



iQMS: IoT-based QMS framework for tracking of quarantined subjects

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Received: 12 November 2021 / Accepted: 23 April 2022 / Published online: 1 July 2022

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Abstract The outbreak of Coronavirus Disease as a pandemic has resulted in a huge saddle on health infrastructure. Preventive measures such as quarantine, social distancing, isolation, and community containment play a pivotal role to contain the spread of exponentially growing COVID cases. This huge burden permitted authorities for institutional/home quarantine for the suspected persons. The biggest challenge for institutional/home quarantine is to monitor and track the movement of quarantined persons. These suspected cases pose a serious threat in outbreak and transmission of the disease. In this paper, an intelligent-Quarantine Monitoring System (iQMS) has been presented which comprises of a wearable IoT-based wristband, bundled with an android mobile app to track and report the absconding quarantined subjects in near real-time. The iQMS incorporates a cloud-based solution with IoT sensors using a global positioning system (GPS) based tracker for geo-fencing breach. The proposed system will facilitate the authorities in remote monitoring and tracking of identified subjects.

Keywords IoT · Wearable · Wrist band · Coronavirus · COVID-19 · Smart devices · Android App · GPS monitoring system

1 Introduction

The Coronavirus Disease (COVID-19) has spread globally within a short span of time deteriorating the socio-economic conditions of the effected nations. Most of the countries are opting for more and more IT based interventions to contain the spread of the disease. The quarantine of suspected individuals or groups is an effective measure to contain COVID-19 spread to reduce the overburden on health infrastructure. Many researchers have estimated the exponential growth of COVID-19 cases with a high reproduction number ($R_0 > 2$) [1, 2].

However, quarantine effectiveness depends on an individual's social responsibility [3]. It has been reported that many quarantine cases get absconding. Tracking such absconding cases is one of the major challenges and needs to be addressed on priority to contain spread of Coronavirus. Further, tracking quarantine cases in near real-time would be useful to alert public health authorities to take effective measures to contain spread of rising Coronavirus cases.

In this context, a mobile app named Arogya Setu was developed in India to limit the spread of COVID-19. It is a bluetooth-based contact tracing app that maps the hotspots and disseminates COVID-19 related information. However, The effectiveness of the App depends on the voluntarily cooperation of the individuals by way of disclosing the write information.

iQMS, an IoT-based quarantine monitoring system is a tool developed for tracking absconding cases from hospitals/quarantine centers. The solution comprises of a IoT based wearable wristband bundled with a mobile application along with web interface. The purpose of the band is to ensure that Quarantined persons remain at the designated location and do not leave the premises unnoticed. Provisions made in iQMS based wristband to keep a check on the breach of

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virtual boundaries, temperament, body temperature and raise alerts to authorities as required.

2 Literature survey

The internet of things (IoT) is a scenario where interconnected devices, objects, and sensors have the capacity to produce, process, exchange, and share data with limited human interventions. In recent years, IoT based devices made a tremendous presence for innovative solutions like smart homes, security systems, smart speakers, smart lighting etc. Recently, the healthcare domain has received special attention for IoT devices to combat Coronavirus pandemic [4] like Smart Thermometers [5], IoT-Q band [6], Thermal Imaging Drone [7], Disinfectant Drone [8], and Surveillance Drone [9], automatic and telerobots [10], mobile applications like Capp [11], StopCorona, AarogyaSetu, Trace Together [5].

A variety of technologies like global positioning system (GPS), bluetooth, blockchain, and geographic information system (GIS) [12] were majorly used to combat spread of Coronavirus.

Mardiana et al. [13] has proposed an IoT-based quarantine monitoring to maintain for social distancing features via implementation of GPS based geofencing surveillance system that comprised of low cost reusable wristband connected to mobile apps for monitoring and surveillance of population. Hoang et al. [14] has proposed an alert system consisting of wearable device with integration of IoT based real-time quarantine monitoring of person's body temperature in isolation. El-Din et al. [15] proposed an E-Quarantine system to remotely monitor and identify high-risk coronavirus-infected patients to mitigate the contamination. It uses parameters such as blood PH level, blood pressure, heart rate, respiratory rate, and body temperature to predict emergency cases.

