, boarding house's time table, and so on. In addition, pandora offers the possibility to send email messages to their subscribers. Architecture of pandora consists of database server, web server, and pandora's box firmware. Database tables are designed and developed in MySQL version 4.1.1. web server is responsible of managing all activities in pandora web page and enrich pandora database with fresh information such as news, weather, and etc. such information is extracted from other websites' RSS feed files.

Pandora's box firmware contains Nokia 32 GSM modem with PBX connectivity terminal. This modem supports ATcommand technology and it is connected to pandora host PC via RS232 communication. Driving program of Nokia 32 GSM modem is developed using Java programming language. Paper of pandora system [4] presented a detailed and densely description of its components, pseudo code of each task, SMS-based services, pandora kernel, and many other development issues. However thus, paper of pandora does not include performance evaluation criteria.

S. Biswas et el. [5] presented SMS-based information retrieval system which is designed especially for the users with low-end mobile devices in educational realm. The aim of this system is giving the ability to users (students) to search about specific information by sending a formatted query about this information via SMS message to the system. If the system hits required information in its local database, it will prepare a response SMS-message and resend it to the user. If required information is not found in its local database, the system searches about it on other websites such as Wikipedia, search engines, and RSS feed aggregators. After that, it extracts required feedback information by using Nano XML parser and then it prepares a feedback SMS message to be sent to user. To sum up, this system gives the ability to some of low-end mobile users to use SMS technology for searching about specific information on websites and search engines such as Wikipedia, Google Define (i.e. SOAP API services), however they cannot access them because low-end mobiles cannot access internet. Authors of this paper employ Java programming language during development process of database server, parsing algorithms, and connection serially with GSM modem. They do not mention type of GSM modem that employed. Performance evaluation within this system is not adequate. It is clear that system in S. Biswas et al. [5] can be considered a pull-based system.

The system designed in F. Givehki et al. [6] is an obvious example of employing SMS notifications in IT applications. F. Givehki et al. [6] presented a SMS-based system for controlling, management, and monitoring of computer and telecommunication networks via employing SNMP protocol. SNMP (Simple Management Network Protocol) is used to collect information about connection status or failure of any network's component via GET messages or control components that participate in a network via SET messages. Network administrator in such system can receive SMS notification in push-based paradigm manner. In addition, network administrator can send his/her commands to control and alter status of specific

components in a network via SMS and get a SMS-based feedback as a response if his/her commands are executed. This means that this system supports pull-based paradigm. SMS notifications are sent/received via ATcommand technology of GSM modem, but authors do not mention its type. The aim of this system is to enable network administrator of instantly recovering and troubleshooting failures on a network to prolong as much as possible the useful lifetime of the network without the need of internet access or enforcing network administrator to be present physically on the spot. Performance evaluation included in this paper is closely related to measuring performance of network itself rather than verifying performance of SMS messages exchange process. It is noticed also that the system within this paper deals with few users (i.e. network administrators) or may be one user. As a result, authorization is performed by checking telephone number or the community name that escorted within his SMS message.

In recent years, many proposals and researches inaugurate employing SMS notifications in healthcare of humans or in some researches for animals. They called this field of research as mobile healthcare (m-healthcare). C. S. Evangeline et al. [7] proposed and designed a human health monitoring system (HHMS) which helps in improving diagnostics at an earlier stage or monitoring various health parameters of a patient during his recovery period without the need to visit hospitals. This article surveyed literature that related to the same topic. Diversity of health parameters are measured in this paper such as temperature, heart rate, SPO2, fall, and location of the person via wearable sensors like LM35 (for temperature), MAX 30100 (for heart rate and SPO2), triple axis accelerometer ADXL 335 (for fall), and GPS module with NEMA standards (for location). Authors employed a 32-bit microcontroller (LPC 2148) to collect and process these parameters. The output of such system is received as an alert SMS message along with the person's location to the caregiver when the person's condition is critical. This SMS-based alert notification is sent via employing SIM 300 GSM module. In addition, all these health parameters are displayed on IOT-based website called Thingspeak by sending them via Wi-Fi module ESP 8266. With commensurate to beforehand description of this system, we can consider SMS notification of m-health application is complying with push paradigm because notification flow is unidirectional from patient to caregiver.

Moreover, SMS notifications is extended to monitor and diagnose animal diseases as described in J. L. Raheja et al. [8]. The authors presented a remote system for diagnosing animal disease to aid the farm-manager (owner) in restricting the spread of disease in the flock and initiating treatment at early stage anywhere and anytime without the need to go to hospitals continuously. This application is provided in three forms: mobile version, desktop version, and website version. Mobile and website versions are employed to provide all remote services to both animal's owners and doctors. Desktop version are dedicated to doctors for analyzing the animal's symptoms for detecting disease and its level using fuzzy-based DSS. One of the important services in this application is exchanging SMS messages to assist the remote user of getting various remote services. There are four types of SMS messages. The first one is scheduled SMS which enables user of getting medical prescriptions with the timing to take medicine. The second type is an appointment SMS which enables the users to send SMS to a special doctor for reserving an appointment to check animal. If the doctor accepts to determine an appointment, he will send a confirmation to user or send a rejection SMS message. The system will send a reminder SMS message to the user about the appointment

before its time. The third type is alert SMS that the system sends it to a user as alert message for new disease in a specific city or alerts about new hospitals, medical shops in his area, and so on. The last type of SMS is "Search SMS" which related to give the user the ability to send SMS to system to search about available hospitals, medical shops, or doctors in his area. The system will replay with a feedback SMS containing all information needed. The authors called the feature of four SMS types as "Dr-SMS". Dr-SMS can be considered a mixture of pull and push paradigms. For example, alert SMS and scheduled SMS type are push paradigm, while appointment and search SMS are considered pull paradigm. Database of such application is developed using MySQL. Mobile application and server (desktop) version are implemented in Java while website version is developed using PHP scripting language. This article does not mention type of GSM modem that used or presents any performance evaluation results.

SMS notification techniques become a concern in recent literature of remote monitoring, metering, and controlling of energy and electricity. A. Rashdi et al.[9] presented a comprehensive SMS-based system for automatic meter reading (AMR) and Energy Profiling System (EPS) to assist any electric supply company from effective collection of energy consumption information and its analysis for accurate billing. A. Rashdi et al.[9] employed a GSM module SIM 548C to send electricity consumption data that attained from single phase digital energy meter A238 (that manufactured by Microtech industries in Pakistan) as SMS-based and GPRS-based notification messages to a server over a predefined definite time intervals (i.e. push SMS-based paradigm). The server has the ability to pull consumption data at any time by sending and update reading (UPD_READ) message to trigger consumer digital meter for sending a response message (i.e. pull SMS-based paradigm). The server has a C#-based application that receives one SMS message at a time and it extracts the consumer number and energy reading and then use them to update its database for each consumer. Database of such server is maintained using MySQL. In addition, a website was developed in PHP scripting language with the purpose to generate energy profiles of users and to facilitates displaying user records, energy consumptions, and billing information. Authors of such paper does not mention the benefit of using GPRS technology that they employed and how data is sent via GPRS. In addition, performance evaluation, development description, and parsing algorithms of SMS are missed. It is noticed that digital meter at consumer side send SMS message to only one SIM number of server which means that the data transmitted is secured. SIM 548C GSM module is derived via simple 8052 microcontroller that is responsible of measuring consumption reading and formulate its SMS message to be transmitted to server.

