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Real Time Nursing Management System for Health Care Industry by using Xenomai Kernel

Swapnil Vir Lal[1*], Ravishankar Palaniappan[2] and V. Prakash[1]

[1]School of Electronics Engineering, VIT University, Chennai - 600127, Tamil Nadu, India; swapnilvirlal@outlook.com, Prakash.v@vit.ac.in
[2]Research and Development (R and D), Strobilanthes Tech. Sol. India Pvt. Ltd., Chennai - 600010, Tamil Nadu, India; ravishankar@strobilanthes.com

Abstract

Background/Objectives: Doctors and patients are the primary stake-holders in patient care life-cycle. The vital role of nursing assistants and other supporting medical staffs like cleaning is often neglected. The goal of this work is to create a bridge-module between nursing staff and patients to provide best standard class patient care. **Methods/Statistical Analysis**: This paper discusses the issues in nursing management and proposes methodology involving real-time intelligent embedded system and analyses its outcomes. The proposed solution comprises of Radio Frequency (RF) and wearable technology to bridge the communication between patient and care-giver and data analytics modules to store, analyze and access the in-sights. The Xenomai Real Time Kernel on a System on Chip (SOC) that is imperative for real-time scheduling of critical tasks. This system also got capability to store and analyzes the urgency records from patients, which are critical for identifying the inefficiency in process or resource utilization. **Findings**: Existing Nursing management systems are software based solutions which lacks in maintain the communication from the patients in real-time. Proposed system provides facility to patient to request for service and any time. This also stores the services in its database, which can be utilized for prediction by performing data analytics modules. By predicting the patient's service, nursing staff can prepare itself in advance for serving patient services, Hence it is providing support in utilizing the resources effectively. **Conclusion/Improvements:** In this paper, the gateway is designed to act as a central monitoring system, which provides worthy addition to present hospital management systems. RF Remote and watches are used to provide communication between patients and nursing care. Both hardware and software design of gateway is discussed briefly with series of outputs, which proves that proposed systems is feasible and efficient in real-time scenario.

Keywords: Health Care, Nursing Management System, RF Technology, System on Chip, Xenomai Real Time Kernel

1. Introduction

A health care system includes an institution or an organization of people that delivers health care services to meet the health needs of patients. In hospitals, number of patients is increasing rapidly every day. Due to overcrowding in hospitals, patients fail to get proper treatment on time due to shortage of doctors, nurses, cleaning staff and sometimes also due to lack of resources like non-availability of bed, electricity etc. The Indian Express newspaper states that India is having just 1 doctor per 1700 people[1,2]. And this ratio is decreasing day by day. Due to which, it is becoming increasingly difficult for a doctor to focus properly on patients which turns out be a major reason for poor health care. As per the Indian Nursing Council, 3 nurses per patient should be there[1]. But as per statistical survey[3], only one nurse was found available for 40 patients in Bangalore, which is one of most developed city in India. Cleanliness or hygiene plays an important role in being healthy and fine. According

*Author for correspondence

to reports, hospitals in India are in tight crunch of hospital staffs which is resulting in hygiene hit. Hygiene and cleanliness must be maintained properly at hospitals to prevent any disease from spreading[3]. Cleaning assistance is required on time for the critical patients who are unable to move themselves and are not able to help themselves to washroom either due to surgeries or bone fracture etc.

Most of the people misunderstand that only doctors play the role in patient-care life cycle. In fact, nurses, cleaners, maintenance, almost the whole hospital management plays vital role in a patient-care life cycle in hospital industry. Survey conducted by Centre for Disease Control and Prevention (CDC) states that 51.3% of adults are regular drinkers, which causes various liver disease and 18,416 deaths. More number of new flues like "Ebola" is spreading exponentially. Hence number of patients is increasing in hospital throughout the world[4]. So, to manage such situation at hospital, more members of staffs like nursing staff, cleaning staff etc. are required.

Most of the times, it is not necessary to increase the staff. It all depends on how smartly and how effectively management do planning and the available resources are scheduled based on requirement of patients. The problem calls for a solution which serves as resource planning and resource management.