Similarly, researchers [16] have developed a graphical smart health system for physicians who can remotely visualize patient's data. Likewise, smart medical systems for hospitals to monitor patients' health status are proposed by many researchers [17, 18]. Most of the earlier works on healthcare wearable are based on fitness tracking [19, 20]. Zhao et al. [1] also proposed a multigesture wristband solution for gesture recognition using data segmentation techniques to segment hand gestures considering a series of hand movements.

Moreover, Woo et al. [21] have proposed one, mHealth and smart devices [22]. Senapati et al. predict covid-19 cases in India using piecewise regression method [25], Khanday et al. uses machine learning algorithm on text data to predict covid-19 cases [26]. Taking cues from the worldwide scenario of the pandemic at the time, the Government of Delhi realized the pressing need to track and isolate infected

individuals for their treatment and to prevent the spread of infection to healthy individuals.

3 Remote healthcare monitoring

Under digital health (tele-medicine) projects attempts had been to extend the specialist services to remote and inaccessible places through remote monitoring. The idea has been used in remote diagnosis of covid-19 cases using wearable devices. Since the health infrastructure had been insufficient to accommodate all diagnosed persons under hospital admission, authorities permitted housing of infected persons at various locations. But there were not sufficient healthcare professionals to monitor such quarantined patients. Hence the idea was conceptualized to implement the system which helps in remote monitoring of quarantined persons using IoT and GPS technology. The system can also be used to monitor the physical conditions of the quarantined patients.

3.1 Proposed quarantine monitoring system

This section presents a detailed description of the quarantine monitoring system (iQMS) to monitor quarantined subjects and to track any breach. The architecture of the proposed quarantine monitoring system comprises a sensor-based wearable monitoring device, command and control center, android mobile application, and a web interface is represented as in Fig. 1. The web interface includes dashboard associated with the quarantined subjects for administrative authorities.

The proposed solution is being implemented at New Delhi District on pilot mode and shall be rolled out to other areas. The system consists of a sensor-based wearable monitoring device that monitors the body temperature of the quarantined person and periodically sends alerts to the mobile app through Bluetooth. The band uses a

