An IoT-alert System for Chronic Asthma Patients

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***Abstract*—Asthma claims thousands of lives every year, especially during the cold season, mostly because of delayed access to first-aid and lack of immediate and adequate medical care. Asthma-related fatalities are preventable by home remedies, exercises, prescribed treatments, and providing rapid response and care to patients in case of asthma attacks. The latter is paramount to many asthmatics who are not able to predict an asthma attack well in advance. This work proposes and deploys an IoT-alert system that a chronic asthma patient (or any asthma patient) can use to trigger an alert to inform emergency contacts in case of a sudden asthma attack. This research, done in Rwanda, aims to alert emergency contacts early enough for a rapid response in order to reduce the number of asthma-related deaths in the country. The proposed system, in its basic form, uses a keypad unit as an interaction point with the users, which when pressed triggers the alert system to send SMS messages to registered emergency contacts and sounds a buzzer to alert few of the immediate neighbours of the asthma patients living close by. The intention is to provide support and help the chronic asthma patients, particularly those living alone, to receive appropriate medical aid within five minutes of alerting the neighbors and emergency contacts during a sudden asthma attack. The keypad interaction unit, which is the primary component of this IoT-alert system, can be wall-mounted in any room so that patients can easily access it. A small functioning prototype of the proposed system has been successfully tested at Kigali and testing has proven its effectiveness in helping the asthma patients.**

***Index Terms*—asthma, smart health, Internet of Things (IoT), SMS, alert system, wireless sensor network**

I. Introduction

Asthma, a respiratory ailment, is primarily caused by genetic inheritance or as a result of environmental factors, like poor air quality, cold temperatures and indoor mold, cockroaches' allergen, pollen and outdoor mold, dust mites, pet dander, dust, and thunderstorm [1], [2]. Asthma attacks can also be allergy-induced [1], [3], [4]. Percentage of patients suffering from asthma or even chronic asthma vary across the different countries globally and generally countries having higher pollution levels have an increasing number of asthma patients. For example, given the pollution levels, particularly, in the urban and suburban areas, Rwanda experiences a big number of asthma patients.

Asthma affects a large number of the world population. According to the United States' Centers for Disease Control (CDC) the number of asthmatic people account for up to 26.3% [4] of the natural mortality rates in the country with children being more affected than the adults. One in thirteen Americans is an asthma patient and as per the 2017 CDC statistics, asthma, one of the most costly and prevalent ailments in the country, takes the lives of ten Americans everyday [4]. The situation is also quite concerning in Rwanda, where the 2017 health statistics has revealed that asthma condition is quite prevalent among the population with a mortality rate of 31.3% per year in the natural mortality category [1], [3].

Generally, an asthma attack can be detected when a patient tends to cough, wheeze, or feel breathlessness [1], [3], [5]. In response to this condition, clinical researchers [1], [3] have innovated inhalers, nebulizers, and herbal treatment that help asthma patients in not only providing short-term relief but also helping in long-term control of the asthma condition. Further, asthma patients are directed to adapt home remedies such as breathing exercises, herbal and natural remedies to prevent the attack. A significant percentage of asthma patients get sudden or unexpected asthma attacks that can be triggered by any factor, including allergic reactions, and a big number of such sudden attacks may happen when patients are alone at home. In such situations, how can a patient alert others to receive any help within a short time? An IoT-based alert system, like the one proposed in this work, can help in such situations.

A significant number of IoT research have been done on developing systems to monitor patients with varied health conditions or keep a track of their physiological behaviours and send out alerts and warning signals to medical personnel and caregivers so that patients can get help and support promptly [6]–[15]. These systems help out in long-term monitoring of patients and enable the medics to advise on the possible treatments before anything fatal happens. However, none of

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these systems provide swift alerts for patients with chronic ailments, like asthma, who may need instant help in case of a medical emergency, like having an asthma attack.

