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# SmartCovidAssest: A Remote Monitoring System for Self-Quarantined COVID Positive Patients and Suspects in an IoT Environment.

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**Abstract:** In this work we have developed a Remote Monitoring System to monitor the Covid positive patients and contacts who are in the quarantine centers or self-quarantine at their homes. The system uses the Internet of Things (IoT) and mHelath powered Mobile App technology to develop a Mobile App for the patients to upload the symptoms selected from predefined list of symptoms if they have during the quarantine period. These symptoms will be uploaded to the Monitoring System in Cloud Environment to analyze the patient's condition. The patients and contacts must register in the system before it is used and they have to provide general information with the Grama Niladhari (GN) division. The daily uploaded data of the patients will be analyzed and the result will be compared with the standard threshold values defined in the system and visualize the patients' condition to the patients, to the Medical Officer or Public Health Inspector (PHI) in MOH offices. If the patients need any further medical treatments, system will indicate it, then the PHIs can immediately get actions to give further treatment before the patient's conditions becomes worst. The back-end system uses the predictive data analytic techniques to analyze the data and to generate the up-to-date reports and to provide the real time information about patients to the MOH divisions, districts, and provinces. This information can be used as a MIS for Covid -19 prevention program. Moreover, using this system, many reports can be easily generated and can provide a dashboard having information of the Covid-19 patients, contacts who are being quarantined at their homes and centers and PCR testing in GN division level, district level, province level, and national level which can be used to decide the Covid-19 control mechanisms and to get effective decisions with regard to the pandemic control.

**Keywords**: Internet of Things, IoT, mHelath, Mobile Apps, Data Analytics, Data visualization

## 1. Introduction

After analyzing the past few decades, it was noted that, deaths caused by viral epidemics and pandemics have exceeded several millions [1]. The COVID-19 which is also caused by a deadly virus (SARS-CoV-2 (corona), was first diagnosed in 2019 in the seafood wholesale market in Wuhan, China with a cluster of unknown patients with β-coronavirus pneumonia [2].

SARS-CoV-2 is a novel β-coronavirus that infects humans, which can bind to the human angiotensin-converting enzyme 2 (ACE2) to infect cells and replicate, leading to a range of clinical symptoms [3]. Now it has become a fast-spreading disease with different permutations all over the world having more than 414 million patients and more than 5.8 million death tall at the time of writing the paper but it will increase with the time [4]. Hence, it has become a global concern and the World Health Organization (WHO) declared this epidemic to be a Public Health Emergency of International Concern (PHEIC). The severity of this virus is that it can induce an infection in the respiratory tract of humans which results in the higher number of patients requiring advanced respiratory support due to the Acute Respiratory Distress Syndrome (ARDS) as the lung is the major – although not exclusive – target of the virus [5]. Moreover, patients with Atypical Pneumonia can present with or without symptoms such as fever, dry cough, and shortness of breath. In addition to the symptoms mentioned above diarrhea, chest tightness, dyspnea, palpitations, sneezing, fatigue, runny nose, chest pain, dizziness, nasal obstruction, headache, conjunctival congestion, myalgia, chills, itchy eyes, dizziness, and joint pain can also be observed in patients but not frequently. Many patients say their symptoms resolved within four to eight days but more severe cases tend to worsen about five to 10 days after the onset of symptoms.[6][7]. Overall, the SARS-CoV-2 would infect respiratory system, digestive system, circulatory system, locomotive system, nervous system, and eyes of the human body as shown in the Fig.1.

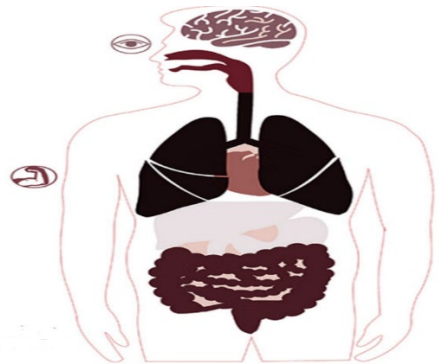

Figure 1: SARS-CoV-2 infect organs in human body

Recent experiments have revealed that the new permutation of highly transmissible SARS-CoV-2 lineage – B.1.1.7 originally detected in the United Kingdom has been spreading in Sri Lanka with exponential growth by increasing the number of patients in each city and increasing the death rate daily. Moreover, it is also announced that the SARS-CoV-2 lineage – B.1.617 which is rapidly spreading version in India has been identified from a quarantine center in Sri Lanka. Most of the Corona identified patients today in Sri Lanka are with omicron (B.1.1.529) variant that was first reported to WHO from South Africa on 24th November 2021.