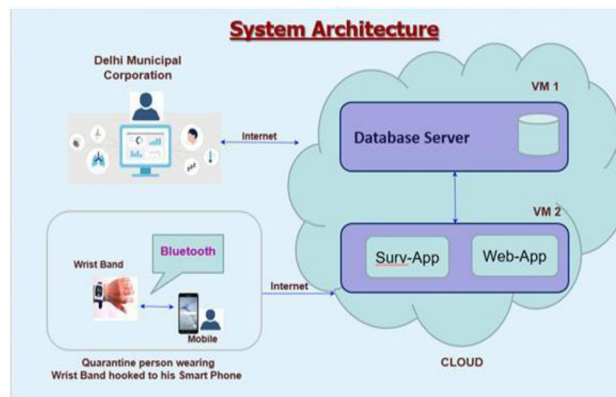


Fig. 1 Architecture of iQMS

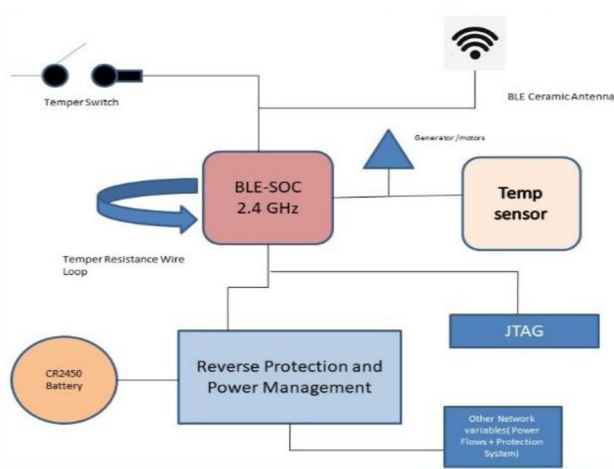


Fig. 2 Block diagram of the wrist strap

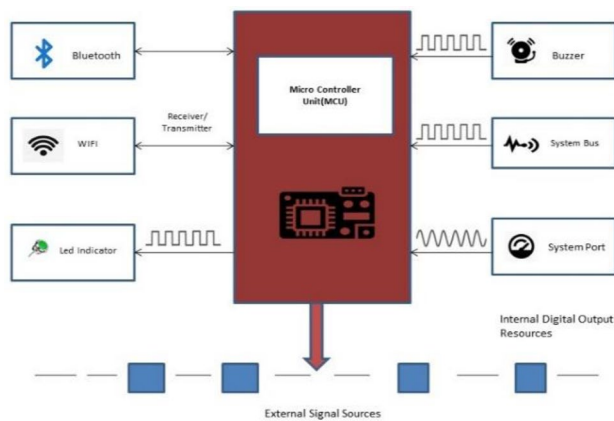


Fig. 3 Systematic representation of wrist band architecture

system-on-chip (SoC) integrated circuit [23] with bluetooth low energy (BLE) wireless sensors [24] used for a wide range of IoT applications. The SoC-BLE senses the tampering of the band at regular intervals to ensure proper functionality. The band includes temperature sensor to sense body temperature of the quarantined subject for prescribed temperature threshold. The wrist band communicates with mobile app to generate alerts for necessary action by the authorities.

The block diagram of the Bluetooth BLE-enabled wrist strap with a highly sensitive I2C semiconductor temperature sensor is referred at Fig. 2.

The main component of wrist strap contains CR2540 battery, a tamper switch, BLE ceramic antenna, and a power management component. Systematic wristband architecture is depicted in Fig. 3.

3.2 Administrative command and control

It is proposed that the integrated quarantine monitoring system (iQMS) will be deployed in Municipal Corporation and District Disaster Management Authority (DDMA) will be authorized to command and control the iQMS implementation. Authorities can access the system through Android app supported by web interfaces. This iQMS system will also be integrated with Covid-19 Control and Command Centre.

4 Operational methodology

Algorithm:

- Step-1:* Connect wristband with smart phones,
- Step-2:* Collect GPS data,
- Step-3:* If connected then go to next step else go to step-6,
- Step-4:* Verify location,
- Step-5:* Check if in geofence then go to second step else go to next step,
- Step-6:* Send location to the server,
- Step-7:* Play wristband buzzer,
- Step-8:* Connect with person.

4.1 Command and control centre

iQMS comprises a layer of server applications including Web App, Surv App, and backend database used by the authorities of covid-19 command and control centre. At initial stage the web-based dashboard displays role based login for various administrative setups. Next, the Surv App is used for sending time bound SMS alerts and monitoring mobile connectivity. Alerts are generated for high body temperature, geo-fencing breach, temperament with band, connection lost, inactive GPS, internet/mobile off, loss of connectivity with the cloud. Using administrator role, one can manage users and assign roles for various authorities like state admin, district magistrate, sub divisional magistrates and field staff.

4.2 User web interface

The system has role-based web interfaces for various authorities for monitoring of quarantine centers. Authorities can access information associated with the quarantined subjects/centre after authorization. Figure 4 presents the user registration form for addition of role-based users on the system. Figure 5 depicts the login window for registered users.