M. Jalilian et al. [11] presented a GSM-based monitoring and control system and control system for tap changer of the distribution transformers. This system consists of many sensors that are tangent to transformer for measuring its parameters such as temperature, humidity, silicon gel color, Buchholz relay status, the status of input and output phases, the current flow in each phase, and power of each phase. Authors employed Atmega 128 microcontroller to collect all these parameters. Atmega 128 microcontroller is connected serially to a GSM modem (SIM 900 type) to send an SMS-based notification when these parameters exceed the permitted level to another GSM modem which connected to control center. There is no any description about how control center can send SMS-based control messages to transformer, so, we can consider SMS-based notification system in this paper is push paradigm. a GUI-based application is developed at the side of control center by using Visual Basic

programming language and this paper provides flowcharts about development process. This paper is supported with a practical prototype of monitoring and controlling system. Similarly to any distributed monitoring and controlling system (DMCS), SMS-based notifications in this paper are exchanged between few GSM-based users. Performance evaluation included is closely related to parameters measurement of transformer itself.

4. Components of NATEGA System

Architecture of NATEGA system consists of two parts: hardware part and PC-based software part. Hardware part consists of three main hardware components; GSM/GPRS Module (GGM), DC-to-DC Converter module (DDC), and USB-to-TTL bridge Module (UTM). The testbed that aggregates all these hardware components, is shown in fig. 1.

4.1. GSM/GPRS Module (GGM)

SIM800L GSM/GPRS modem [11] is employed within NATEGA system due to many reasons such as small footprint, low cost (i.e. it costs 2.5$), simple UART interface which facilitates connecting it directly to any terminal (microcontroller or PC) via suitable converters such as UTM, or RS232 converters. SIM800L modem supports employing GSM standard protocols for handling activities and voice calls and SMS (short message service) exchange using quad band frequencies (850, 950, 1800, 1900 MHZ). In addition, SIM800L modem supports applying GPRS protocol in sending and receiving data packets vis cellular network infrastructure. Employing GPRS expands functionality of these tinny modems to exchange data remotely with different and current technologies such as emails, Internet of Things (IOT), cloud computing platforms, and so on.

AT command technique is used to access different functions and tasks of SIM800L [12]. ATcommand technology refers to that any terminal device is able of accessing a function by sending a string-based command to SIM800L modem. After executing such function, the modem will replay by another string-based response. Response of SIM800L is an indication if the command is executed successfully or not. The operation of SIM800L modem requires putting a micro-type SIM card (Subscriber Identity Module) into its socket just like mobile phones to access connectivity and to identify the modem to a cellular network. It means that any GSM/GPRS modem should have its own IMEI number which is stored in SIM card similar to mobile phones for this identifications. IMEI refers to International Mobile Equipment Identity.

Specifications of SIM800L is shown in table 1 [12]. It is notices from table 1 that SIM800L operates by providing typical power voltage equals 4 volts and its power current can reach to 2 Amperes (2000 mA) during GSM/GPRS data transmission.

4.2. USB-to-TTL bridge Module (UTM)

USB-to-TTL bridge Module (UTM) is a miniature and pre-manufactured SOC chip that is used to convert USB data signals to standard TTL levels of serial port data and vice versa. UTMs enable the direct interfacing between PC and any UART-based apparatus or modules such as microcontrollers, GSM/GPRS modules, Wi-Fi modules, Bluetooth modules, Zigbee modules, and/or different USRT-based sensors and actuators. In this paper, we employ a cable based UTM board kit which employs CP21XX SOC chip [13] as shown in fig. 2. A software

driver of CP21XX should be installed manually on PC operating system such as windows to make PC able of detecting and processing data signals from/to such CP21X-based UTM.

When CP21XX UTM board Kit is connected to PC via a USB port, its pre-installed driver on PC creates a virtual COM port which shows up in device manager on windows. This virtual COM port can be accessed and used as if it was a built-in physical serial COM port. As shown in fig. 2, TXD and RXD pins are connected to corresponding pins to enable serial communication with any UART-based apparatus. In addition, CP21XX UTM outputs 5 V, 3.3 V, and Ground on other pins. Maximum output current of these voltages is 500 mA (i.e. 0.5 A). these output voltage pins provide sufficient power voltage source for operation of some UART-based apparatus. In case of SIM800L modem, these voltage sources should be modified from 5 V to 4 V and from 500 mA to 2000 mA to cope with the electrical specification requirements of SIM800L (refer to table 1).

4.3. DC-to-DC Converter Module (DDC)

As stated previously, the power voltage range of SIM 800L modem is from 3.8 V to 4.2 V. the recommended voltage is 4 V. During GSM or GPRS transmitting burst, the employed power supply must be able to provide sufficient current up to 2000 mA. Around this context, our aim is to employ 5V output voltage of CP21XX -based UTM (i.e. 5V with 500 mA) to provide power supply for SIM800L instead of using external power supply. Contributing to this issue, we are mobilized into implementing an electric circuit called DC-to-DC converter (DDC) which is mentioned in manual of SIM800L hardware design [14]. Schematic diagram of DDC is shown in fig. 3.

LM2596-adj chip is the most prominent component of DDC. The LM2596 simple switcher regulator is an easy-to-use, non-synchronous, and step-down DC-to-DC converter with a wide input voltage range up to 40V. The LM2596 series operates at a switching frequency of 150 KHZ [15]. LM2596-adj is capable of delivering up to 3A (i.e. 3000 mA) DC load current with excellent line and load regulation. LM2596 family requires few additional external components to output adjustable voltage as shown in schematic diagram in fig. 3.the role of variable resistor, in fig. 3, is determining and tuning the output voltage of LM2596 DC-to-DC regulator which is ranged from 1.23V to 37V according to applied input voltage. From example, if input voltage is 5V, so the output voltage can be ranged from 1.23V and up to only 5V according to the manual alteration of value of variable resistor.

4.4. PC-based Program of NATEGA System

As stated previously, NATEGA system supports sending students' results and advertisements in both push paradigm and pull paradigm especially in our university community. NATEGA system has been used in real by sending student results of all academic levels of the faculty of Electronic Engineering (FEE) – Menofia University as a case study. In FEE, the result sheets are organized and outputted in Excel files which is the only format that used to list these data in Arabic language. According to push paradigm of NATEGA system, two types of SMS-based notification can be sent to a group of students. The first type is Sending Result Alerts (SRA) for all students that included in a Result Excel Sheet (RES) file. The second type is Sending Advertisements (SAV) to one student or a group of them.

4.4.1. Sending Result Alerts (SRA) Panel

Fig. 4 shows the window form that designed and employed to send a result notification for each student. First of all, COM port, that will be dedicated to UTM module, should be selected. When a user presses a "Push" button, a window panel will appear. In this panel, a user should provide some information (i.e. column positions) about the prospective loaded RES file. For example, a a user will write column number in each textbox that placed near of Acd Number (i.e. ID of student), name, case, and phone number of push panel.in addition, push panel provide a grid of text box components along side name of "subject" which is shown as pairs for each course. The first textbox of such pair must be filled with course name that a user wants to be shown within SMS message, while corresponding column number, of such course in RES file, should be putted in the second textbox of this pair. All courses pairs (i.e. courses names and their corresponding columns numbers) should be filled before pressing "Enter" button which will show another window dialogue to browse and load the required RES file from any location in PC. Fig. 5 shows how courses names and their corresponding columns are filled to prepare sending result alerts to 3rd academic level of our faculty FEE. A sample of RES file of such 3rd level students is shown in fig. 6.