Hierarchy of hospital management is shown in Figure 1. The duty of hospital management is to manage all the

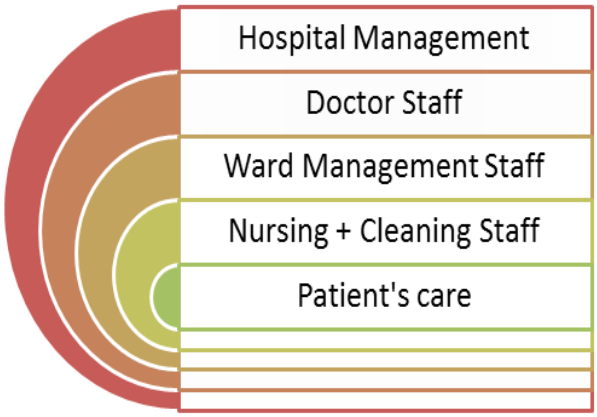

Figure 1. Hierarchy of hospital management.

staff like hospital's doctors, ward management, electrical dept. of hospital etc. and the duty of the ward management are to manage the nurses who are in direct contact with patients. Patients' care is a centre core part of the hierarchy in any hospital management.

The problem requires an intelligent management system. Management system will monitor the demands of patients' services like when patient is requesting nurse service, SOS, cleaning etc. By keeping a record of all requirements at peak hours about when patient is requesting more number of nursing or SOS, cleaning etc., Predictive data analysis can be done by using knowledge of big-data analytics in order to plan the resources for patients.

To manage it efficiently, the system requires skills like operational efficiency, Internet of Things (IoT), RF Technology, Data Analytics, Knowledge engineering, etc.

Various kinds of Hospital management Systems are available in market as follows: Software based hospital management; Hardware based solution like Nutans-H treatment hotline etc. Presently in India the basic design of hospital management system is a kind of web application, in which the application lies in a web server and only authorized peoples can access it via web-browser over HTTP/Internet. But all such software based solutions are either to take appointment or to interact with doctors from home. Minimal solution is for the patient who is admitted to the hospital.

Some hardware based systems also exist in market to monitor the patients' condition. But all such systems are complex systems because they monitor the vital body parameters like body temperature, ECG, etc. Such systems have some threshold value based on doctors' advice and it compares the current body parameters with threshold value. They raise an alarm or send a message in critical situation to inform the care-giver. It is a good system for specific patients like old people, diabetic patients, etc. These systems lack in scheduling properties and managing the hospital's resources and they do not convey patients' on-demand requirements to the hospital ward/nursing station automatically.

Current problem demands a system through which, the patient can convey a message to care-giver, by pressing a button of their requirements like cleaning, nursing etc., at any instant of time. This message must reach to the care-giver without any delay. In parallel, these demands/requirements of patients must be stored in a database, in order to perform data analytics, to generate a management report. This report will have information on how many patients require cleaning, how many patients require nursing along with the requirement's time stamp.

This report will help in predicting the requirement of services needed for the patients in appropriate time.

Nutans-H is a product which is designed by Strobilanthes Technology Solutions for care giving industry. This system consists of two small devices. One is RF based remote and other one is watch. RF based remote is kept with patients and watch with care-giver. Remote consists of 4 buttons i.e. nurse, clean, SOS and cancel. When a patient presses any of these buttons, a message is transmitted to watch which displays the patients' message and id. The range of this system is less and this patients' data does not get stored, so statistical report cannot be generated to assist the hospital management in resource planning. Another drawback in the system is the absence of a central console to monitor whether care-giver responded to the patient on time or not. For that, a web-based dashboard is required at nursing station to keep track of all the room services.

This paper focuses on designing the IoT gateway that will act as a central console. The central console runs on XENOMAI real time kernel. The proposed gateway will not only collect the data from RF remote but also will store it in its database[5,6].