In context to the above discussions, the work done in this paper proposes an IoT-based alert system for chronic asthma patients in case of a sudden asthma attack. The proposed system alerts the neighbours of the patients (let's say occupants in adjacent/nearby residential units) through a sound (buzzer) alert so that they can immediately rush for help. Alongside, the system can also sends out SMS alerts to emergency contacts including a medic or an ambulance so that medical first-aid can arrive soon. Also, the system can emit loud sound to alert people around. So, the primary aim of this alert system is to seek immediate medical attention from neighbours and/or first-aid paramedics until the patient is shifted to hospital for treatment. Additionally, the system has a door unlocker system specially designed to enable users leave a room by automatically unlocking the door using the servomotor to enable the first aid providers or the paramedics access the asthma patient.

This research work also intends to assess the impact of the proposed system in terms of affordability, accessibility and whether this can be utilized at the Rwandan medical infrastructure as a suitable IoT-alert system for chronic asthma patients.

A. Novelty of the paper

Considering all the instances of asthma deaths, it can be concluded that as per statistics most asthma patients failed to get instant access to medical care or first aid from the people closest to them [1], [4], [8]. The design and deployment of this system can significantly reduce the number of asthma deaths by providing rapid responses through several modes of alert. The system allows the users to add their emergency contact list, closest neighbors, and medical personnel to ensure that they can be alerted promptly.

Moreover, as home-based care is gaining popularity during this Covid-19 pandemic circumstances, mostly because of overwhelmed healthcare infrastructure, this system can prove to be effective not only for the chronic asthma patients, but also can be advanced to accommodate the needs of the Covid-19 patients who may need constant monitoring and have underlying ailments. For example, patients with respiratory problems such as shortness of breath and fatigue, as well as loss of speech and motor skills, can benefit from this proposed system. Covid-19 patients, either at at home isolation or in quarantine facilities, can use this system to receive timely medical aid during any kind of medical emergency. Also, the system can be used to aid patients with other chronic ailments apart from asthma.

B. Organization of the paper

The remaining paper is organized as follows. Section II discusses the related research work proposed by the research fraternity. Section III provides a description of the proposed IoT system design, modelling and simulation performance. Further, the impact of the deployment of the IoT alert system is discussed in Section IV. Section V provides an explanation of the results of the tests performed and discusses the findings, and finally, Section VI, concludes the paper.

II. Related Work

Swift alert systems are essential in providing response to emergency cases to reduce the mortality rate, in this case, for the asthma patients. These alert systems inform the asthma patient's emergency contacts, or medical practitioners of an emergency situation that needs to be addressed. There are different alert systems: some are manual such as toll-free call lines, others are automated systems and exist in different forms, some are wearable smart-devices or made in other fitting forms [9], [16]. In this section, we refer the recent literature that indicates advances in the development of IoT assistant systems and their deployment environments. Several researchers have used the existing manual systems and add automatic features while others have shifted the paradigm and innovated new solutions that link patients directly to their doctors to provide constant monitoring. Table I presents the comparison of remarkable innovative solutions for both relevance and limitations.

Countries have emergency toll-free numbers that patients use to alert the medical healthcare facilities, fire department, or the police department in case of an emergency. For instance, in the USA, 911 [4], is used to help Americans access several emergency services. In Rwanda, a victim can dial 113 for traffic emergency services and 912 [1], [3] for health emergency services and ambulance services. In Rwanda, the estimated time to contact the toll free number and get swift response and access to the services is above 25 minutes. Contacting the emergency unit does not, however, guarantee access to efficient and appropriate medical care instantly. As such, the asthma patient may be incapacitated by the time they access first aid or get any other medical assistance.

In response to this, researchers have developed wearable IoT assistant devices that sense the physiological features on the asthmatic patient's body and process the sensor data using a microcontroller [14]. The processed data can trigger an alert or simply log the data as normal condition of the asthma patient. In [10], [13], [14], the embedded system engineers work with medical practitioners to determine what are the extreme levels, and they calibrate sensors to measure the heart pulse rate, muscle tension, blood oxygenated levels, body temperature and pressure. However, in [9], [10], [17], there is a 15% chance that the sensors' calibration faults may result in erroneous data. The sensor fusion to measure different physiological features would lead to electronic disturbance and interference especially when fitted in a small device like a smart-watch.