The next step is pressing "Send to all" button to perform repeatedly many tasks for each row in RES file. The first task is extracting courses grades, ID, name, case, and phone number from their corresponding columns of loaded and pre-opened RES file. The second task is constructing only one string that contains all these data besides courses names and grades. Finally, this one string and phone number are sent to GGM according to ATcommand format that is shown in fig. 7 to enforce this GGM to send it as SMS message via GSM network operator. The previous tasks will be repeated for each row until finishing all rows of loaded RES file. It is noticed from the previous description, that SMS content will be changed for each row. If the user wants to load another RES file with different data (i.e. courses names with different columns numbers), he can simply press "Reset" button to refill all previous textboxes with the new required data.

We intended to design push panel as it is shown in fig. 4 to allow the user of the dynamic usage of such panel in case of determining courses names and their columns positions for each RES file when pushing results for different academic levels. In our regional universities (which include different faculties and departments with different academic syllabuses), RES files are produces differently according to syllabuses of each level and according to how administrators output them.

4.4.2. Sending Advertisements (SAV) Panel

Sending Advertisements (SAV) methodology refers to sending the same ads-based SMS message to many students and or employees. SAV window panel will be displayed as soon as a user press "Send" button as shown in fig. 8. Some preparation steps are required before the actual sending of ads-based SMS. First of all, the user should determine how phone numbers of multiple recipients will be provided to SAV. Panel of SAV provides two choices; Get phone numbers from an excel sheet or user can enter recipients' phone numbers manually.

As soon as, the user selects "Get numbers from Excel" choice, two textbox components are displayed as shown in fig. 8. The user should fill advertisement context in the first textbox and put column position of recipients' phone numbers, that will be loaded from the prospective excel sheet, in the second textbox. In this case, excel sheet includes only phone numbers of

recipients. As soon as, "SEND" button is pressed, a window dialogue will be displayed to browse and load the required excel sheet from its locations in PC. The same ads-based message will be sent to each recipient by sending the ATcommand sequence as shown in fig. 9. "AT+CMGW" command will be used according to its format in fig. 9 to enforce SIM800L of storing SMS context in its SMS-memory storage area. As a result, executing "AT+CMGW" command, SIM800L modem will send back a replay containing memory location number of such stored SMS context. SAV will extract this location number of the replay and will put it within "AT+CMSS" command according to its format that is shown in fig. 9 For each recipient's phone number. Using "AT+CMSS" command facilitates broadcasting the same ads-based SMS message to all recipients without the need to repeat sending the same SMS context to SIM800L modem as described in SRA.

The SAV panel will slightly differ when user selects "Enter number manually" choice. Textbox of advertisement context will remain on panel as it is. Another textbox will be displayed to be filled with phone number manually by the user for each recipient as soon as the user press "Add Recipient" button. Each manually-entered phone number will be added and stored inside internal array of SAV panel. The user can preview all stored phone numbers by pressing "Recipients" button.

4.4.3. Read Panel

An extra panel is designed to read and display a group of stored SMS messages from their dedicated memory area of SIM800L modem when a user press "Read" button. Read panel provides five choices for user to select freely and read a group of SMS messages with the same status. For example, if "ALL" choice is selected , it means that read panel will send the ATcommand (AT+CMGL = "ALL") to read all SMS messages and return back and display them in a list format for the user. ATcommand "AT+CMGL" is employed to read status-based group of SMS messages. Table 2 depicts different formats of "AT+CMGL" command that can be used to read such groups of SMS messages.

It is noticed from table 2 that type of each SMS group is determined according to its accompanied parameter such as "ALL", "REC READ", "REC UNREAD", "STO SENT", or "STO UNSENT" [12]. SIM800L modem will execute "AT+CMGL" and will respond by returning collection of SMS messages that are similar in their status according the accompanied parameter. For example, it will return received and read SMS messages if the parameter is "REC READ". When "STO SENT" is used, it will return stored and actually sent SMS messages, and so on.

5. Performance Evaluation of NATEGA

5.1. Experiments setup of NATEGA

In order to verify the feasibility of NATEGA system, modules of a GGM, a UTM, and a DDC are soldered in one PCB-based test bed. Two different SIM cards from Vodafone Egypt, and Etisalat Egypt (2G/3G/4G Network provider) are employed during experiments alternatively. A UTM in the form of cable is used to connect such test-bed to a laptop via USB 2.0 interface as shown in fig. 10. The employed laptop, with Pentium i3 core, 2.20 GHZ microprocessor, 4 GB RAM, and a windows 7 O.S, serves as the backbone platform for

running the program of push-based NATEGA system including SRA and SAV methodologies (i.e. panels). Push-based NATEGA program is developed in C# programming language using Microsoft Visual Studio 2017.

Four performance metrics are chosen for evaluation of NATEGA system. Three of them are time-based metrics because the provision of timely information is crucial in many applications. These metrics are as following:-

- **Message Construction Time (MCT)**: it is related to the consumed time for building and aggregating the required SMS message as one string which includes all courses grades of each student. Courses grades are collected by opening the RES file and picking grades from cells in each row.
- **Message-to-Modem Delivering Time (MMDT)**: it represents the elapsed time between sending pre-built SMS message to GGM module until receiving OK-based response from it. This OK-based response is considered as indication that GGM module receives required SMS message successfully from c#-based NATEGA program.
- **SMS Delivery Report Time (SDRT)**: it represents the elapsed time between actual sending of SMS message from GGM module to a recipient via mobile network provider until receiving a deliver status report. SMS delivery status report is an indication message that original SMS message is delivered to its recipient or not. It is sent back from SMS gateway center (SMSC) of network provider to the sender terminal. In order to activate the service of SMS delivery status, the developer needs to execute ATcommand in fig. 11 before sending each SMS message [12].
- **Success of Delivering SMS Ratio (SDSR)**: this ratio is used to evaluate the effectiveness of delivering result-based SMS messages to their recipients successfully. It represents the ratio between the number of SMS messages that delivered successfully with complete context (Ss), and the total number of SMS messages that actually sent via NATEGA system (Ts) according to equation 1. Each student is requested to send back a SMS-based response as indication if he receives his result SMS without any errors or not. Only OK-based response SMS messages are counted via NATEGA system to calculate Ss parameters. Ts parameter is found by counting each result SMS message that constructed and sent to GGM module.

$$SDSR\ (\%) = \frac{Ss}{Ts} * 100 \qquad (1)$$

5.2. Experimental Results

This section is devoted to shed light on experimental and practical results that collected during multiple real runs of NATEGA system. There are some parameters that are determined during these experiments. For example, default baud rate of GGM module is selected which equals 9600 bps (bits per seconds). This baud rate is important to regulate rate of transferring data between PC (i.e. NATEGA system) and firmware of GGM module. Five RES files are provided to NATEGA system which represent grades of five academic levels of FEE (faculty of Electronic Engineering – Menofia University) for academic year 2018/2019. All grades and information of such students are provided in Arabic language.

Number of students in first RES file is 50 students., in second RES is 100 students, third ones is 200 students, fourth one is 300 students, and last one is 400 students. Two SIM cards are used in different experiments from Vodafone and Etisalat network providers in Egypt.

