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# A theoretical model of healthcare monitoring surveillance system for patients with severe allergies

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ABSTRACT

Allergies influenced by some unwanted foods, dust, and pollens create quick reactions, which may be basic skin diseases, life-threatening disorders, and serious breathing problems such as asthma. The most severe allergic reaction data is quickly and efficiently handled by the healthcare monitoring systems when merged with the information and communication technologies (ICT). A four-month study was conducted with the existing healthcare monitoring systems to know how quickly they provide solutions to the patients suffering from severe allergies. The study comprises collecting patients data, especially children under the age of five years, which include regular and specific food they eat, hygienic or dusty surrounding, environmental conditions influenced by allergy creation actors and quality of life before and after the allergic reactions. Accuracy of the data depends on the efficiency of the Healthcare Monitoring Surveillance System (HMSS), which employs the Multiple-Input Multiple-Output (MIMO) scheme as a new mechanism. In this research work, HMSS with MIMO technology provides not only better accuracy, quality of life, and quickness as compared to existing state-of-the-art HMSSs, but also improves the lifetime of the monitoring system with reliability, maintainability, and availability. The produced results show the supremacy of the proposed mechanism when accuracy is the main concern.



## 1. Introduction

Allergic reactions not only create basic diseases but also results in serious and complicated aspergillosis, which creates asthma and let suffer 4.38 million people globally (Agarwal et al., 2016). Asthma is one of those allergic reactions which make severe wheezing and breathing problems identified by some children and adults. Various sources such as food, dust, and pollens, create a wide range of adverse health effects, including asthma, eczema, allergic rhinitis, inflammable, and toxic reactions. Allergic rhinitis (Seppänen et al., 2015; Wakamiya et al., 2019) is a major chronic respiratory disease influenced by birch pollen allergy (Smoldovskaya et al., 2016). It has attacked more than 500 million people around the world. According to the study Cuello-Garcia et al. (2016), the World Allergy Organization (WAO) discussed the use of probiotics, which support some recommended people who face the serious stage of allergic reactions (Sánchez-Borges et al., 2019).

A basic MIMO configuration and its properties are studied to apply for enhancing channel performance in wireless communication that allows us to increase the facilities of e-Health applications (Cavalcanti et al., 2010; Peters and Heath, 2012; Jayasheela and Rajeswari, 2012). The MIMO system transmits information about health issues based on allergy over multiple channels. Regarding the e-Health applications, managing huge medical information using ICT is difficult because lifestyles and medical facilities use advanced technologies. So, this research focuses on the MIMO scheme as a novel approach that enhances the ICT functionalities while single or multiple e-Health application is being processed. In

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the MIMO approach, manifold techniques provide most of the benefits to improve the functionalities and features with low-cost. Modern medical devices need reliability, maintainability, and availability (RMA), which provides efficiency when multiple symptoms are being examined. Regarding the proposed model, functionalities of accuracy that depend on the various signals need the discussed MIMO approach to cooperate with sensors and other interfacing units (Kim et al., 2010; Eroglu and Westrick, 2012).

Examination theatre using HMSS and sensors in which patient is being examined for the serious and complicated problems should use technical limitations like high throughput, larger channel capacity, and smoothing of the transmitted signal and low-cost.

In light of the above discussion, the call of the day is to develop a very simple to use and comprehensive system that can efficiently respond to allergic reactions and classify it on the basis of severity.

The modification to the existing ICT systems on the basis of allergies classes by using MIMO technologies can pave the way in obtaining the goal of using medical devices in a useful way. A strategic forum organized by European Academy of Allergy and Clinical Immunology (EAACI) targeted the aim of finding and discussing the real-world allergic problems, especially asthma where they have focused on technological treatment procedures by connecting science with patient care to ensure better treatment (Agache et al., 2019).

### 1.1. Contributions

1. A MIMO based architecture is proposed that facilitates the ICT functionalities for single and multiple e-Health applications.
2. The proposed model provides RMA (Reliability, Maintainability, Availability), which can provide efficiency when multiple symptoms are being examined.
3. Three types of allergies (food, dust, and pollen) were focused and categorized on the basis of the age factor in the range of 2-5 years.

## 2. Background

In health monitoring, the system should show the level of nutrition in each diet with food safety and hygiene to people who live in developing countries and remote areas. In the modern world, patients are being examined in a fixed or mobile location inside or outside the medical center, where we need an efficient health monitoring system (Batistatos et al., 2012).

Whenever they need, wherever they go, and whatever they eat–the monitoring system should be able to alarm the food safety and hygiene efficiently through the appropriate healthcare management steps.