The use of highly sensitive sensors would be preferred, but that would increase the cost of the device and rendering it quite expensive despite its relevance to the asthma patient. In addition to that, many physiological features may change as a result of the activity being carried out by the asthma patient yielding to false alerts. For instance, yoga or gym

TABLE I
COMPARATIVE ANALYSIS OF THE EXISTING IOT ASSISTANT SYSTEMS FOR CHRONIC ASTHMA PATIENTS

IoT system	Description	Strengths & Relevance	Limitation
Mbreath (2013)	The system self-monitors a patient's symptoms and the surrounding condition and sends out information to a dashboard that the system is monitored.	The system deploys a wireless body area network for the wearable with sensor fusion to measure physiological features on the patient that would detect an asthma attack.	The IoT device does not allow the patient to alert the medic for emergency aid when they get an impromptu asthma attack. The system is implemented as a wearable IoT device hence may not be affordable or available for use by any asthmatic in both rural and urban areas.
Wireless health alert and monitoring system (2006)	The system uses sensors, communication module, and a server unit to communicate emergency cases to medics on the patients condition remotely. The communication module used is a free service that relies on RF-433MHz band.	The system uses highly-calibrated and accurate sensor units to measure physiological features. The system enables the medics to monitor the patient over time and they can be called to hospital when their vitals are on the extreme level.	The medics have access to the patient's conditions through a dashboard, however, the system does not discuss how the medics would handle an impromptu emergency case.
CustoMed (2005)	The system architecture is implemented as a re-configurable embedded system that allows the users to customize the system to suit their medical needs.	The system uses a fusion of sensors and is easily deployed and customized at both hardware and software level by both the engineering and non-engineering staff	The system requires medical knowledge to operate the architecture and it is not yet customized for commercial use. The system can be utilized in a medical facility whereas there is need to monitor patients in home-based care as well as other chronic patients outside the confines of the hospital environment.
IoT-Based Smart Edge for Global Health (2019)	The system performs remote monitoring with severity detection and alerts transmission.	The system is quite efficient as it uses GSM to transmit data to the remote server making it suitable for use in urban and rural environments. The system develops a wearable IoT device that measures the physiological features of the patient.	The system data obtained solely depends on the sensor fusion measurement of the physiological features. The data is sent via SMS to the medics. However, the system does not describe its ability to respond to emergency cases and the estimated response time for chronic cases.

activities, may increase the heart rate resulting into a reading of extremely high values which would trigger an alert on the device yet the patient may not be having an asthma attack. This would imply that the computation algorithm used in the microcontroller should have machine learning model techniques to accommodate the uncertainties.

Most of the wearable IoT assistant devices use the calibrated sensors fitted into a light-weight device to alert the asthma patient and periodically sends data to a remote location accessible by doctors through a web dashboard. The smart-watches are linked to the user's smartphone via Bluetooth and the smartphone application shares the data with the remote server. For other standalone systems, the microcontroller unit connects to a communication module that transmits data to a remote server. In [12], the system uses ZigBee communication in deployment environments where the wireless sensor fusion is a few meters from the response unit. In [11], [14], [18], the deployed system uses Wi-Fi communication based units to transmit the information wirelessly. Such a system requires a good Wi-Fi signal coverage with a strong received signal of a minimum received signal strength indicator (RSSI) of -20dBm [7] to avoid data loss due to latency and bandwidth constraints when multiple devices are using the same Wi-Fi connection.

The drawback in using ZigBee and Wi-Fi in the alert systems is the latency during transmission that is prone to the wireless technologies, and the affordability of the device. Additionally, Wi-Fi technologies depend on a hotspot and when implemented on chip or the microcontroller, they tend to be more costly. In addition to that, their efficiency depends on the proximity of the device to the WiFi hotspot or the internet service provider (ISP) transmission backbone. The devices that use WiFi may not be efficient in peri-urban and rural areas which may not have a good network coverage.