When a pathogen such as a virus infects humans, the immune system could clear the infection by limiting viral spread (effective antiviral response), or cause an excessive inflammation and tissue destruction by cytotoxic cells and consequent development of immuno-pathological damage. The epithelial cells are critical for balancing these two extreme situations. The upper respiratory tract provides the first line of defense in that it activates a very complex system of signaling and recruitment of immune cells, in order to prevent pathogens from reaching the alveoli, the most important part of the respiratory system because it is responsible of gas exchange. Nevertheless, coronaviruses (especially SARS-CoV-2) are able to reduce or delay the expression of cytokines in human lung epithelial cell lines. This is an effective system to escape immune recognition by innate receptors in the infected cell which could therefore facilitate the progression of the virus into the lower respiratory airways (i.e. the alveolar space) [5].

When a corona patient was identified, the PHI of that Grama Niladari division comes and arrange to get the PCR for first contacts of that patient. Due to the limitation of laboratory facilities and the higher number of samples, the results would be delayed 3-4 days and during that time even the COVID-19 positive 1st contacts who haven't symptoms of COVID would go to the society and it will result to spread the virus in public. Currently all most all the hospitals, ICU wards and quarantine centers have reached to the maximum capacity and new quarantine centers are being built and existing hospitals are being converted to corona hospitals to meet the future demand of the hospital facilities. Moreover, it is evident that it is not practicable to admit the 1st contacts who are awaiting the PCR result.

With this current situation of exponential growth of the COVID positive patients, PCR result pending or 1st contacts to get a vacant hospital or quarantine center would be difficult due to the high demand. Some patients have to stay at their homes by quarantining themselves when they have identified as COVID positive but asymptomatic and when they have supportive environment at their homes. Therefore, the COVID 19 Prevention Center of the Health Ministry has given a guideline mentioning how to behave at their homes during the quarantine period.

However, the patients who need medical caring and suffering some breathing problems must not stay at homes. However, when there is a plan to manage asymptomatic patients at their residences, it will require a continuous monitoring of COVID symptoms they have and liaise with the PHI or with the Medical Officer in Health (MOH) office regularly. Although the PHIs have been assigned to many Grama Niladari (GN) Divisions for COVID monitoring duties they may not have enough time to continuously monitoring the existing patients who are in home quarantine or in the intermediate quarantine centers with the exponentially growth of new COVID cases.

In this study we understood the difficulties faced by PHIs and introduced a low-cost solution using Mobile app and back-end system to monitor the quarantine patients in intermediate centers and at their homes. The proposed system-SmartCovidAssist which consists of two components: a Mobile App for the patients and quarantined 1st contacts to send the COVID symptoms given in predefined symptom list to the Back-end system. The Back-end monitoring system which is in the Cloud environment is given for the officers in different levels such as PHIs, MOH, Provincial Directors and to the Ministry of Health to monitor the patients and visualize the COVID statistics in each area in real- time. Also, the system provides the facility to monitor the 1st contacts whose PCR samples have already been taken but the result has not been released yet and PHIs advise them to quarantine by themselves at their homes. The features of the SamrtCovidAssist system will be explained in section 3. Moreover, the section 2 and 3 explain the related work and further description about the SmartCovidAssist system. The section 4 and 5 explain the implementation of the system and the results and concluding remarks.

## 2. Related Works

Different systems and tools have been introduced continuously to diagnose the Covid 19. B. Udugama et al.in [8] introduced A combination of computed tomography imaging, whole genome sequencing, and electron microscopy were initially used to screen and identify SARS-CoV-2. Their main aim was to inform the audience diagnostic and surveillance technologies for SARS-CoV-2 and their performance characteristics. Thao Thi Ho et.al in [9] , introduced a deep learning modules for predicting severe progression in COVID-19 infected patients.Their main objective was to develop deep learning models that can rapidly diagnose high-risk COVID-19 patients based on computed tomography (CT) images and clinical data. They have analyzed 297 COVID-19 patients from several hospitals in South Korea and introduces a mixed model called ACNN; based on the artificial neural network for clinical data and a convolution-neural network for analyzing the 3D CT imaging data. Using the ACNN model the patients can be classified to high-risk cases with a severe progression from low-risk COVID-19 patients. By

using the mixed ACNN model, they could obtain high classification performance using novel coronavirus pneumonia (NCP) lesion images (93.9% accuracy, 80.8% sensitivity, 96.9% specificity, and 0.916 AUC (Area Under the Curve)) and using lung segmentation images (94.3% accuracy, 74.7% sensitivity, 95.9% specificity, and 0.928 AUC) for high-risk cases vs. low-risk groups. In these researches, they explained, how to identify the seriousness of the infected patients in order to get the clinical decisions.