### 2.1. Existing monitoring ways for allergic reactions

External environmental conditions and other unnecessary interferences damage the quality of communication when mobile patients are handled by the existing monitoring ways. According to Diaz et al. (2015), the pocket navigation system enhances the performance of the allergic detection algorithm depending on the heart rate. In this algorithm, the heart rate is monitored through electrocardiogram sensors. It measures not only the allergic reaction but also the daily life physical activities of the patient. In this experiment, allergy tests take up to 4 hours, but patients are allowed to move out of the room with the 3D localization device. User-centered mobile health device allows people to test the life-threatening allergic reactions such as anaphylactic (Munoz and Woolley, 2009). It is designed as a support tool to directly assist anaphylactic people and their care assistants. It provides first aid video demonstrations through the multimedia technology and 3-axes accelerometer mounted on the adrenaline injector, which sends the necessary information to emergency services. Solutions using geographical information system (GIS) and remote sensing techniques are also some of the monitoring ways to investigate the allergic reactions caused by the pollen grains, environmental pollution, etc., (Sadiq et al., 2007). In the existing monitoring approach, the ECG signal is used as a real-time measurement when a patient is being reacted by food allergy (Gutiérrez et al., 2013). Biosensor technology is a low-cost approach that detects peanut allergy reactions quickly and efficiently. These days, a smartphone allows us to monitor the allergic reaction using an external tube, which collects the samples of the allergens and provides the level of the attack and the reactions (Coskun et al., 2013). The automated analyzer and computer-based monitoring system are used for multiple detections of allergen. It tests the allergic reaction when the patient takes oral food. It has identified allergic subjects 17 min earlier than the trained clinicians (Oh et al., 2015; Twomey et al., 2013). Regarding the monitoring of environmental allergens and airborne allergens (Wu et al., 2014; Bastl et al., 2016), atmospheric pressure cold plasma (APCP) treatment which includes further tests using blood sera from the allergen sensitized humans reduces the size of environmental allergens and airborne allergens and prevents the allergic diseases.

### 2.2. Absorbing symptoms and HMSS

According to the Thayananthan and Alzahrani (2012) and Qureshi and Thayananthan (2016), monitoring symptoms for selected e-Health applications and health based on food safety and hygiene are detected through the sensors and passed to HMSS that has efficient transmission facilities. To transmit the monitored symptoms, efficient ICT is being implemented for the next generation schemes,

which is the part of technology in HMSS. In this implementation, the latest version of MIMO technology provides more advanced facilities such as high-speed transmission and energy efficiency, etc. Table 1 categorizes food, dust, and pollen allergies by symptoms, HMSS, and provides their possible solutions (Sicherer and Sampson, 2010; Sicherer, 2011).

### 2.3. Technical improvement in HMSS

To achieve the technical challenges, HMSS needs an efficient MIMO technology, which uses $P_n$-manifolds. In HMSS, these parameters are useful to optimize the overall challenging problems targeted for e-Health applications and predictions of allergic symptoms (Thayananthan et al., 2013). In the HMSS, manifold concepts have been introduced to solve some problems such as complexity, rate, optimization, etc. According to Krishnamachari et al. (2013), the manifolds can be used to simplify the large channel matrices used in massive MIMO. So, HMSS increases the efficiency and accuracy of allergic reactions based on food safety and hygiene around remote areas. It also helps to increase the capacity of communication in all situations, such as priority and emergency services. To improve accuracy, HMSS needs the channel state information and feedback that plays an important role with $P_n$-manifold. To get rid of the distortion that affects the accuracy, the design of HMSS must have a proper optimization technique that is achievable through $P_n$-manifold. The efficiency of the channel dominates the enhancement of efficiency of the allergic care scheme in the proposed system.

Quantization noise needs to be minimized using appropriate design in which $P_n$-manifold provides some benefits needed for accuracy. Calculating quantization always depends on the distance between any two points on the chosen shape of the manifolds, which influence the dimensions of channel matrices. Also, bits per feedback index affect the quantization procedures and calculations. $P_n$-manifold minimizes the rank and dimensions of the channel matrices and helps to determine the feedback rates. The quality of feedback also provides necessary benefits to improve the accuracy of HMSS in which the number of bits used in the codebook can be considered for minimizing quantization effects.