According to 3G TS 27.005 standards of GSM-based network [16, 17], maximum number of English characters in any SMS message is restricted to 160 characters. in case of sending arabic-based SMS messages (i.e. Unicode SMS messages), maximum length of it will be 70 arabic characters. as a result, each constructed result message for each student will be divided automatically to 2- 4 real SMS messages during transmission of it. A delay time between sending two consecutive result messages should be used and it is chosen to be initially 30 seconds.

Figure 12 and 13 show practical results of MCT and MMDT measurements respectively when using different size-based RES files. It is noticed that increasing in number of students causes slight increasing in MCT and MMDT. When size of applied RES file is 50 students, MCT is 0.223 sec. when number of students becomes 400, MCT becomes 0.397 sec. as stated previously, process of message construction is repeated by opening, picking required data and constructing its equivalent one string message, and closing RES file for each student (i.e. for each row in RES file). This beforehand repetition with large RES file is the reason behind MCT increasing from 0.223 sec to 0.397 sec.

The same syndications are noticed during analysis of fig. 13. Also, MMDT increases slightly and linearly as number of students are increased. MMDT increases from 0.825 sec to 1.127 sec when applying RES files with size 50 students and 400 students respectively. MMDT is started to be measured directly after constructing each string-based message by sending it to SIM800L modem until receiving OK response from such modem. As a result, it is normal that MMDT time measurements is larger than MCT measurements. Timely information of MMDT depends on consumed time intervals for handling and bidirectional serial transmission of each constructed message and OK response between employed PC or laptop (i.e. NATEGA program) and firmware of SIM800L modem.

During averaging measurements of SDRT, we noticed that the majority of SMS messages are delivered to their recipients in range of few seconds as shown in fig. 14. When using Vodafone SIM card, SDRT ranges from 2.6 sec to 3.9 sec as a result of increasing number of students. In addition, using Etisalat SIM card causes SDRT to ranges from 2.8 sec to 4.3 sec. SDRT measurements in case of using Vodafone or Etisalat SIM cards are tightly closed to each other. We think that slight difference may be referenced to HW/SW infrastructure capabilities which employed in each network provider. Also, we noticed that few SMS messages consumed long time intervals until their arrival to their recipients. These long time intervals reach sometimes up to 1 day because some mobile phones of recipients are turned off or not available on network. We are enforced to discard these abnormal results of SDRT to make other results consistent.

SDSR performance results versus number of students are shown in fig. 15 which depicts the success of SMS arrival to their recipients correctly and completely without any errors. To achieve such SDSR results, value of an important parameters should be realized, this parameter is strength of signal connectivity between SIM800L and network provider and we make sure that it reaches to 90%. Signal strength is found by executing ATcommand "AT+CSQ" on GGM and convert the returned value to percentage ratio and show it on NATEGA program. It is noticed from fig. 15 that SDSR is the best at small number of students

(i.e. RES file with 50 student) because SDSR equals 84%. SDSR is decreased linearly as number of students is increased until SDSR equals 66% at number of students equals 400.

Degradation of SDSR performance metric can be referenced to many reasons such as status of recipient's phone number if it is turned off, not available, or not. Also, security and routing protocols. That SMSC of network provider use them are considered the other parameter of such degradation. These standard protocols are used to restrict high rate flooding of SMS messages from/to a single SIM card. All previous parameters are out of our control.

Our solution to minimize SDSR degradation is allowing the student to send an ERROR-based SMS message as confirmation instead of sending OK-based message. After that, when NATEGA system receives such ERROR confirmation SMS, it will extract student's phone number and will make some comparisons to reach to information of such student as ID, name, and so on. Finally, NATEGA program will prepare another result-based SMS message for the student and resend it to him again. The previous solution steps support our claim that NATEGA system is characterized as pull paradigm system.

6. Conclusion

This paper discusses and presents the design and the development of HW/SW system for sending results alerts or informational advertisements and announcements for all members in our faculty. We name this system as NATEGA "Naïve and Auto firmware for Transmitting Exam Grades and Advertisements vis SMS messages". NATEGA system is a custom-tailored tool to support and further improve of SMS-based distance services offered to the small-scale academic community using the style of push paradigm and/or pull paradigm.

For example, result data of students should be provided to NATEGA system in the form of excel sheets to be able of pushing all results to their owners' phone numbers. To achieve that, a C#-based program is developed and run on a PC or laptop to extract, prepare, and build each result (i.e. each row in excel sheet) to one string-based message. This one string-based message is sent to a GSM/GPRS modem (GGM) using standard ATcommands to be sent consequently to its recipients via GSM network provider such as Vodafone or etc. the main hardware component of NATEGA system is GGM which employed a SIM800L modem. SIM800L supports TTL-based serial pins but laptop, that run NATEGA program, is supported by USB ports. As a result, a USB-to-TTL converter Module (UTM) is mandatory to achieve interfacing and exchanging data between SIM800L modem and employed laptop. The efforts and design issues, that have taken place intentionally during developing panels of NATEGA program, led to its dynamic nature of dealing with different Result Excel Sheet (RES) files. These RES files may be outputted due to different academic syllabuses from different faculties and academic departments.

NATEGA system, including hardware and software parts, is investigated by running multiple practical experiments. These timely metrics are proposed and used for this investigation such as Message Construction Time (MCT), Message-to-Modem Delivering Time (MMDT), and SMS Delivery Report Time (SDRT). Average results of MCT ranges from 0.223 sec to 0.397 sec when the number of students ranges from 50 to 400 respectively. Similarly, MMDT ranges from 0.825 sec to 1.127 sec. MCT represents consumed time that required to construct one string-based message from each row in RES file. MMDT represents

all time intervals of transfer journey of this string-based message from NATEGA program to GGM until receiving OK response by NATEGA program.

The effectiveness of such NATEGA system is investigated by a comparison between number of SMS messages that successfully arrive to their recipients correctly and completely without ant errors and total number of SMS messages that sent from NATEGA program. This comparison is called SDSR (i.e. success of Delivering SMS Ratio). It is observed that SDSR ranges from 84% (when RES file contains data of 50 students) to 66% (when RES file contains data of 400 students). Each recipient (i.e. student) is requested to send a feedback OK-based or ERROR-based SMS message as indication if he/she receives his/her result successfully or not. NATEGA program is responsible of processing such feedback messages and counts OK-based confirmations.

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Table 1: Electrical specification of SIM800L Modem

Specification	**Value**			**Unit**
	Min	**Typical**	**Max**	
Voltage	**3.8**	**4.0**	**4.2**	**V**
Current (sleep mode)	**-**	**2.0**	**-**	**mA**
Current (idle mode)	**-**	**7.0**	**-**	**mA**
Current (GSM/GPRS transmission)	**350.0**	**-**	**2000.0**	**mA**
Working Temperature	**- 40.0**	**-**	**+85.0**	**C**

Table 2: different formats of "AT+CMGL" command

ATcommand	Description
AT+CMGL = "ALL"	Read **all** SMS messages from modem's memory area
AT+CMGL = "REC READ"	Read all SMS messages that are **received and actually read** from modem's memory area
AT+CMGL = " REC UNREAD "	Read all SMS messages that are **received but are not read** from modem's memory area
AT+CMGL = "STO SENT"	Read all SMS messages that are **stored and actually sent** from modem's memory area
AT+CMGL = " STO UNSENT "	Read all SMS messages that are **stored and are not sent** from modem's memory area