Moreover, Erandi et.al in [10] discussed about how Sri Lankan Government controlled the COVID-19 widespread by actualizing a set of control strategies counting social distancing, quarantine, lockdowns, travel confinements, and isolation of villages and towns. They investigated the effectiveness of the overall control process with the aid of classical compartment models and network models and the results indicate that the prevailing control strategies are effective with at least 50% contact rate reduction or with at least 40% isolation of the contact history of infected population.

To fight against COVID-19, Geographic Information System (GIS), ICT, IoT, mobile technology (mHelath), big data, and data science can play an important role in many aspects to prevent the spread of COVID-19. Chenghu Zhou et.al. in [11] surveyed how GIS, and big data can be used for rapid visualization of epidemic information, spatial tracking of confirmed cases, prediction of regional transmission, spatial segmentation of the epidemic risk and prevention level, balancing and management of the supply and demand of material resources, and social- emotional guidance and panic elimination, which provided solid spatial information support for decision-making, measures formulation, and effectiveness assessment of COVID-19 prevention and control. Also, they introduced ten challengers in using GIS with spatiotemporal big data. Mohammad Nasajpour et.al in [12], explained how IoT-enabled/linked devices/applications such as wearables, Drones, Robots, and smartphone applications can be utilized to lower the possible spread of COVID-19 to others by early diagnosis, monitoring patients, and practicing defined protocols after patient recovery.

Moreover, Y. Dong and Y. -D. Yao in [13], has done a survey; how IoT platform uses for COVID-19 prevention and control and they presented how the IoT could be incorporated into the epidemic prevention and control system by demonstrating a potential fog-cloud combined IoT platform. Also, they explained how that platform can be used in the systematic and intelligent COVID-19 prevention and control, which involves five interventions including COVID-19 Symptom Diagnosis, Quarantine Monitoring, Contact Tracing & Social Distancing, COVID-19 Outbreak Forecasting, and SARS-CoV-2 Mutation Tracking.

However, most of the above mentioned non-clinical research works are surveys and they did not introduce a precise application to monitor the COVID-19 patients and 1st contacts who are being quarantined at their homes or quarantine centers. The more of the patients, the lesser opportunity to find a hospital or intermediate quarantine center with medical caring. Therefore, in this paper we introduce a mobile App and the Remote Monitoring System for Covid patients (RMSC), 1st contacts and those who are waiting for PCR results. The features of the system will be explained in the section-3.

## 3. Proposed System: Smartcovidassist

The SmartCovidAssist is a COVID – 19 patients and 1st contacts monitoring system in IoT environment. This system has two components: a Mobile App and a Cloud enabled back-end system also called Remote Monitoring System (RMS). The components of the system (Front end Mobile app and back-end components of our system will be explained below.

### *A. Mobile App*

- ***User Registration using Mobile App***

A mobile app has been developed to support both iOS and Android users and it can be downloaded and installed from App Store and Google Play Store. The user first register in the system by providing the information about user and he/she can register as an individual user or as a group with family members who are living with the user. Then the user can select one of the following three status:
COVID Positive – In this status, the user has been diagnosed as COVID positive from the PCR test or Rapid Antigen Test (RAT).
PCR Result Pending – The user has carried out a PCR test but the result has not been given the yet. Hence, as there is a possibility of COVID positive or negative they also can register in the system under this status.
COVID Contacts – This group of people are the 1st contacts of a COVID patients, and the PCR tests have not been done yet and the PHIs advise them for self-Quarantine at their homes. Moreover, the PHIs paste a notice in front of the house saying the inhabitant of this house is currently undergoing quarantine and these people cannot go out of their homes until the duration of 14 days.
The Fig. 2 and 3, illustrates the Mobile app for the registration with the remote system and select the status of the patients or contacts.

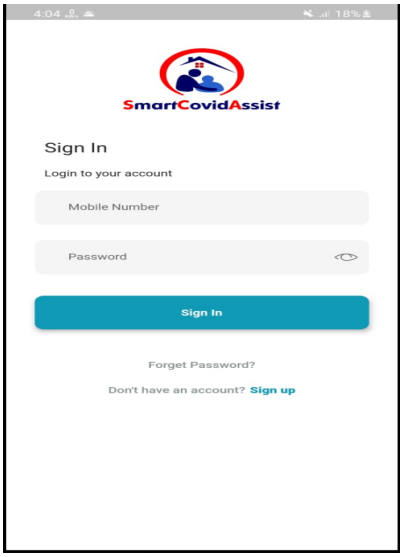


Figure 2: Mobile app for the registration of the user

The COVID patients and 1st contacts must clearly mention in the system when they registr in the SmartCovidAssist System whether they are COVID Positive, or they are waiting for PCR result (PCT result waiting), or 1st contact of a COVID patient in the profile window of the mobile app shown in the figure 3.
The status can be changed from the profile window after PCR result comes and can be changed the status as COVID positive or negative.