**Table 1:** Epidemiology of food, dust and pollen allergies

| Possible Allergy | Basic symptoms | Serious symptoms | HMSS | Solutions |
|---|---|---|---|---|
| Food | Sneezing eczema, stomach pain, headaches, hives, flushing, itching, nausea, vomiting, cramps, diarrhea | wheezing, hoarseness, loss of voice, chest tightness, anaphylactic shock, decreased blood pressure, swelling of lips or tongue | Accuracy of wheezing rate, Quickness of sending data, influenced with the allergy. Adjustable when environmental condition changes or policy of medication | Ep pen, Ambulances, doctors |
| Dust | persistent runny nose and sneezing eczema itchy or water eyes | symptoms worse at night and when awakening, improvement when outside | Nil | Nil |
| Pollens | runny nose, sneezing, coughing, watery eyes, conjunctivitis, allergic shiners (dark circles under eyes) | asthma, anaphylactic shock, worse in mornings, fatigue, mental dullness | Accuracy of systolic, diastolic and pulse | Nil |

## 3. Objectives

The main objective of this paper is to present the results of the accuracy improvement of the theoretical model regarding technical feasibility and to monitor allergic reactions based on symptoms. Technical feasibilities are reliability, maintainability, and availability (RMA), which provides the accuracy, efficiency, and quickness in most of the situations. Monitoring allergic reactions deals with user acceptance, patient adherence, change in health status, and change in the quality of life.

## 4. Methods

Fig. 1 shows the methods explained through the theoretical model where the body sensor network (BSN) collects all symptoms of allergic reaction from the body and sends to the MIMO transmitter via data differentiators. This model should be able to handle the massive data obtained from e-Health applications. To manage the transmission facilities, emergencies, and priorities efficiently with low-cost, manifold techniques in the feedback channels are used in the proposed design.

Application of HMSS uses data transmissions that include control signals used in the hardware of Fig. 1 and information of e-Health applications based on food safety and hygiene.

### 4.1. Data capture and analysis

Enhancement of HMSS comprises the following categories, which are the satisfactions and confidence in finding allergic symptoms.

### 4.2. Patient survey

Allergic reactions influenced by the food, dust, and pollen are considered in the data collections of a patient survey. Children under the age of 5 are the survivors who need correct and quick medications,

which improve the quality of life, including their memory power. According to the patient survey in Saudi Arabia, HMSS provides a quick and early decision that avoids severe allergic reactions. Fig. 2 shows the number of patients who know that they have allergic reactions. When parents know the allergic reactions and symptoms of their children quickly with HMSS, they can find the necessary treatments. According to the survey, a lot of children who live in remote areas not only face the fatal but also they spoil the quality of life, which is long term mental diseases, short memory, depression, etc. So, HMSS is essential to identify allergic reactions and symptoms.