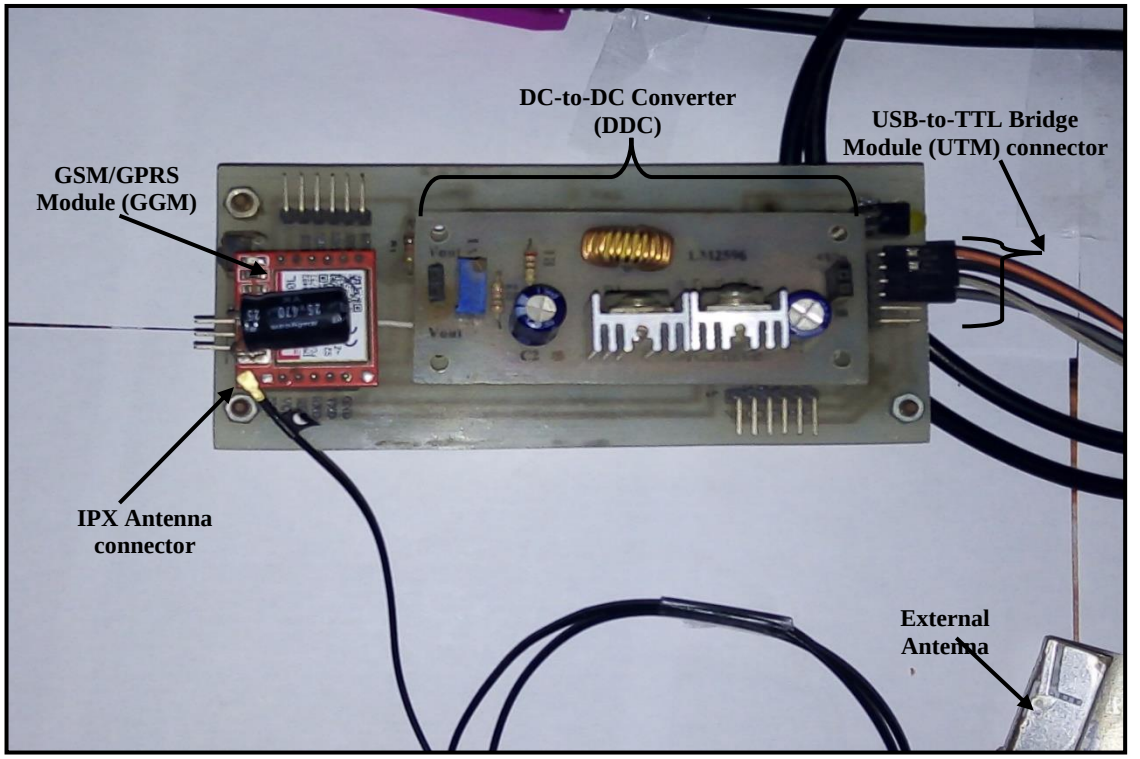

Fig. 1: Hardware Components of NATEGA system

Fig. 2: CP21xx-based UTM board kit.

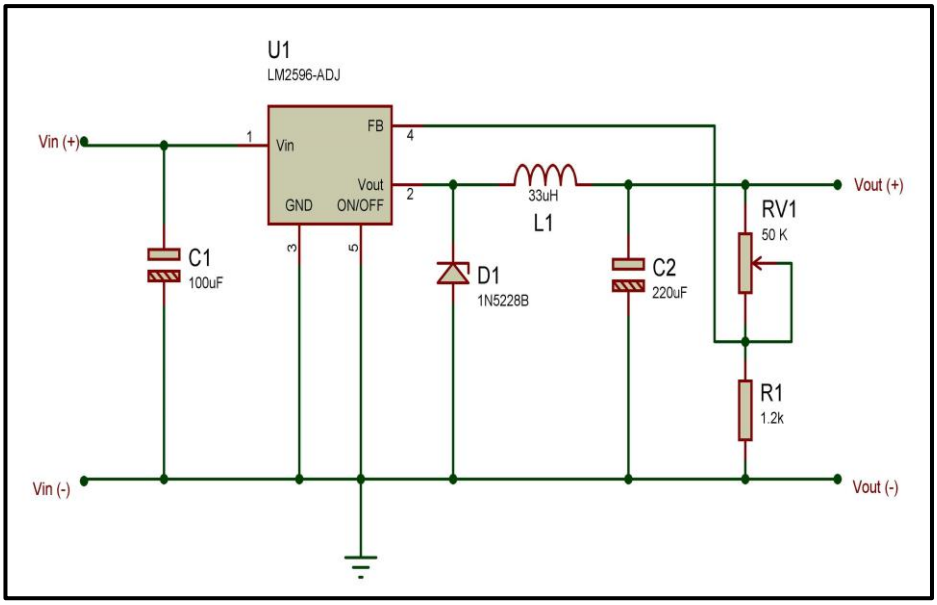

Fig. 3: Schematic diagram of DC-to-DC Converter Module (DDC)

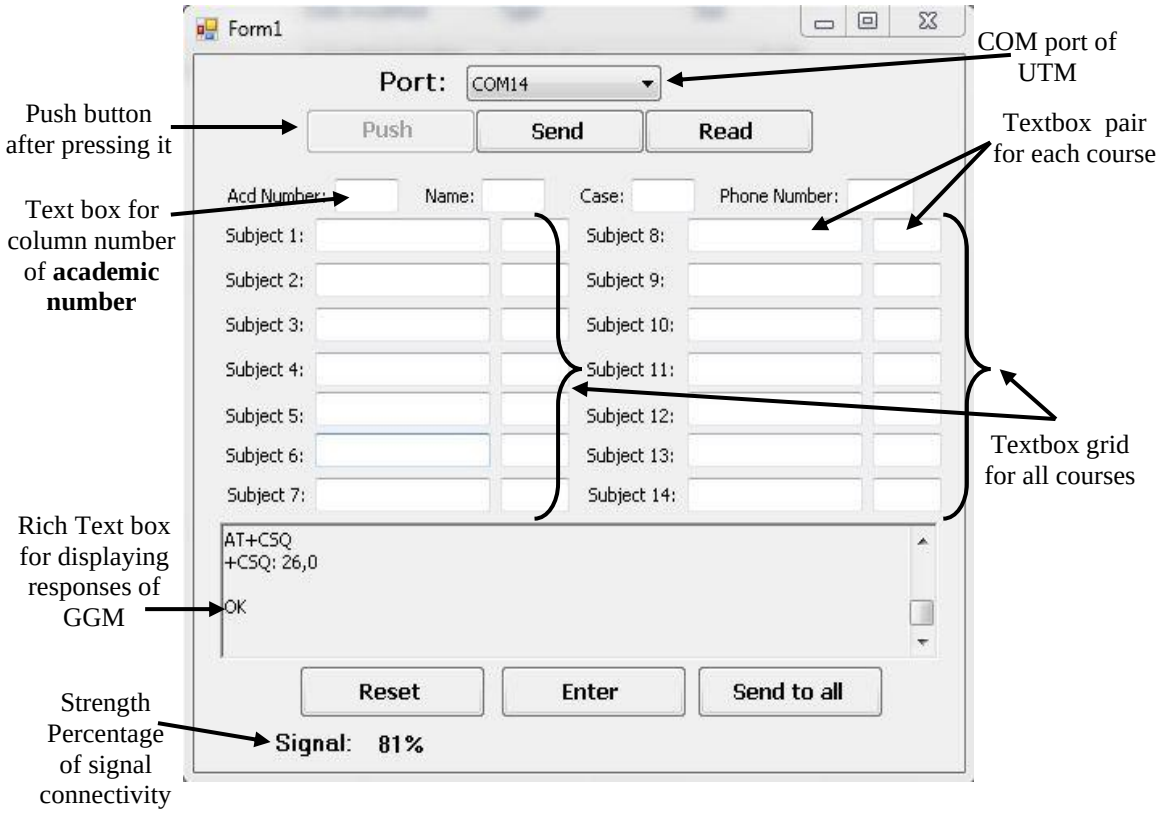

Fig. 4: Panel of Sending Result Alerts (SRA)