For the IoT assistant devices, the system power consumption is a significant criteria for the design and for the system user. In [13], [15], the power consumption by the sensor fusion wireless body area network (WBAN), microcontroller, and communication module ranges between 0.5-1KWh which is considerate for residential units and office complexes. In [19], [20], the microcontroller unit requires 5-12V power source while the sensor power consumption varies per sensor. In [15], [17], [20], the IoT assistant wearable devices are fitted with Lithium batteries which can support 6-8hrs on moderate system performance. To reduce the power consumption, in [8], [11], [16], [19], the system transmits the data periodically instead of instantaneously. Conclusively, there is a lot advantages in using less power consuming processing units to ensure that the system performs optimally [6]. The WBAN design requires proper power computation which guides the design and placement of the sensors on the printed circuit board. In addition, the asthma patient needs to know how long they can use an IoT assistant wrist-wearable device before they need to recharge it.

Researchers have adopted a two-coined approach in developing IoT assistant systems for chronic asthma patients. Firstly, systems are developed to monitor physiological features periodically and the information is shared through an efficient wireless communication system to a remote location. The medic can track the readings and advise the asthma patients on how to maintain their health condition in good shape for the long-term. The system sends data in bursts and the medics observe the patient data periodically unless there is an emergency alert message sent to them. Further, it would take a substantial amounts of time to respond to the patient considering that the patient may be far from the healthcare facility. Secondly, systems are developed to alert the asthma patient of an extreme level in their physiological features. The warning allows the patient to either stop undertaking a strenuous activity or to adjust the environment conditions, such as moderate the air conditioner, or turn on the heater. Of these two approaches the patient is unlikely to get immediate help considering the first aid window of an asthma patient is limited.

Researchers have come up with innovative technologies to provide solutions for chronic asthma patients. This paper

TABLE II
IoT-ALERT SYSTEM: PATIENT INTERACTION MODULE

Key	Description	Comment
1	Asthma attack module	Activates the module
2	Door unlock module	Initiates the door unlocking
3-9	Future modification	For additional features to the system
0	Reset function	Resets the system after asthmatic gets help
* #	Controls	For future modification

seeks to develop and assess an IoT alert system for indoor implementation to help the asthma patients access medical aid by alerting emergency contacts whenever they get an asthma attack.

III. PROPOSED IoT-ALERT SYSTEM

Chronic asthma patients may get an asthma attack anywhere and at anytime. Unfortunately, the situation becomes extremely concerning if the attack happens indoors and maybe at a time when the patient is completely alone at home. The IoT-alert system proposed in this paper aims to aid the patients who may get an asthma attack while living at home alone without any assistant tools such as an inhaler or nebulizer. Such patients will generally be in dire need of receiving quick first-aid and subsequently a proper medical treatment within a short time to avoid falling into unconscious state or eventually succumbing to death.

This section provides a description of the IoT-alert system that we have developed. The proposed IoT-alert system was first simulated on TinkerCAD circuit simulation software [21] for testing before the hardware implementation. The system (a) allows the asthma patient to send out SMS alert messages to emergency contacts, which could be the family members and/or medical professionals/ambulance, by pressing a button on the keypad, which is a simple unit that can be wall mounted (a sophisticated version of a wall-mounted unit is shown in Figure 1); (b) also sends out emergency alerts to the wall-mount systems of some of the immediate neighbours of the patients, who may be residing within the same residential block or *umudugudu* and have their contacts registered in our proposed system.

In case of an asthma attack, the proposed system sends out a command message via SMS to the wall-mounted alert system of the immediate registered neighbours, which activates a loud sound buzzer to notify the neighbours of the asthma attack. The wall-mounted unit at the neighbours' also display the house number and details of the asthma patient that needs help; (c) emits loud sound from the wall-mounted units at the patient's residential unit to notify anyone around about the asthma attack and that help is needed.

Moreover, the system periodically sends out alert logs to the back-end database on the remote server (this could be a cloud-based one), which can later-on be used for data analysis and assessment of the system when needed. Algorithm 1 shows the proposed IoT-alert system for chronic asthma patients.