Once logged in, the users can see a dashboard displaying information about the quarantined subjects such as number of individuals under quarantine, number of individuals completed the quarantined period, various alerts for individuals on geo-fencing breach, mobile data status, temperature threshold, band tampered, total alerts sent etc. The

Username:
 Name:
 Mobile No.:
 Role:
 State:
 District:

Fig. 4 User registration

Username:
 Password:
 Role:

Fig. 5 Login form

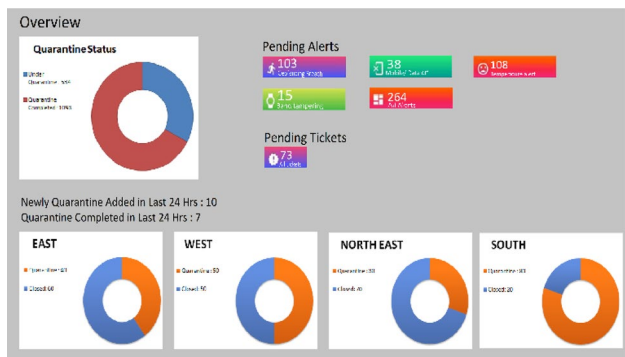


Fig. 6 Quarantine dashboard

dashboard also displays the 24 HRS status for individuals quarantined or quarantine completion in different regions as shown in Fig. 6.

The 24×7 running mobile app needs to be installed into the subject’s mobile for configuring the details of quarantined person for wrist band connectivity, geo-fence location, and permitted radius. To facilitate ease of registration and user support, the quarantine tracker app is facilitated with quarantine configuration guidelines, safety tips, helpline numbers, report formats and tracking issues. The home screen of the mobile app is depicted in Fig. 7. The



Fig. 7 Home screen of the quarantine tracker mobile app

Add Quarantine Person
 Patient Name:
 DOB: Age:
 Father's Name:
 Male Female Other
 Mobile No.:
 Alternate No.:
 Band Id:
 Address Line 1:
 Address Line 2:
 Pincode:
 State:
 District:
 Subdivision:
 Police Station:
 Quarantine End Date:

Fig. 8 Configuration details

quarantined person can be registered by a field user who is an authorized person for processing registration through quarantine configuration. Figure 8 presents the form for quarantine configuration. SMS-based authentication is also provided for registration.

A quarantined person can raise tickets to the concerned authority if facing any issue. During registration of a person under quarantine his details, the band Id, quarantine end date, location (GPS location auto fetch), and radius for creating geo-fencing (between 10 to 100 m) are fed by the field user.

The mobile app checks the availability of the band Id and if the band Id is free to use, the app gets the mac address for entered band Id and uses it for Bluetooth connectivity.

The band connectivity is periodically checked at every 1 min interval and if any band disconnection alerts are generated it is displayed on the mobile. Moreover, if three consecutive alerts are generated then the alerts are sent to the server and the corresponding SMS are sent to the concerned authority (e.g. SDM). In addition, alerts are generated whenever any tempering happened with the band. Besides these,

the mobile app also provides a number of safety tips and the latest information related to COVID-19 to quarantined users. It also shows the helpline numbers to quarantined users if he/she requires any additional supports. Further, the mobile app has the facility to report any issue faced by the users and the users can track the reported issues.

While registering a quarantined person at his home, the GPS location of his home center point is being taken, and depending on the area of house geo fence radius is being entered by field user who is doing registration process on behalf of quarantine person.

The location of the quarantined person is periodically checked at a regular interval of one minute to track whether the person is within the defined periphery or not. If the quarantined person breaches the defined radius then a local alert is prompted on the mobile. If three consecutive alerts are generated, the alerts are sent to the server and the corresponding SMS shall be sent to SDM. When the geofencing is breached the mobile app sends coordinates to the server for monitoring. Alerts are also generated whenever the temperature of the quarantined person as recorded by the band sensor is above the predefined threshold value.

On the server side, there is a facility to check the mobile connectivity whether the mobile connectivity is available or not. If the mobile connectivity is not found three consecutive times, alerts are generated and sent to the higher authorities.