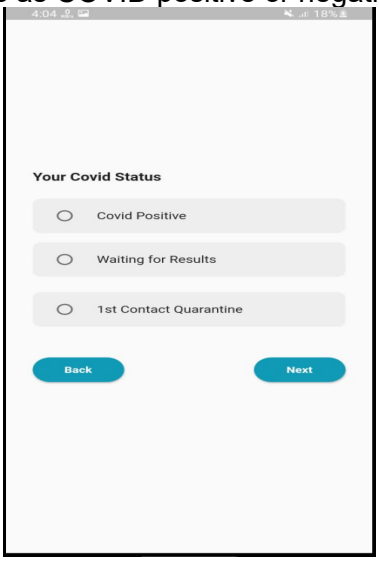


Figure 3: Mobile app to select the status of the user

- ***Sending the Symptoms to the back-end system to analyze***

The above-mentioned user groups might suffer from fever, dry cough, and/or shortness of breath. In addition to that diarrhea, chest tightness, dyspnea, palpitations, sneezing, fatigue, runny nose, chest pain, dizziness, nasal obstruction, headache, conjunctival congestion, myalgia, chills, itchy eyes, and joint pain can also be observed in patients but not frequently. The Mobile app provides the facility for the registered patients and 1st contacts to send the above-mentioned illnesses to the back-end system twice a day using following UIs. The system sends alerts two times a day reminding to the patients and 1st contacts to send symptoms they have and marking the symptom levels given in the mobile app to the back-end system. The figures 4,5, 6 and 7 show the snapshots of the mobile app that the patients can use to send the symptoms to the back-end system.

The Figure 4, will be used to get the shortness of the breath of the patients and they inhale in hold the breath and press. When they feel uncomfortable press stop and release the breath. The number of seconds that they hold the breaths will appear in the mobile screen and it will automatically submit to the system.