Algorithm 1: Algorithm of the IoT-alert System

```
Result: Alert emergency contacts
Initialization;
while system powered on do
    1. Display system info on display screen;
    2. Medicine cabinet locked;
    if key 1 pressed then
        Unlock medicine cabinet door;
        Send out SMS alerts to emergency contacts;
        Sound the alert buzzer;
        Send out an SMS command to umudugudu
          neighbor's devices;
    else
        if key 2 pressed then
            Unlock medicine cabinet;
            Unlock room door to allow access;
        else
            if Key 0 pressed then
                Reset system to initial state;
                Send out SMS reset command to
                  umudugudu systems;
                Send "Help received" SMS to
                  emergency contacts;
            else
                Sound the alert buzzer;
                Send out SMS alert to emergency
                  contacts;
            end
        end
    end
end
```

A. Input/Output module

In the case of apartment block that has several units (like in a hotel), one of the keypad units (similar to the one shown in Figure 1) can be installed in the residential unit of the asthma patient, another can be installed at the property manager's unit and one more can be installed at the reception. Moreover, some of the immediate neighbours can also have such keypad units already installed in their residences and their contact details can be registered on our proposed IoT-alert system.

Except during an asthma attack, all other times the keypad unit at the patient's place will be in idle mode and will display an e-guide with informational messages such as system name, description, health tips, and key options to activate the system. For patients, all interactions with the IoT-alert system can be done through the installed keypad. To activate the different modules of the system as discussed in Table II, the keypad has got the following keys: 0-9, #, *. When the user gets an asthma attack, he presses key 1 on the 4x4 keypad.

This triggers the asthma attack alert module which sends out SMS alerts to the emergency contacts as well as immediate neighbours registered in the system. The alert triggers the loud buzzer sound on the wall-mounted units at the neighbours

Fig. 1. LCD keypad wall-mount system [Source: WT5500]

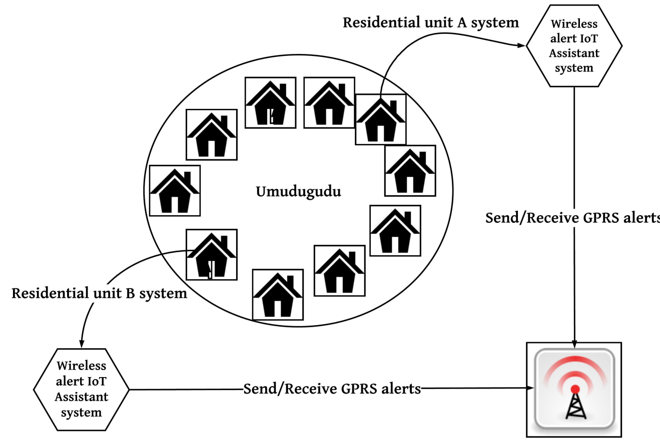

Fig. 2. System deployment in the *umudugudu* setup

notifying them of the asthma attack and that the patient is requiring immediate medical help. When key 2 is pressed, it just unlocks the door to allow access to the patient.

B. Communication module

On pressing 1, the triggered asthma attack module sends out alert SMS alerts with the patient's location details to the registered emergency contacts and registered immediate neighbouring devices. The IoT-alert system uses SIM card to facilitate transmission of alert messages. The SMS alert model, herein, allows for up to 5 contacts to be registered: 1 medical practitioner or emergency services personnel, 2 family members, and 2 immediate neighbors residing nearest to the patient.

Apart from the functionalities of Keys 1 and 2 as explained before, when key 0 is pressed it resets the system and sends out SMS messages to registered contacts informing them that the asthma patient has received first-aid while the emergency medical services are still making their way to the asthma patient's location.

The proposed system uses GSM AT commands to send out SMS to the emergency contact list. The neighbor's system units receive the system generated SMS and process it to trigger the peripherals such as the buzzer to emit a loud sound while displaying the information of the system unit from which it receives the SMS. The system generates the message automatically as the system user details are already configured on the device during installation. Further, the communication module, SIM808L, is attached to the serial communication ports of the Arduino board to facilitate communication between the Atmel 328 microprocessor and the peripherals.