Once the quarantined person is registered, the mobile application continually sends packets with embedded information to the cloud server at a regular interval of time. The packets possess information such as GPS coordinates, and wearable bands working state. There is also a web-based facility to escalate the alerts in a hierarchy from SDM to DM

to State admin whenever any concerned authorities do not respond to the pre-defined time of response.

Figure 9 represents a complete workflow diagram of the quarantine monitoring systems. The quarantined person wears a band, which reports the band status and body temperature to the mobile app.

The app is configured with geolocation and geofencing radius, and the number of quarantine days left in the quarantine center or home. Alerts about the quarantined persons, band status, and geolocalized data are pushed to the IoT-based cloud server. All these details are fed into the admin dashboard which is monitored by the administrative authority state admin and the authorized users such as DM, SDM, and Field staff. The web interface of the quarantine monitoring system allows centralized control and helps to track together quarantine subjects.

4.3 System implementation

The proposed technology solution is developed and attested in Municipal Corporation of Delhi (MCD) zones for Once the approval of received from a Security authorities DGHS (Director General of Health Services) they shall be rolled out to other areas including Airports, Railways, and other sensitive localities. The prototype of the system is deployed over the NIC cloud.

System requirements: two virtual machines (VMs) are envisaged on Cloud for the QMS project of which one is for database and another for application hosting. Table 1 presents the required database VM configuration, while Table 2 presents the required configuration for application hosting VM. Table 3 presents the system requirement for

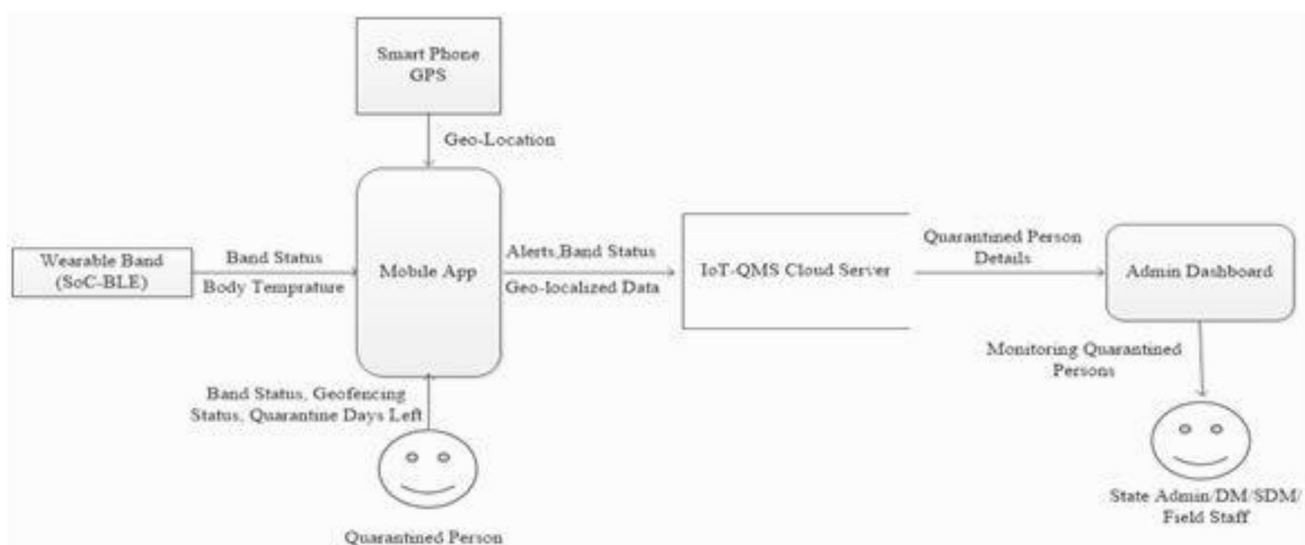


Fig. 9 Workflow diagram of the quarantine monitoring system

Table 1 Configuration of database VM

Type	Required configuration
OS	RHEL Server 7.4
CPU	16 Core
RAM	32 GB
Space	60 GB; additional 500 GB