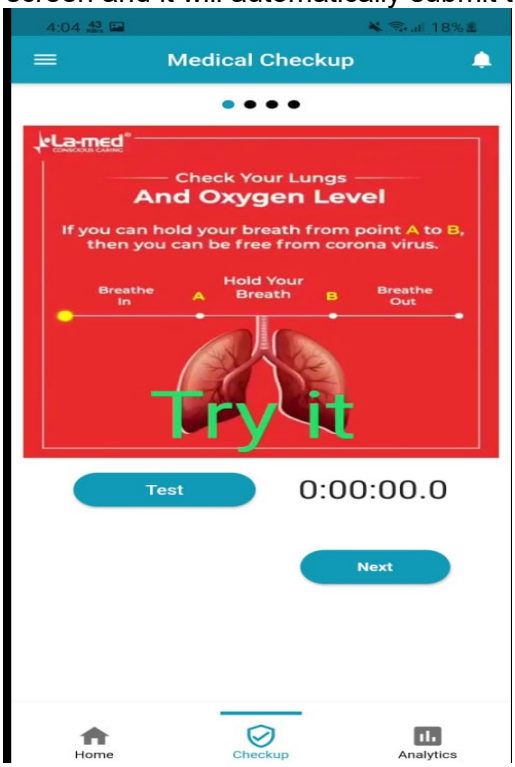


Figure 4: Check the shortness of the breath of the user

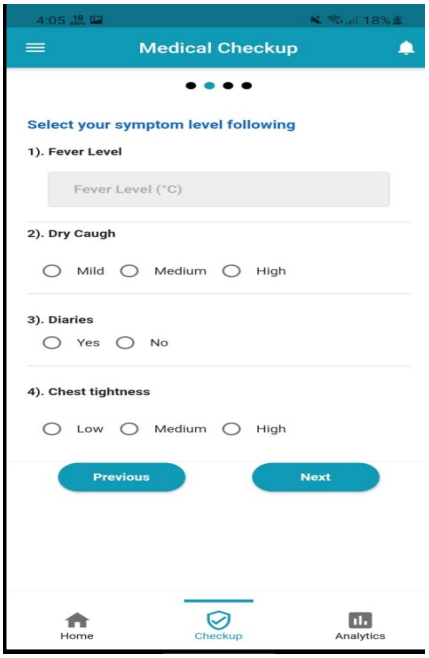


Figure 5: Select the patients' Symptom Levels and send to the back-end

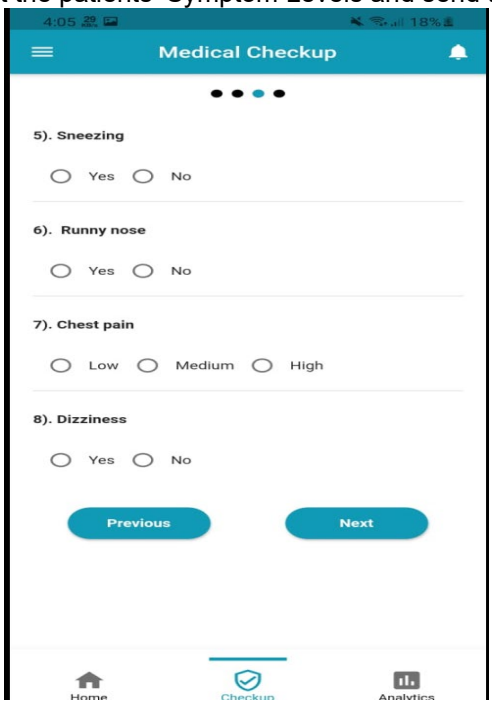


Figure 6: Select the patients' Symptom Levels and send to the back-end

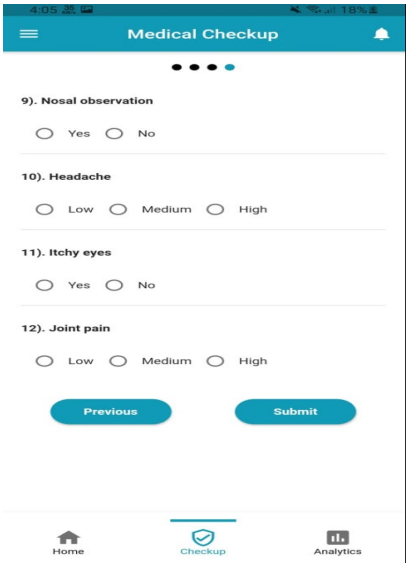


Figure 7: Select the patients' Symptom Levels and send to the back-end

### *B. Remote Monitoring System (RMS)*

The symptoms with its levels will be sent by the patients and 1st contacts to the back-end system. The sent data will be analyzed by using the threshold values given by the panel of doctors in different specialties. These threshold values were given after examining many COVID patients and their symptom levels. The threshold values for such symptoms are and given in table 1 below.

**Table 1: Threshold values of the symptoms**

| **Symptom** | **COVID positive values** | **Normal values** |
|---|---|---|
| Shortness of the breath | Yes | No |
| Breath hold | Less than 25 second | More than a minute |
| Fever | (98-100)0c | 940c or less |
| Dry caugh | Yes (3 days) | No |
| Sneezing | Yes (3 days) | No |
| Runny nose | Yes (3 days) | No |
| Chest pain | Yes (2 days) | No |
| Dizziness | Yes (2 days) | No |
| Diarrhea | Yes (one day) | No |
| Chest tightness | Yes last 1 hours | No |
| Headache | Yes | Yes/No |
| Joint pain | Yes/No | Yes/No |
| Itchy eyes | Yes/No | Yes/No |

The Remote Monitoring System is specially developed for monitoring the COVID -19 Positive patients and 1st contacts who are being self-quarantined at their homes or quarantine centers. Moreover, the family members who are being quarantined in the same location can use the Smartcovidassist system and it provides the facility to register with family members. The features of the RMS system will be explained below.

The RMS system provides different user levels: different user levels will be given the different privileges. For instances, the PHIs can only see the information about the patients and 1st contacts who are in the GN divisions assigned to him. Moreover, he will be given alerts and generate reports only from the assigned GN divisions to him. The MOH medical officer can see the COVID information of its MOH division and generate reports. As same as the Provincial Director of Health can visualize and generate reports only in his province and the Director of the COVID Prevention Center - Ministry of Health will be able to see the information of all the provinces using our RMS system.

Each RMS user levels can see the COVID positive list, PCR result pending list, PCR Negative list, list families and individuals who are being quarantined at their homes and the people who have finished 14 days of quarantine period in GN wise, MOD division wise, province wise, hospitalized list and list of the death in quarantine period.

The RMS system dashboard shows the summery of the statistics COVID patients and 1st contacts of the user's name space. This shows the real-time information such as number of Covid positive patient, hospitalized patients, patients who have finished the quarantine period, number of vaccinated people etc.
The critical patients whose medical illness reports are below the threshold level will be shown by blinking the patient's name in red color in the dashboard. The PHI can get an immediate action to the patient by hospitalizing him/her or sending to a vacant ICU to give the necessary immediate medical treatments.
If the patient is hospitalized, the status must be changed to the hospitalized and the patient is deactivated from the system and add to the hospitalized list. This can be done either PHIs. If a patient passed away during the quarantine period, the RMS system must change the status of the patient as Death and enters the date that he/she died.