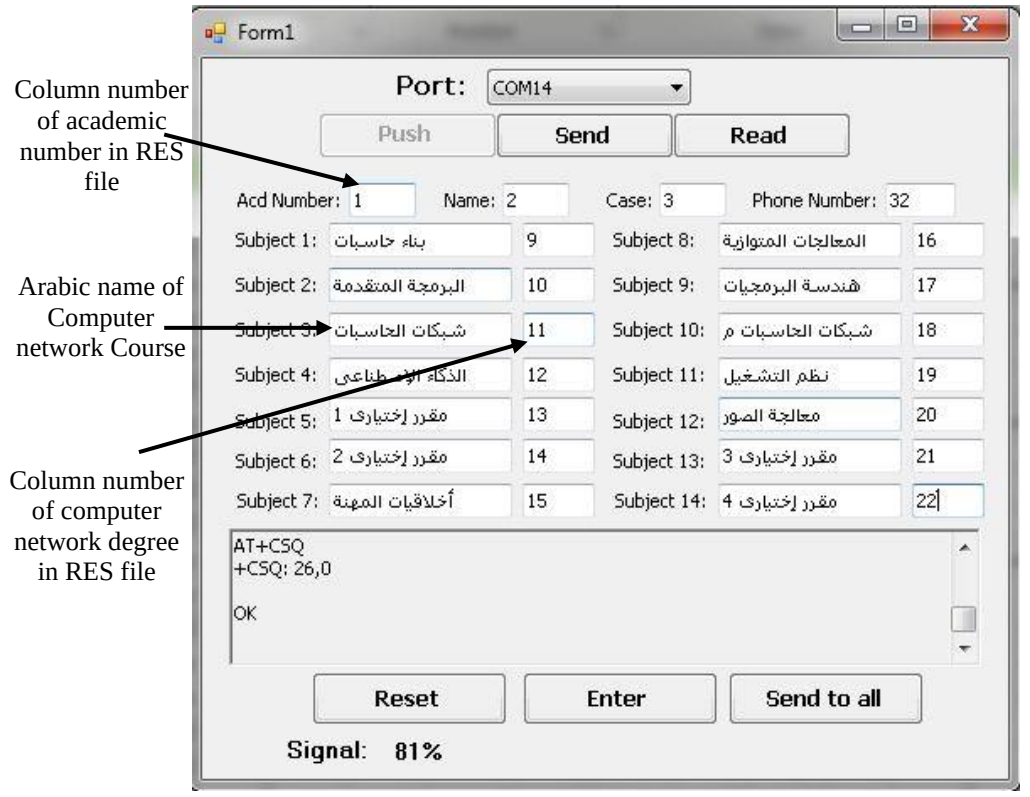

Fig. 5: Sample of filling courses names and their corresponding column numbers of 3rd academic level in FEE

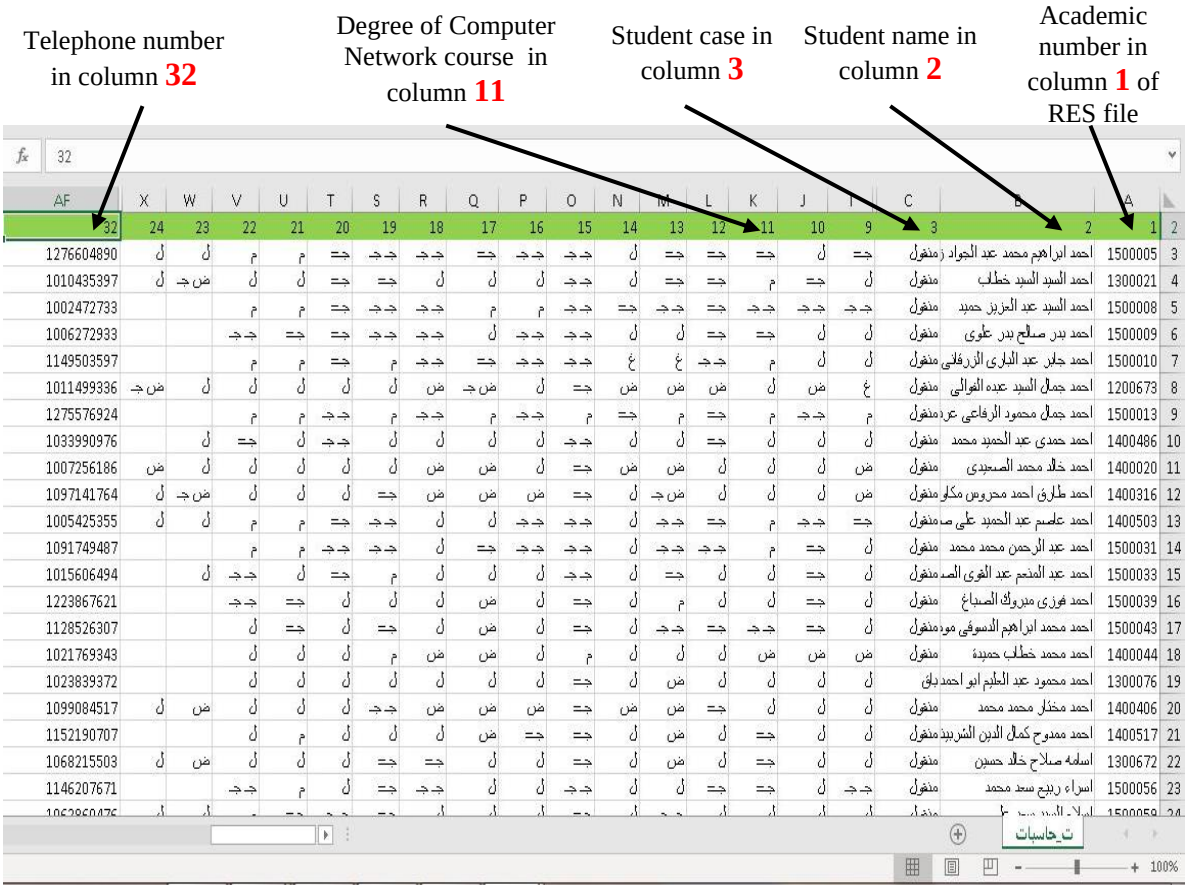

Fig. 6: Sample of RES file for 3rd academic level in FEE

AT+CMGS = " *Phone number* " <CR> *Message details* <CTRL+Z>

Example:

AT+CMGS = "+201093458458" <10> "This is an example to how write ATcommand for sending an SMS message" <26>

Note:

CR → refer to ascii code of "carriage return" and it equals **10** (decimal value)

CTRL+Z → refer to ascii code of "CTRL+Z" character and it equals **26** (decimal value)