2. System Architecture

The system architecture of nursing management system includes RF watches for nurses at nursing station and patients' remotes are kept near their beds in patients ward/rooms which are as shown in Figure 2.

The proposed design includes an intelligent gateway for hospital management system. RF Remote consists of a RF transceiver with 4 buttons attached to it as Nurse, SOS, Clean and Cancel. When patient presses any button, it sends a signal with device ID and button id, to the real-time gateway. Gateway receives the signal and stores in its database and then it sends message to care-giver's watch-The gateway also hosts the GUI web page to monitor the patient's request[7]. When care-giver sees the message in his watch than he/she is supposed to attend patient to service the request made and will manually acknowledge the gateway. If care-giver is busy then care-giver will not send any acknowledgement to gateway, so any other care-giver whoever is available will be directed to go and serve the request. For SOS signal if no one serves the request within a stipulated time, then it triggers an SMS to the higher authority. It also sends an e-mail with details of the bed in case of emergency, it calls authorized phone number with recorded emergency message. Scanner is interfaced in gateway to scan watch ID and care-givers ID. The scanning is done to indicate, which watch is assigned to which care-giver[8].

Later after few days, all the past services requested by the patient can be collected from the database to perform data analytics on it to generate statistical report.

2.1 Hardware Architecture

Smart intelligent gateway is designed to enable the RF communication between the transmitter and receiver

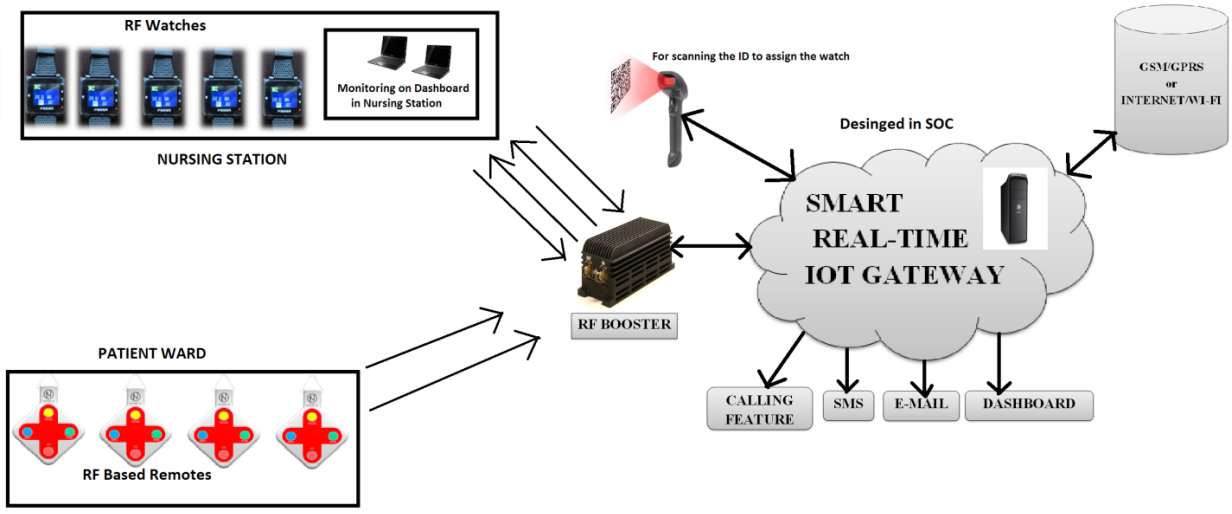

Figure 2. System architecture.