The RMS system provide the facility to the registered patients to see their analyzed medical reports and charts daily. Figure 8 shows patient's symptoms have been analyzed and show in charts and graphs to the patients from the mobile app.


Figure 8: Visualize the analyzed data to the mobile users

The RMS system uses the Artificial intelligence and data analytic techniques and algorithms (clustering) to predict the COVID spreading in each province in future. It will help to get the strategic decision for controlling the COVID -19, by imposing lockdown the places.The patient's mobility will also be recorded using the coordinates sent from the mobile phone and analyze his movements by the PHIs.

## 4. Implementation of the Smartcovidassist system

The following Fig.9 illustrates the high-level architecture of the SmartCovidAssist system. The architecture consists of three layers: Perception Layer, Network Layer and Cloud Layer. Each of the layers are explained below.

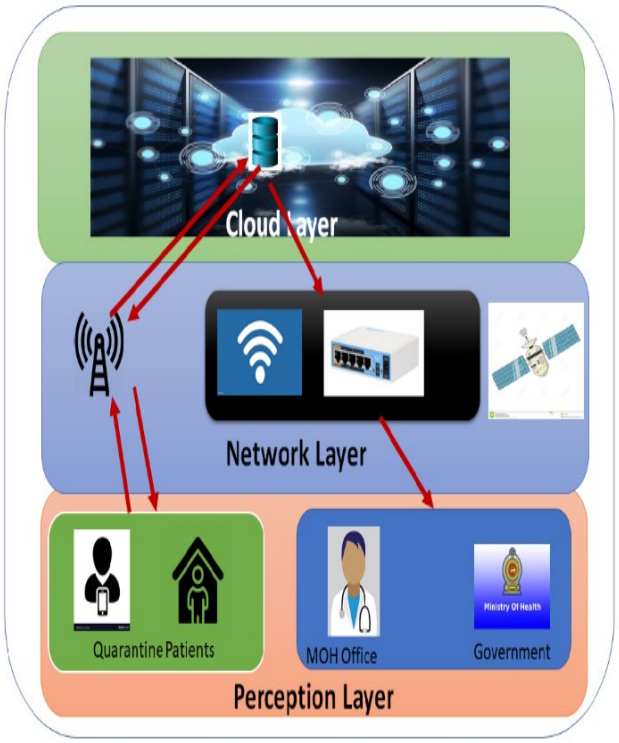


Figure 9: Illustration of the SmartCovidAssist High-level System Architecture

### *A. Perception Layer*

This layer provides the facility for the end users such as the COVID positive quarantined patients and PCR result pending 1st contacts to enter the symptoms to the system and the MOH and PHIs in the divisions, provincial Director of Health, and the Director of the COVID Prevention Center – Ministry of Health to view the analyzed COVID information The Quarantine patients can use their mobile device for entering the symptoms twice a day. Also, using the inertial sensor such as accelerometer and gyroscope equipped in the mobile phones and using the GPS technology the system can detect the mobility or movements of the patients continuously during the quarantine period.

### *B. Network Layer*

The network layer is responsible for data communication between the RMS system in the cloud layer and the information and/or instructions to the end-users who are in perception layer in IoT platform. The information transmission relies on the public or private network with the wireless or wired communications mode, which includes 4G/5G cellular networks, Wi-Fi networks, and satellite networks. The mobile users may only use the 4G/5G cellar networks and the other RMS

users may, use all sorts of communication modes abovementioned, for accessing the RMS system.

### *C. Cloud Layer*

The cloud layer in this system architecture, uses a data center, which possesses strong information processing and storage capability. The data center of the cloud layer is responsible securely store the COVID related data sent by the end-users analyze it and the result also will be visualized to the end-users. We executed the system using 120 test cases and we selected 8 GN divisions in 4 MOH divisions in two provinces. We got equal number of COVID positive, PCR pending and 1st contacts to validate our system. Each MOH division tested 2 GN divisions with PHI and each of which was given equal number of cases to check with the system. The summery of how the test cases were allocated is given in the Table 2.