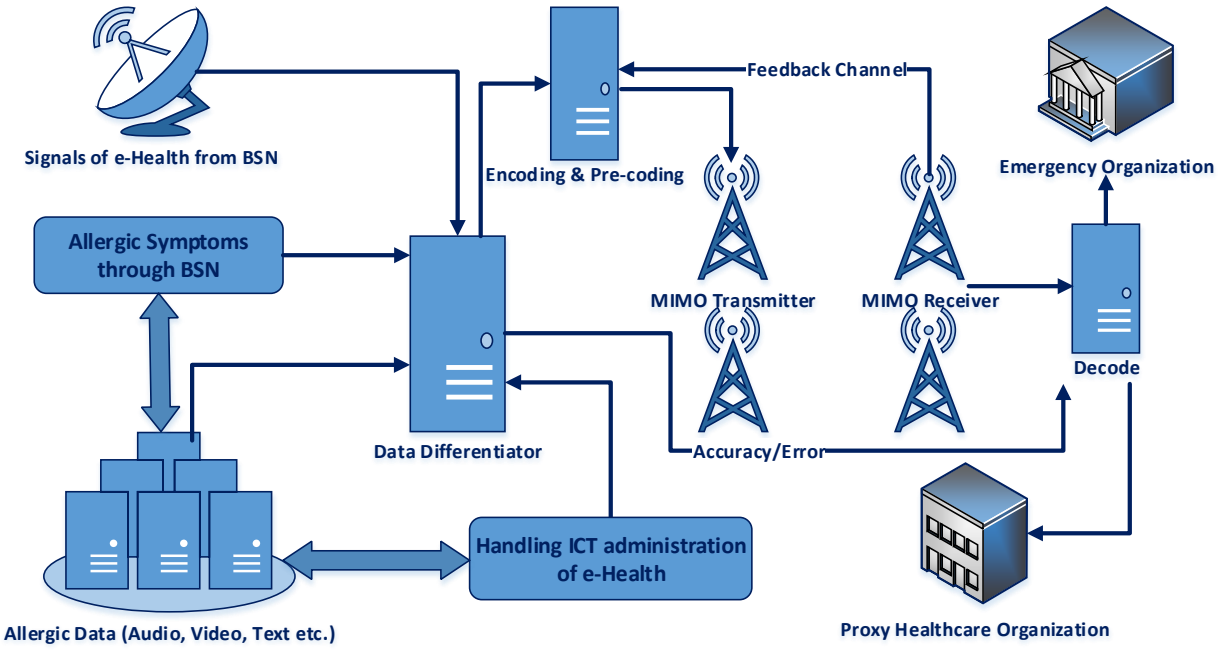


**Fig. 1:** Theoretical model of HMSS

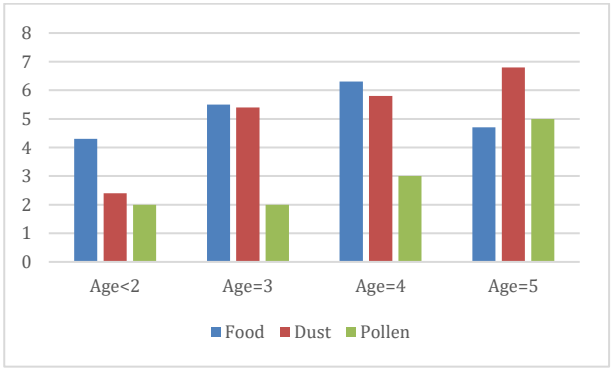


**Fig. 2:** Identified patients within 4 months

Allergic patients are increasing because identifying allergic reactions with fast food processing, modern furnishing, and pollens are not easy. When we have a device configured with the HMSS tool in handy, people can identify the allergic reaction themselves quickly. According to the allergic reaction mentioned in Fig. 2, children under the age of 5 are identified perfectly and treated quickly.

## 5. Results and discussion

Using a theoretical model that employs MIMO with feedback, results for accuracy, and RMA of e-Health applications seem that the allergic reactions based on food safety and hygiene are controllable. Results show that the MIMO techniques and manifold properties allow designing efficient HMSS with which minimizing the overall power and complexity reduces the cost of technology to improve the allergic reactions based on food safety, hygiene, and health.

Studies indicate that diagnostic accuracy is closely linked to the quality of data obtained from the HMSS, which is most likely to be used by medical professionals. This study highlights several findings of interest in that respect. To begin with, there is a great variation in the perceived quality of the data collected from different symptoms of allergic reactions and environmental conditions. Furthermore, some symptoms were identified in four different remote areas and compared well with the HMSS. In all four cases, average diagnostic accuracy is significantly better than the existing approaches.

### 5.1. Accuracy and RMA

In HMSS, measuring accuracy is one of the proposed features designed with the MIMO system. In this feature, the capacity and feedback rates are improved by a specific or selected category of $P_n$-manifold, which is considered as the main parameter.

Reliability represents stability and a maximum lifetime of the system needed to continue the management of health issues that demonstrate the level of food safety and hygiene in all environments.

Maintainability is guaranteeing the time that will be able to fix and restore the system for all up-to-date managing information of e-Health applications. It allows us to maintain the HMSS that has more operational functions and features integrated to receive all types of data from health monitoring devices. Here, $T_{MTTR}$ represents mean-time-to-repair (MTTR), which is an average time to maintain the system.

Availability (A) depends on the $T_{MTBCF}$, which is the mean time between critical failure (MTBCF) and MTTR. So, availability can be defined as

$$A = \frac{T_{MTBCF}}{T_{MTRCF} + T_{MTTR}} \quad (1)$$

Using Eq. 1, the availability of HMSS in scenarios mentioned in Fig. 3 shows that some patients do not get enough facilities because availability is very poor in some remote areas.

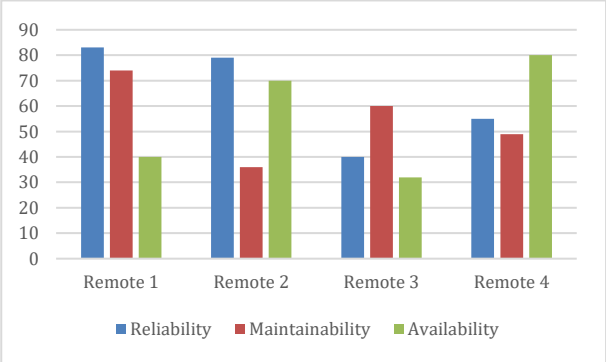


**Fig. 3:** Efficiency of e-Health applications

Administration issues of e-Health applications illustrated in Fig. 3 shows four scenarios in which patients who live in remote areas do not get that many facilities. More than 75% of public hospitals are far away from the remote areas where HMSS facilities will certainly be useful to identify allergic patients. Fig. 4 shows identified allergic patients in remote areas.