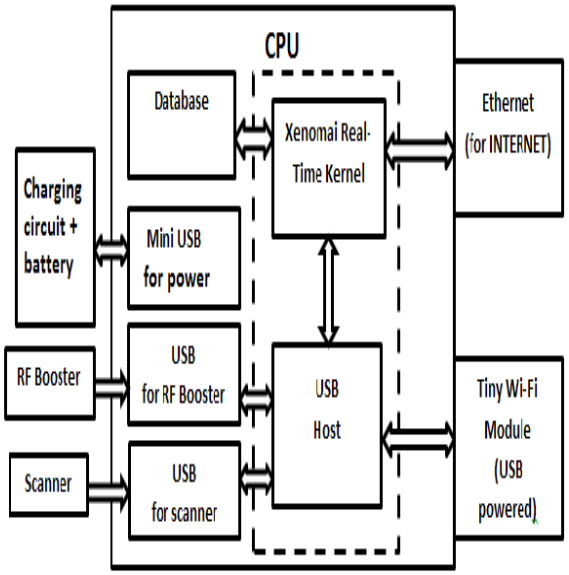

Figure 3. Hardware architecture of gateway.

and to host the dashboard for online monitoring of the patients' services. The architecture is as shown in Figure 3.

2.1.1 Central Processing Unit (CPU)

The Intelligent gateway is designed on SoC - Raspberry Pi. The CPU is of 700MHz, based ARM1176JZF-S architecture. Xenomai real-time kernel is implemented for deterministic behavior because the application is hard real-time and a small scope of delay can prove to be fatal for patients[9].

RF booster is interfaced using the USB port to the CPU. It is used to boost the RF signal and also to collect the signal from transmitter for storing in the database. It increases the signal strength and thus the range by re-transmitting the signal.

Extra-battery with charging circuit is attached to Raspberry pi, to provide power for running all the modules in case power failure occurs.

Scanner is interfaced to scan the barcode of watch and the ID card of the care-giver, during the time of watch distribution to the care-givers. Initial recording of barcodes and their associated names is required at the beginning of usage of system. This enables effective monitoring of all the watches and their corresponding users. Wi-Fi connectivity support is also provided with the help of small Wi-Fi module to provide internet connection. Ethernet is an alternate option if Wi-Fi not available.

2.2 Software Architecture of Gateway

The overall software architecture of real-time gateway is as shown in Figure 4, which includes I/O interface, Database manager, RTnet and Web based server.

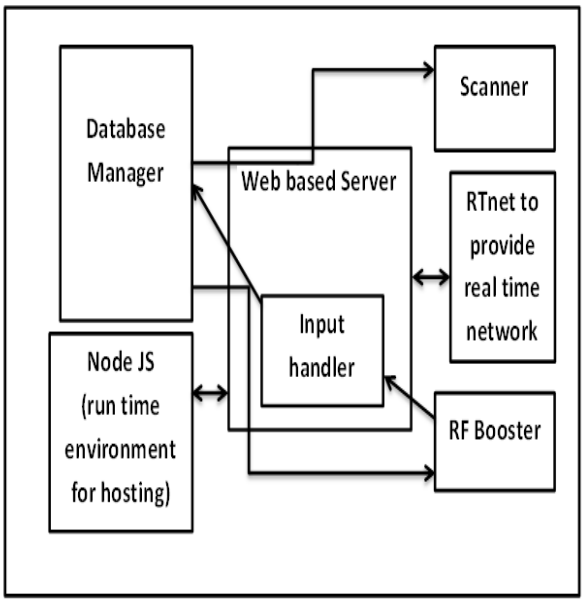

Figure 4. Software architecture of gateway.

2.2.1 Web based Server

It is an open-source, web server and servlet container, which was developed by Apache Software Foundation. It is basically used to implement the Java Servlet, Java Server Pages (JSP) and even Java EE Specs., Web Sockets, Java EL and provides pure Java HTTP Web Server environment for java code to run. It contains Catalina, coyote, jasper, cluster, high availability and web-application. Basically web-based server is being used to give services to other scripts and to accept the services from other modules and to serve them. It is connected with database manager too.

2.2.2 Node.js

It is used for hosting the dashboard page which can be opened from anywhere to online monitor the patients' on-demand service. It is an open source cross platform run time environment for server side and networking applications. Java scripts are used to write.

2.2.3 Node.js Application

It is basically works on event-driven architecture, non-blocking I/O APIs that optimizes the applications throughput and scalability. It is used to design real-time webs.