**Table 2: Summary of the Test Cases**

| Province | MOH Division | GN Division | PHI | COVID Positive | PCR Pending | Contact home quarantine |
|---|---|---|---|---|---|---|
| North Western | Kuliyapitiya , Hettipola | 4 | 2 | 20 | 20 | 20 (including a family) |
| Western | Maharagama Kaduwela | 4 | 2 | 20 | 20 | 20 |

Here we mainly considered and entered the MOH division, GN division and the addresses of the test cases. The patients and, PCR result pending, and 1st contacts were registered in the system in different dates in a week. All these groups had to upload the symptoms twice a day from their mobile app. Then the RMS system analyzed the result, and it was visualized to the patients and to the PHIs, MOH of the said divisions, Provincial Director and the Ministry of Health.
During the period of testing the system, we changed the status of the PCR result pending contacts to PCR positive, and let the patients and quarantine contacts to finish the quarantine period. The system automatically deactivated the 14 days completed patients and names of such patients were added to the quarantined list. Also, we tested the above-mentioned features from these test cases to validate the system and to implement the QA process.

## 5. Results and Concluding Remarks

We tested all the functions of the SmartCovidAssist system mentioned in the Section III, using the above-mentioned test cases (120 test cases) in the two provinces. All the functions were working well, and we got the good comments

from the PHIs, MOH and other administrative officers who used the system. PHIs were highly satisfied with this system as they need not to enter the patients' information to the system and they could get the real time information about the patients. As the system provides the GPS location of the patients, the PHIs could easily find the places of the patients. Further, they wanted to generate the certificates given by MOH office to the COVID positive and Quarantine 1st contacts after they finish the quarantine period from the system. The system did not provide that facility and we will develop that feature before the system is going live. Moreover, they said that the system was very convenient as they can see patients and 1st contacts of the assigned GN divisions from the smart phones. Hence, wherever they are and whenever they want, they can easily access the patients and 1st contacts. Also, COVID analysis reports were very useful to understand the future condition and it would help to get the right decision in right time.

Currently, there are 331 MOH divisions and 14022 GN Divisions in Sri Lanka and there are only 1710 Public Health Inspectors (PHI) are working in all these GN Divisions. Hence, one PHI may be assigned 8 or more GN Divisions to work and having the system for managing the COVID patients and Quarantine contacts would be very helpful for them. Furthermore, there were 30.41 million mobile connection in Sri Lanka in January 2021[14]. From this statistic, we can assume most of the COVID positive patients and 1st contacts may use the mobile phone. Hence, they can download the SmartCovidAssist Mobile app, register in the RMS system and upload the symptoms to the app twice a day.
If the system is implemented in Sri Lanka covering all the provinces, MOH and GN divisions it can be generated the reports in GN division, MOH division, district, province and national wide as follows.