Fig. 7: ATcommand format and examples for sending an SMS message via GGM

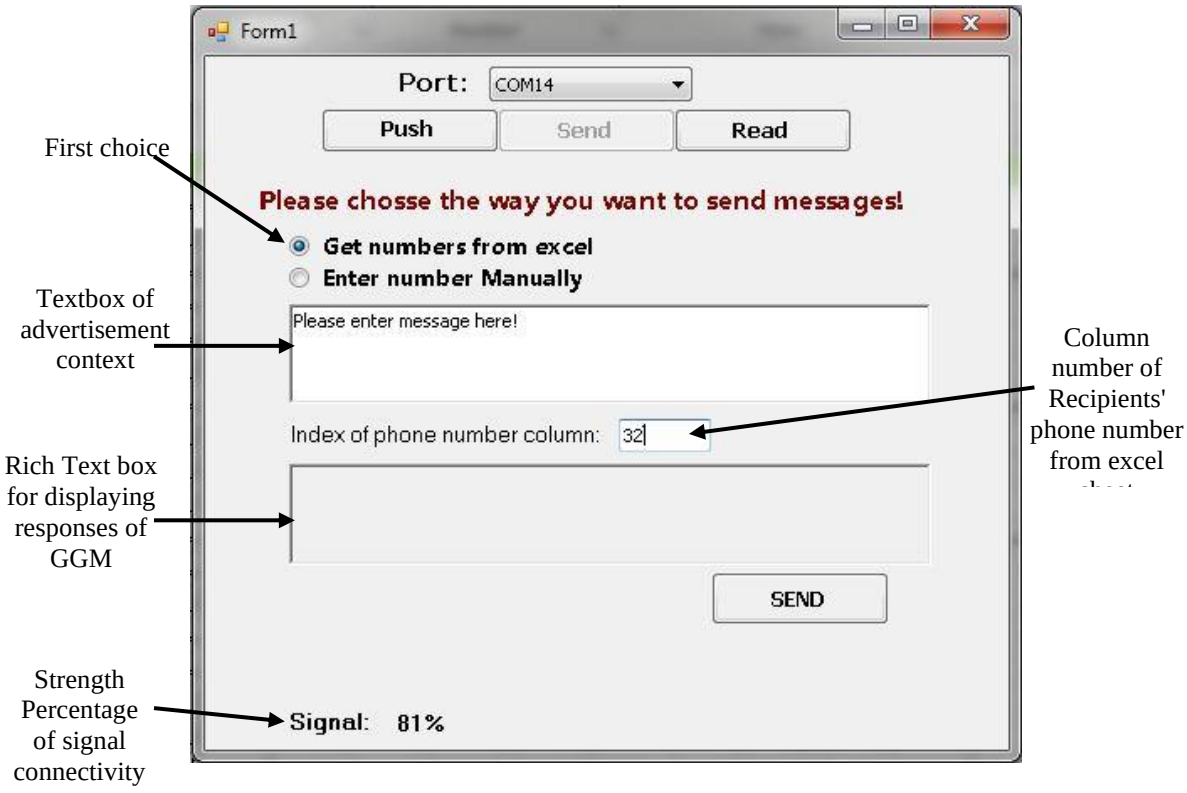

Fig. 8: Panel of Sending Advertisements (SAV)

AT+CMGW = " *Phone number* " <CR> *Message details* <CTRL+Z>

AT+CMSS = *Location number of Message in Memory [,* " *Phone number* "*]*

Example of sending AT+CMGW to Modem:

AT+CMGW = "+201093458458" <10> "This is an example to how write ATcommand for sending an SMS message" <26>

Response sample of executing AT+CMGW:

+CMGW : 15

Examples of sending AT+CMSS to Modem:

AT+CMSS = 15 // *it will send the previous message to phone number with CMGW command*

AT+CMSS = 15,"+201062153011" // *it will send the same message to another phone number*

AT+CMSS = 15,"+201285551391" // *it will send the same message to another phone number*

AT+CMGW = " *Phone number* " <CR> *Message details* <CTRL+Z> // format of CMGW

Example:

AT+CMGW = "+201093458458" <10> "This is an example to how write ATcommand for sending an SMS message" <26>

Response from GGM:

+CMGW=15 // it means that the message is sent to +201093458458 and this message is stored in memory location 15

AT+CMSS = *memory location index* , " *Phone number* " // format of CMSS

Example:

AT+CMSS = 15 , "*01062153011*"

AT+CMSS = 15 , "*01285551391*"

AT+CMSS = 15 , "*01580004321*"