Table 2 Configuration of database VM

Type	Required configuration
OS	RHEL Server 7.4
CPU	16 Core
RAM	32 GB
Space	60 GB; additional 100 GB

Table 3 The system requirement for deployment of NIC QMS

Deployment type	Deployment requirements
OS	RHEL Server 7.4
Web application deployment platform	Apache-TomCat.9.0.6, JDK 1.8.121
Surv App deployment platform	JDK 1.8.121
Database deployment platform	Mongo-DB, JDK 1.8.121

deployment of NIC QMS. Results of the devices over which the mobile app was tested is described in Table 4.

Figure 10 presents the screenshot of the web interface with details of the administrative authorities such as state admin, DM, SDM, and field staff who control and monitors the system. There is a facility to add, modify, and update such users with their details such as name, role, state, district, sub-division, locality, and the concerned police station. The super admin can update the user details by clicking on the update button and can delete or reset passwords. The users of the system have the facility to view and generate reports of the quarantined cases.

Figure 11 depicts the window of a detailed alert report view consisting of information about quarantined persons and the breach conditions. Figure 12 presents the detailed report generation widow with the facility to generate a report of the quarantined cases in a given period depicting the details of the districts, subdivisions, and other information of the quarantine persons. Moreover, the individual alerts of quarantine beaches by the quarantine subjects can be viewed and closed by the users. The view and close alert of the quarantined person who breached the geo-fencing of the quarantine center/home depicting details reaches to authorities on real time like alert type, start and end quarantined date, geo-coordinate, and other information.

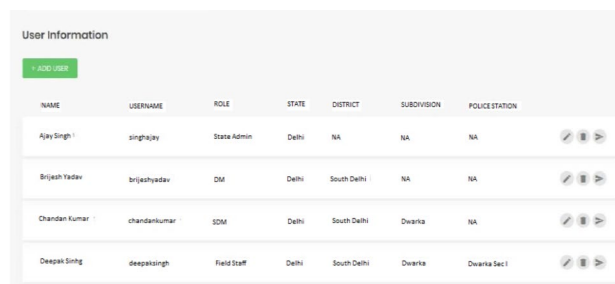


Fig. 10 The screen showing the user information

Further, there is a facility for quarantine persons to report an issue on which the persons need any support. He can report an issue and track the reported issue through the mobile app. Figure 13 presents the screenshot of the widow to report and track issues.

5 Conclusion

Monitoring of quarantined patients is essential to prevent escalation of COVID-19 cases as there is a possibility that defection and absconding cases may transmit the highly contagious coronavirus disease to other persons, groups, or communities. New and innovative means and tech solutions to contain the spread of the virus are extensively explored across the research and technology community. In this context, cloud-based solutions together with IoT-based sensors and mobile applications can easily track the registered quarantine subjects through GPS trackers and alerting the authorities of any geo-fencing breach. In this paper, we proposed a quarantine monitoring system consisting of IoT based wristband bundled with a mobile app, and a web interface and adopting a cloud platform to ingest, process, and analyze information about the quarantine subjects. The proposed system is centered on monitoring quarantined patients to track their movement, body temperature, and breach in the quarantine norms such as geo-fencing and band tampering. The purpose of the system is to contain the highly contagious coronavirus disease and prevent it from spreading further to any individual or community. Such systems will be of utmost importance in situations and countries where there are insufficient infrastructure and public health services, unsafe work conditions, shortage of safety equipment, and overburdened public health workers.

6 Future scope

Health indicators such as body temperature, SpO₂ and pulse rate are some of the important factors to determine the suspected cases of Novel Coronavirus.