C. Processing module

The IoT-alert system is designed using Arduino 2560 as the microcontroller. Atmega 328 is used for the PCB prototype to design the keypad units. The PCB prototypes (fitted with sound buzzers, atmega 328, sim808L GSM shield, and servomotor) along with the LCD keypad WT5500 are used to make the wall-mount unit.

D. Deployment scenario

In Rwanda, the planned system deployment will use the pre-existing strata where ten homes in an area form a subdivision known as *"umudugudu"* [22], [23]. The system units will be deployed in the homes of the asthma patients and in case of an emergency, alert will be sent to those residents who are considered as emergency contacts and/or immediate neighbours within the *umudugudu*. Figure 2 shows the *umudugudu* where the system can be deployed in some residential units.

The diagram in Figure 3 shows how the hardware components of the system are interlinked and how they interact with each other. Being in close proximity, the neighbors can provide first aid or help the asthma patient to get to the nearest medical facility. This system is effective because it supplements the healthcare system and patients can access quality medical care from the nearest facilities. After the system design and hardware implementation, the system was assessed in Kigali-Rwanda, to evaluate its performance and effectiveness.

IV. SYSTEM EVALUATION

This section evaluates the performance of the proposed IoT System for Chronic Asthma Patients. We first talk about the deployment of the IoT-alert system, the system methodology involved in carrying out the experimental tests of the system on a physical environment, and then we proceed with the discussions of the results and findings.

A. Assessing Impact of the IoT-alert System

This research work has proposed the idea of the IoT alert system, developed a small functioning prototype for testing

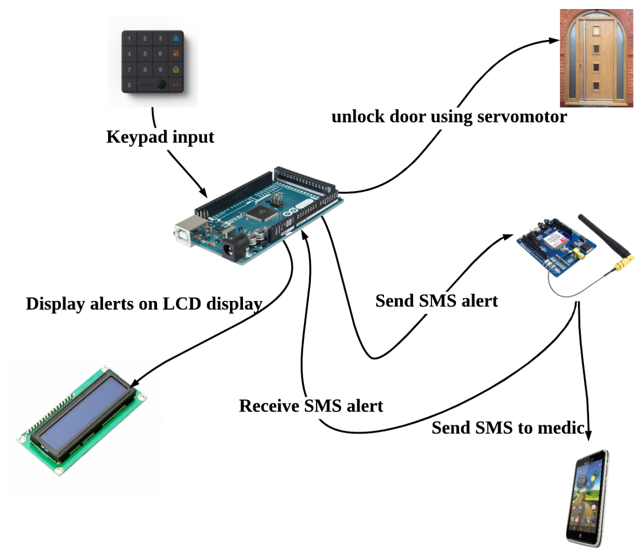

Fig. 3. IoT alert assistant system microprocessor to peripheral interaction

purpose, and assessed the impact and performance of the system in response to asthma attacks. While, our initial research plan was to use real medical facilities in the city to run the experiment, because of the health privacy policies regarding the disclosure of patient information, we were unable to get personal information on asthma patients. So, the system was tested at a university hostel to simulate the *umudugudu* social setup. The data collection phase ran for ten weeks during the short rain season when most cases of asthma attacks are recorded due to a rise in risk factors such as dust, pollen, thunderstorms, and cold temperature during that period.

The participants were selected based on their willingness and availability to participate in the exercise. We used the convenience sampling technique in this case, which turned out to be quite effective as it was able to omit any non-probabilistic bias and the volunteers were committed to the exercise. The team of 15 student volunteers tested the system over the ten weeks' period. Firstly, they were given a user manual and training on how to use the system. Secondly, we installed the IoT-alert system's keypad unit in their rooms at a position convenient to them. Thirdly, we recorded the smart power meter readings at the beginning of the experiment for those units having the keypads installed.