……

and so on

Fig. 9: ATcommand format and examples for "AT+CMGW" and "AT+CMSS" commands

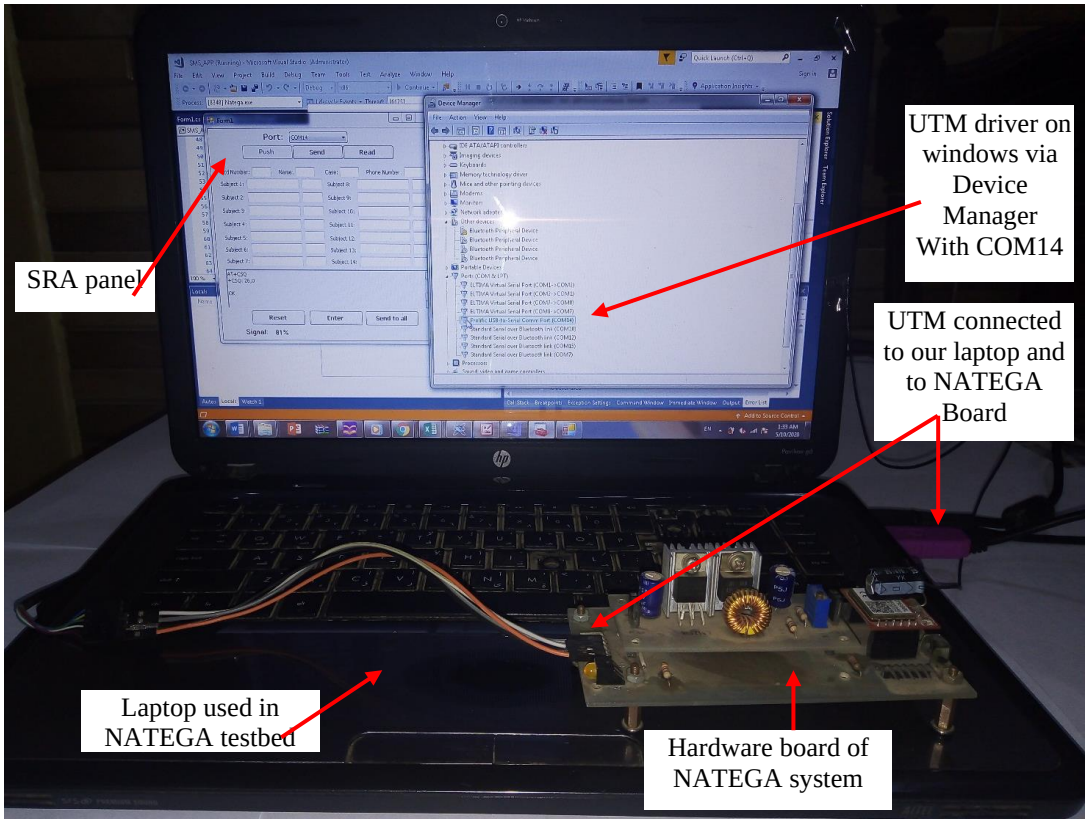

Fig. 10: Test-bed of NATEGA system

AT+CSMP = 49,167,0,0

AT+CNMI = 2,1,0,1,0

Fig. 11: ATcommands for activating the service of SMS delivery status

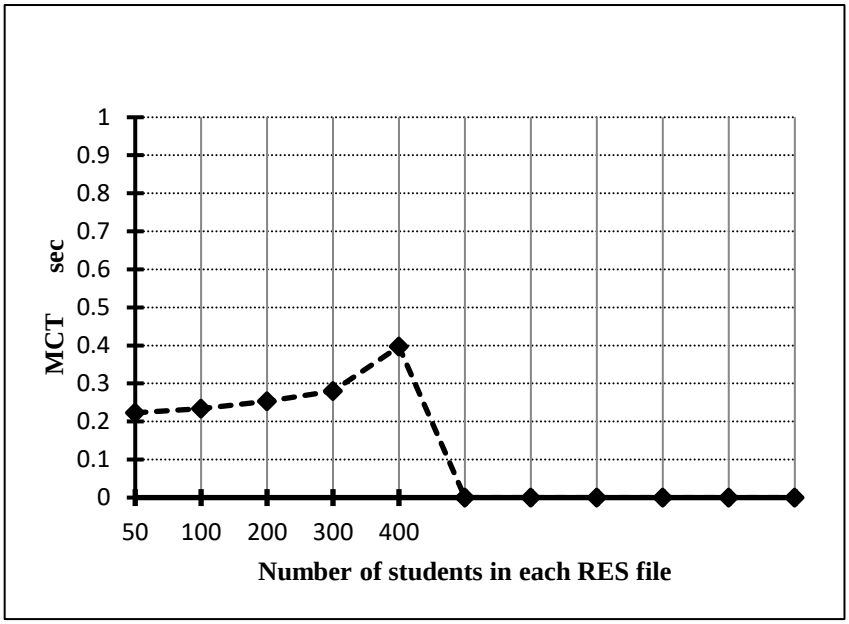

Fig. 12: MCT measurements versus number of students in each RES file

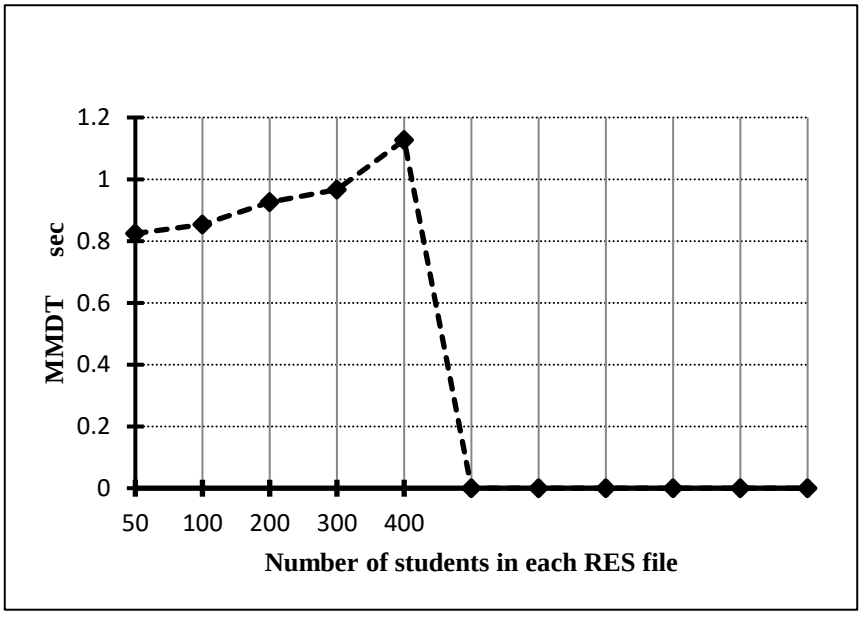

Fig. 13: MMDT measurements versus number of students in each RES file

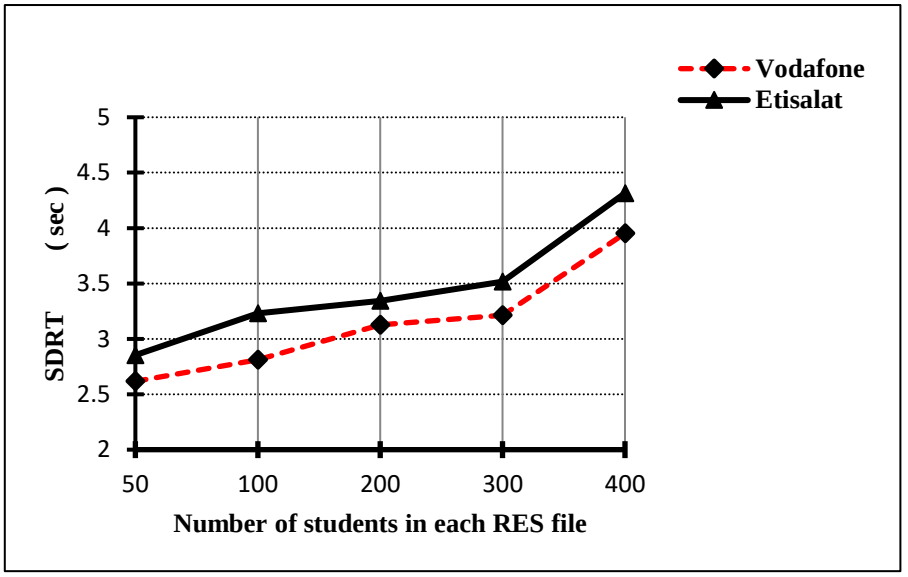

Fig. 14: SDRT measurements versus number of students in each RES file

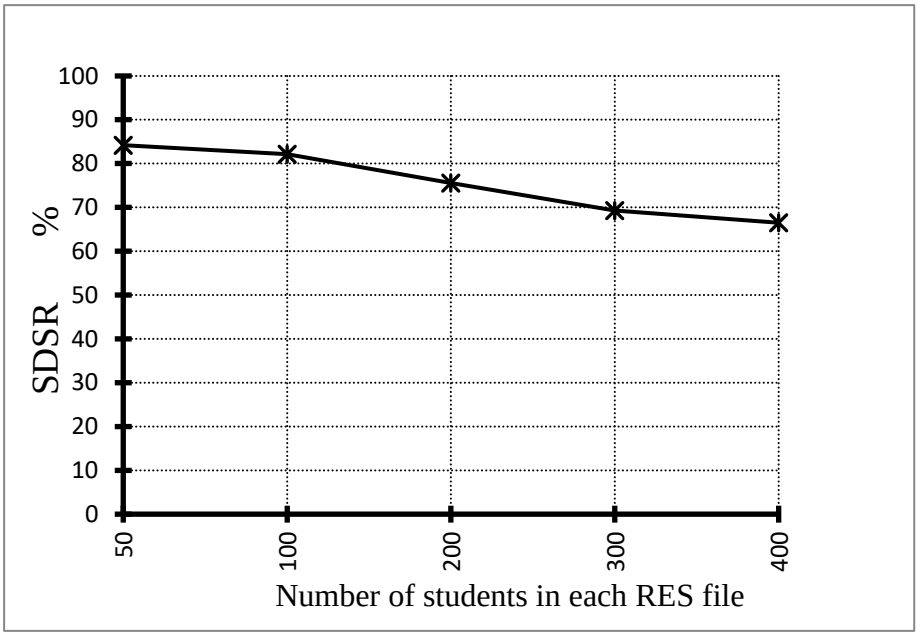

Fig. 15: SDSR measurements versus number of students in each RES file