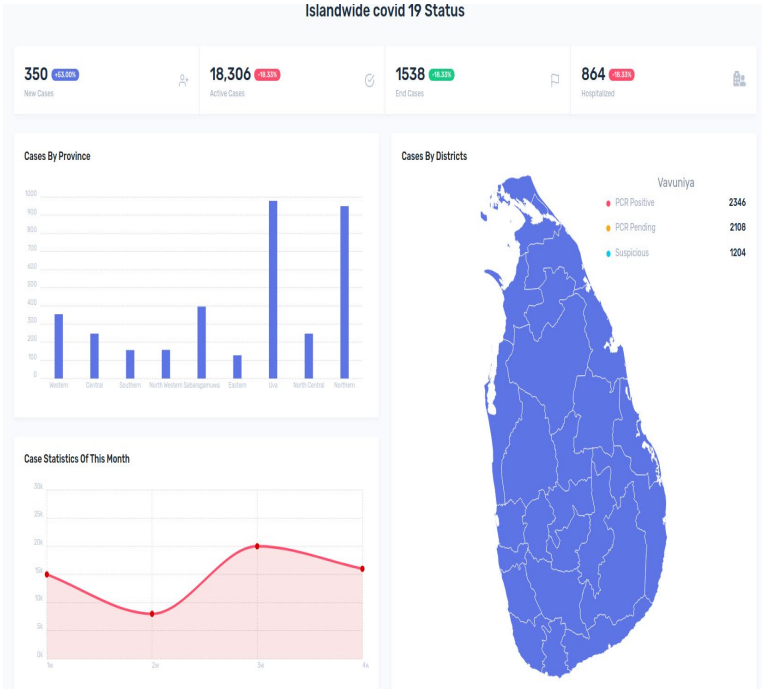


Figure 10: Island wide COVID 19 Status

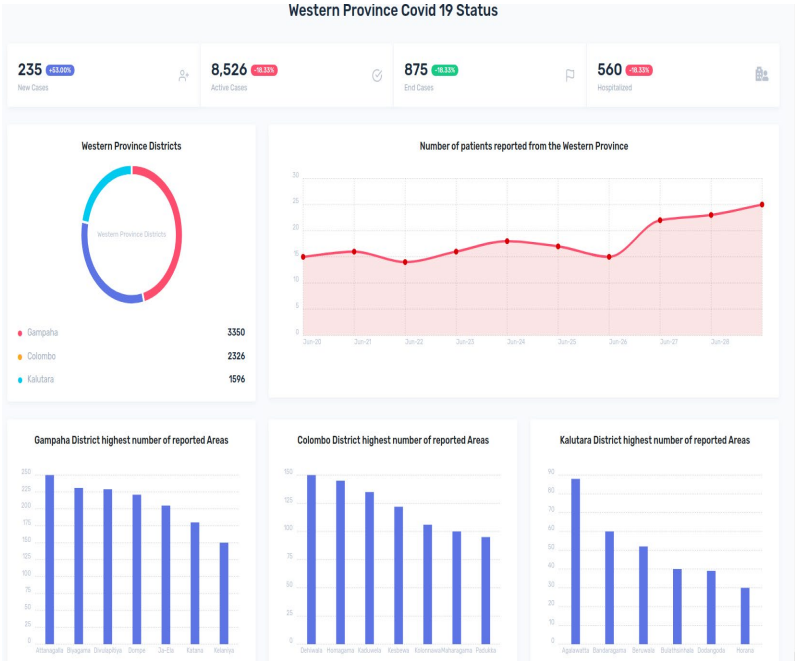


Figure 11: Province wise COVID Status

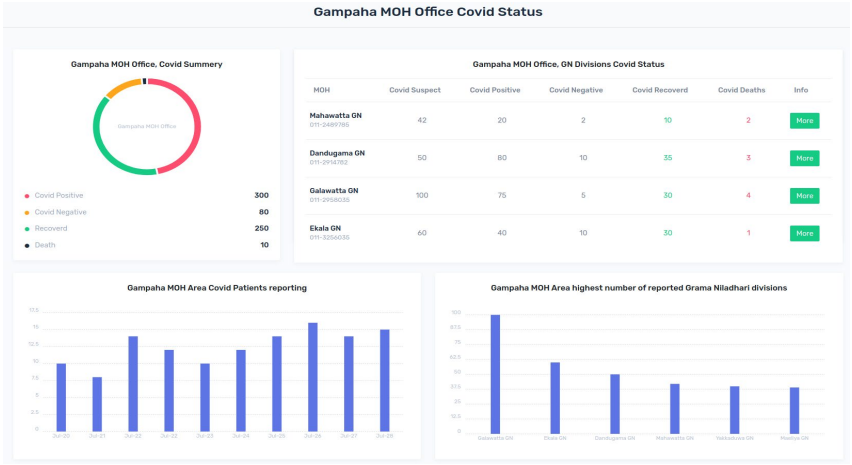


Figure 12: MOH division wise COVID Status

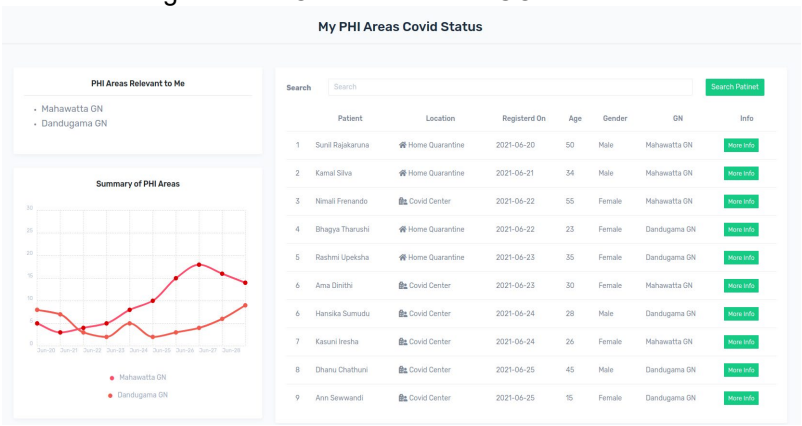


Figure 13: GN Divisions assigned to PHIs can see the patient's information and COVID Status of their GN divisions


Figure 14: Information and the health condition of the Quarantine patients and suspect can be seen by the registered users of the RMS.

At the time of writing this paper, we are in the process of getting the ethical clearance from the Ministry of Health to implement the system. Also, to get the ethical clearance, the system must ensure the maximum security of the patients'data and need to authenticate the access of the system. Therefore, we introduce the authentication methods for each user level of the system users and defined the user levels with set of privileges for each user level to access the system. Finally, the system must be installed in the Government Cloud environment to satisfy the requirements imposed by the government. When the system is granted the ethical clearance, the system will go live in all the provinces in Sri Lanka catering to the pandemic management.

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