The software team developed a script to randomly send *"request-to-test-system"* messages to the volunteers and record the response time on the remote server database. During this phase, arrangements were made with the university medical team to turn up within five minutes of receiving the simulated alert notifications to attend the volunteer patient having the asthma attack every time that we tested the functioning of our system. The medical team was also trained on how to interact with our IoT-alert system once they get to the asthma attack patient. After the asthma patient has received help and treatment, the system also sent out a short SMS survey to

TABLE III
ACTIVITY LOG STATISTICS ON 3 ALERT MODES OF THE PROPOSED SYSTEM

Parameters	**Neighbor Unit**	**Sound buzzer**	**Plain phone SMS**
Count (test)	51	50	49
Mean time taken	4.490196	2.66	6.408163
Standard deviation	3.895498	4.08886	3.581889
Min. response time	1	1	1
25% Quantile	3	2.25	4
50% Quantile	7	7	6
75% Quantile	9	10	10
Max. response time	13	13	13

get the feedback from the patient about the system and the experience in general. Patients were able to select options in the survey to provide their feedback. After the data collection phase, collected data was analyzed and results are reported in the following section.

B. *Results and Findings*

Through the testing carried out, the system proved to be effective in providing support and medical aid to asthma patients within a very short time. During the data analysis, we found that because of the different modes of alerting for help (e.g., sound alert, neighbor unit alert, and plain SMS alert), the asthma patients were able to receive help and medical aid within a very short time. We generated some statistics to determine the mean time taken to get a response from all the alert modes. Table III summarizes the findings and shows that, on average, using our system, asthma patients were able to receive help and medical aid within 1 - 6.5 mins of raising the alerts. Approximately, about 150 tests were conducted during the testing phase and out of those, 51 cases of asthma attacks were responded by the neighbors, 50 cases were notified through sound alerts from the system units installed on the patients' residential units and were attended by people around, and the remaining 49 cases received help from emergency contacts notified through SMS alerts to their phones.

Analysis of the results also revealed that some of the results depicted false positive values where users triggered the asthma alert mode without necessarily having an asthma attack. Such cases accounted for 2.5% of the total results and hence were not considered to be a significant caveat in the system's performance. Effectively, the results implied that the proposed IoT-alert system has the capability to reduce the number of sudden asthma attack-related deaths among the chronic asthma patients (especially who live alone) because they can receive help within a very short time.

Furthermore, the findings also showed that the energy consumption cost to the user for running our system has amount to only 2.5 units per month, which translates to 550 RwF ($0.55). Figure 4 illustrates the design of the system and connectivity of the hardware components during the first testing phase. Figure 5 shows the SMS alert received by one of the emergency contacts from the system during testing. The system is designed to ensure that both children above the age