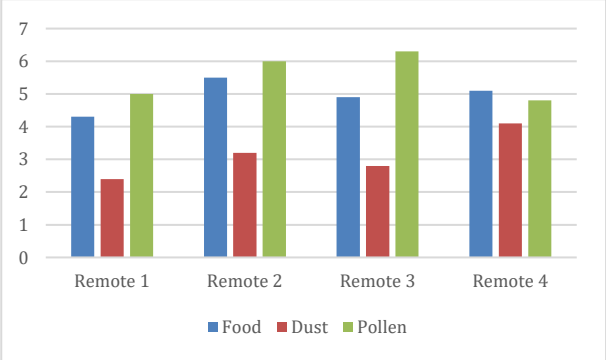


**Fig. 4:** Identified allergic patients in remote areas

Pollen attacks are quite high in remote areas, whereas other allergic attacks related to food and dust are reasonable.

In this result and analysis, consider the MIMO configuration that has $N_t = 3$ transmitting and $N_r = 3$ receiving antennas. Sensors collect all the symptoms from the body and pass on to the transmitting component of the proposed system. It means that an individual symptom is transmitted to the emergency health organization through the MIMO channel, which uses the feedback. Accuracy and RMA can be increased through which the analysis of power based on $P_n$-manifold is being optimized with feedback bits. Fig. 5 shows enhancement of accuracy for allergic monitoring under the age of 5.

### 5.2. Solutions for increasing efficiency

Although automatic, instant, and natural solutions are always useful, and instant solutions are in actions through e-Health applications. In the busy modern world, instance solutions are important to solve the problems quickly online, which increases efficiency with the automatic approach. This automatic alert will encourage the patients and prevent them from serious diseases. An instant solution that creates the proxy server or agent located in the nearest health care units is processed when patients are moving. These solutions certainly improve the design of HMSS for managing and detecting allergic reactions quickly. Fig. 6 shows the enhancement of accuracy for allergic monitoring in remote areas.

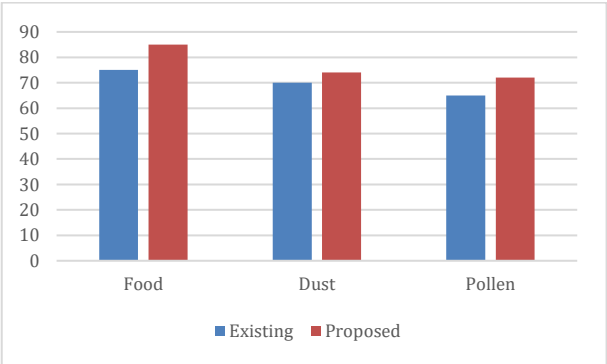


**Fig. 5:** Enhancement of accuracy for allergic monitoring under the age of 5

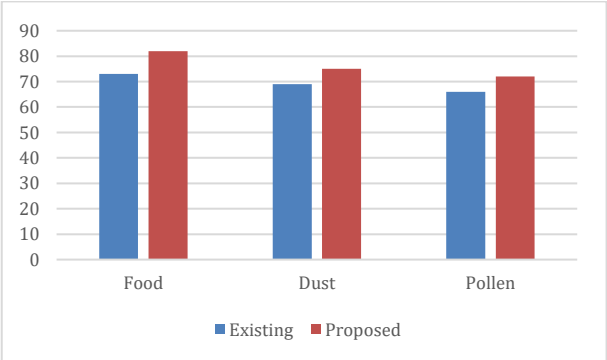


**Fig. 6:** Enhancement of accuracy for allergic monitoring in remote areas

Accuracy depends not only on the technology of the HMSS itself, but it varies with the external conditions such as environmental policies and regulations.

## 6. Conclusion

The finding suggests that the proposed HMSS monitors the prevalence and severity of various types of allergies, which include childhood food allergy quickly and efficiently. The results show that the proposed HMSS can provide quick, automatic, and natural solution with accuracy and availability. The conducted study shows that HMSS can be efficiently used in remote areas where the patients, especially under the age of 5, are more prominent in dust, food, and pollen allergies.

## Compliance with ethical standards

## Conflict of interest

The authors declare that they have no conflict of interest.

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