Table 4 Results of the devices over which the mobile app was tested

S. no.	Test performed with App version 0.17 Status (OK/not OK) as on 8th July 2020									
	Make	Model	Android Version	Band connectivity	Temperature reading	Geo-fencing violation when moved away	Hanging issue under endurance of 2 h	App reopening after closing once	4 devices configurable	Remarks
1	Samsung	7 on pro	6	OK	OK	OK	OK	OK	OK	
2	Asus	Zenphone max pro m1	9	Intermittent	OK	OK	OK	OK	OK	
3	Redmi	Note 7 Pro	9	OK	OK	OK	OK	Not OK*	OK	1. Frequent app. crash issue. * RAM clear when all application are closed at once
4	Samsung	m30 s	10	OK	OK	OK	Not OK	OK	OK	
5	MI	A1	9	OK	OK	OK	OK	OK	OK	
6	Redmi	Note 5	9	OK	OK	OK	OK	OK	OK	
7	Redmi	Note 5 pro	9	Intermittent	OK	OK	OK	OK	OK	
8	Samsung	m30s	10	OK	Not OK	Not OK	OK	OK	OK	# Frequency is more compared to other mobile phones
9	Vivo	z1 pro	9	OK	OK	OK	OK	OK	OK	
10	MI	4	7	OK	OK	OK	OK	OK	OK	
11	VIVO	S1 pro	9	OK	Not OK	Not OK	OK	OK	OK	
12	MI	6 PRO	9	OK	OK	OK	OK	OK	OK	
13	Nokia	6.1	10	OK	OK	OK	OK	OK	OK	

Name	Mobile No	Address	View Breach Condition	View Previous Breach
Rampal	77777777	23 Ring Road South Delhi	📍	📄
Reena	88888888	14 Arthur Road, East Delhi	📍	📄
Raju	99999999	4 East, Ram Nagar, North East Delhi	📍	📄
Tina	785491258	65, Charuch Road, West Delhi	📍	📄

Fig. 11 Alert reports

Name	Mobile No	Address	Details
Rampal	77777777	23 Ring Road, South Delhi	📍
Reena	88888888	14 Arthur Road, East Delhi	📍
Raju	99999999	4 East Ram Nagar, North East Delhi	📍
Tina	785491258	65, Charuch Road, West Delhi	📍

Fig. 12 Window for the report generation of the quarantine persons

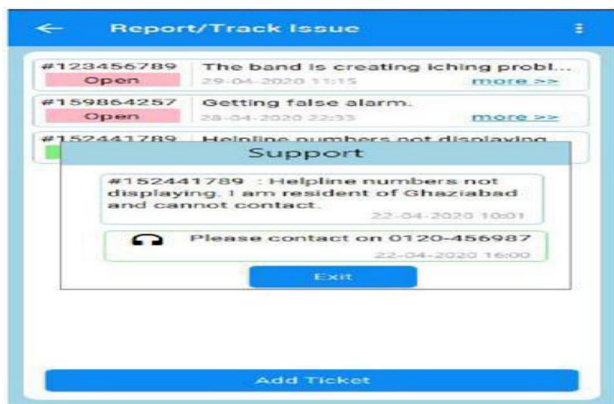


Fig. 13 Window of the mobile app to report and track any issue faced by user

Wearable devices are the physical monitoring systems which are easy to carry, use, affordable and provides real time status as well. The scope and future of IoT base wearable devices to monitor physiological parameters is endless. This handheld system is easy to carry and provide the exact GPS location of the patient and allow the authorities

to respond to any emergencies required. The proposed system uses a wristband which is based on Lithium battery and can be upgraded to solar based wristband for longer battery backup.

There was no functional model at the time we developed and did trail for this model. Though wearable devices were in use in other areas like manufacturing, industrial and scientific applications. It was in conceptual stage as module of telemedicine projects. But the COVID-19 pandemic accelerated the adoption. Several countries were simultaneously working in this area. India being one of the pioneers where this methodology is successfully carried out.

Acknowledgements This research work is supported by Visvesvaraya PhD Scheme, under Ministry of Electronics & IT (MeitY), Govt. of India and Govt. of NCT Delhi

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