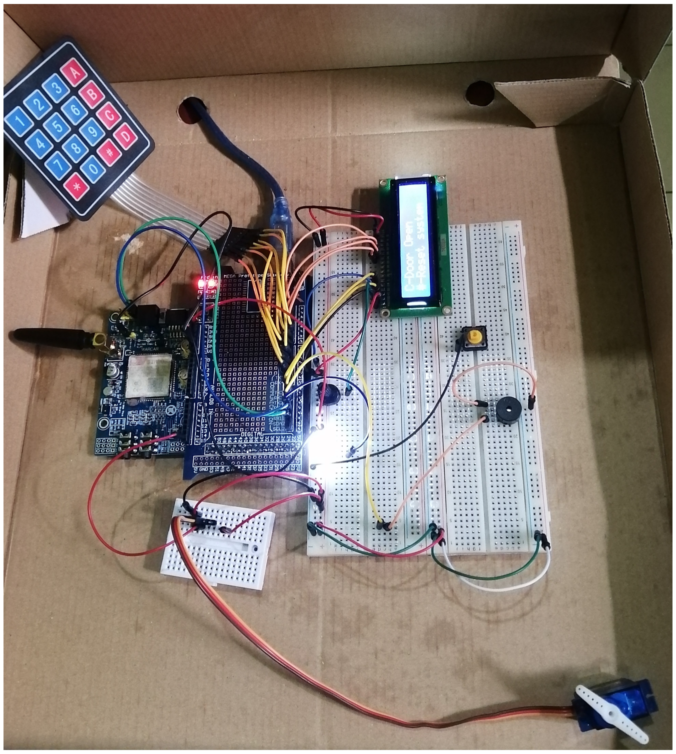

Fig. 4. Interconnection of Hardware Components of the IoT-alert System

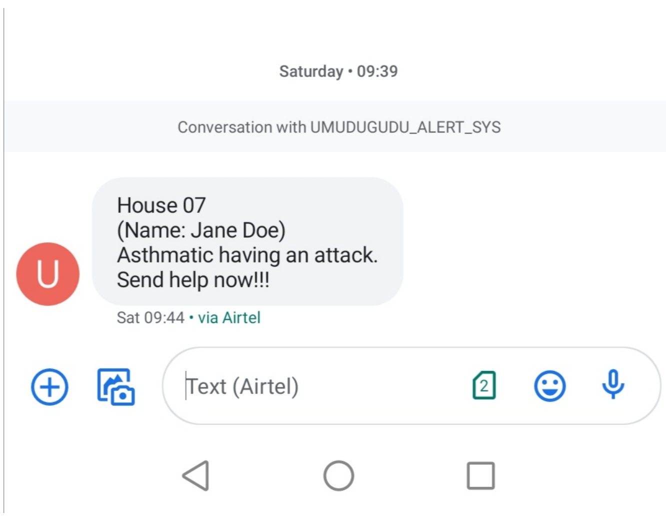

Fig. 5. SMS messages as received by the emergency contact

of 7 years and adults can comfortably access and use it after installation in their respective residential units.

Our system can also be deployed in urban and rural areas of other East African countries, which have adopted the 10-home based residential blocks known as the *"Nyumba kumi"* initiative [24], [25] such as in Kenya, Uganda, and Tanzania. However, it is worth pointing out the different challenges in regards to the deployment and maintenance of the system in the residential units. For instance, currently the system runs on power drawn from the national grid and in instances of power failure, it will cease to run. In future we are thinking of incorporating a rechargeable battery option in the system as backup. We would also like to implement green energy technology option.

V. CONCLUSION

One of the key causes of asthma deaths is slow response to asthma patients in the event of an asthma attack. The statistics as indicated in the introductory section show that the chronic asthma accounts for a very large percentage of the population ailments in the USA, and specifically Rwanda, where we perform our experimental analysis of the system. The cases of asthma deaths can be significantly reduced if the asthma patient is able to access rapid response via first aid from family and friend or quality medical care from paramedics. This proposed system would ensure that these patients are able to access medical aid from their homes in case health care facilities are overwhelmed. The installation areas could extend to hotels, retirement homes, university hostels, and apartment blocks where users can get assistance from their closest neighbors or care givers within the institution.

The experimental phase carried out over a period of ten weeks showed that an asthma patient was able to get aid within 1- 6.5 minutes, on average, through any of the alert modes. From the data analysis, it was evident that the sound buzzer drew more attention to the asthma patient and provided rapid first aid while the medical practitioners were alerted of the same through a text message. The system sends out a loud sound buzzer to the neighbor units configured as emergency contacts and that increased their chances of obtaining aid.

Some cases of chronic asthma result in convulsions or immediate loss of consciousness of the asthma patient. These are very extreme cases which would account for a small percentage of the general population with asthma. Such cases would require an on-site caregiver to check on the patient periodically. Further, for such patients we can have a bed-mount installation of the system to ensure that the patient does not have to walk to the wall-mount to alert others of their impromptu asthma attack.

Conversely, the paper does not consider asthma cases that would occur outdoors which may be caused by environmentally induced triggers.

VI. FUTURE WORK

The wall-mount household system unit can be advanced to have more features such as sending the medical team the current geographic location of the asthma patient. Notably, asthma attacks not only affect the asthma patients indoor but also in outdoor environments.

This system can be advanced to allow the chronic asthma patient to have a wearable IoT alert system which they can configure using a mobile application to inform their emergency contacts, mainly a medical facility using the country specific toll free line, of their current location. This would trigger the system to inform the ambulance service or health care facility nearest to the patient to send help to a given location.

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