2.2.4 Database Manager

In the design of real-time gateway, MySQL is chosen which is an open-source solution and can be called as embedded database management system. Scanner's data, RF signals data etc., everything gets stored here with the help of input handler[10]. Direct access of this database is not available to any module except server. Scanner and RF transmitter have to send the services to server in order to access the database. Web based server acts as an input handler for the SQL.

2.2.5 Xenomai

Xenomai is real-time kernel co-operating with Linux kernel in order to provide a hard real-time, pervasive and interface-agnostic support to our system design. Its architecture is in Figure 5[11].

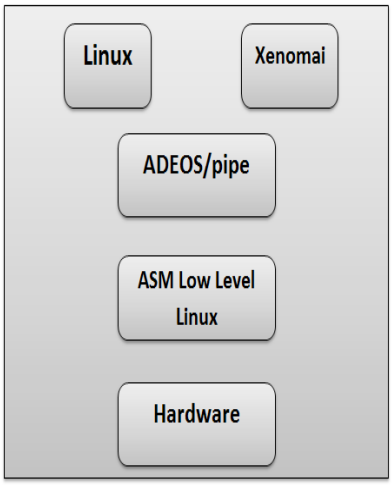

Figure 5. Structure of operating system using Xenomai.

It supports ARM architectures like Raspberry pi, beagle board etc. The real-time tasks are scheduled on Xenomai kernel and non-real time tasks are scheduled on Linux[12]. Xenomai supports various skins as shown in Figure 6. Xenomai provides RTnet patches to establish real-time network[13,14].

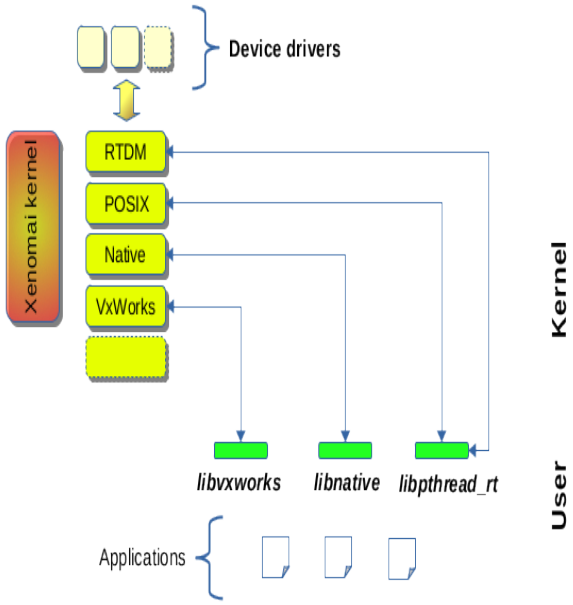

Figure 6. Xenomai skins.

2.2.6 RTnet

Real Time Network (RTnet) provides the customizable and extensible framework for hard real-time communication, over Wi-Fi, Ethernet and other media. [15]This completely fits with Xenomai kernel.

2.2.7 I/O Interface

It is used to connect external modules like scanner, status led and RF booster. Serial buffer is used in case of RF receive and transmit data.

2.3 Email and SMS Service by the Gateway

E-mail is sent using sSMTP Gmail server. It allows the system to send a mail with desired subject line. The E-mail service provides upper level information exchange between manufacturer, hospital staff and client for monitoring. The E-mail contains the IP of the gateway which keeps changing dynamically for security reasons. Twilio APIs are used for phone calls and SMSs. By writing a shell script with if-else statement, it triggers the necessary feature based on the requirement. IFTTT is another tool in which, it is not required to port anything to raspberry pi in order to send as SMS. It contains simple if else recipes. On receiving of mail from raspberry pi, it triggers an SMS.

3. Message Flow Between Modules

Basically Hospital management system consists of total three parts: RF Booster/Collector (to communicate between watch and remote), Gateway and Scanner. Scanner is an input device whereas Gateway acts broadcasting device dashboard hosting, E-mail, SMS etc.

The intercommunication among three entities is as shown in Figure 7.

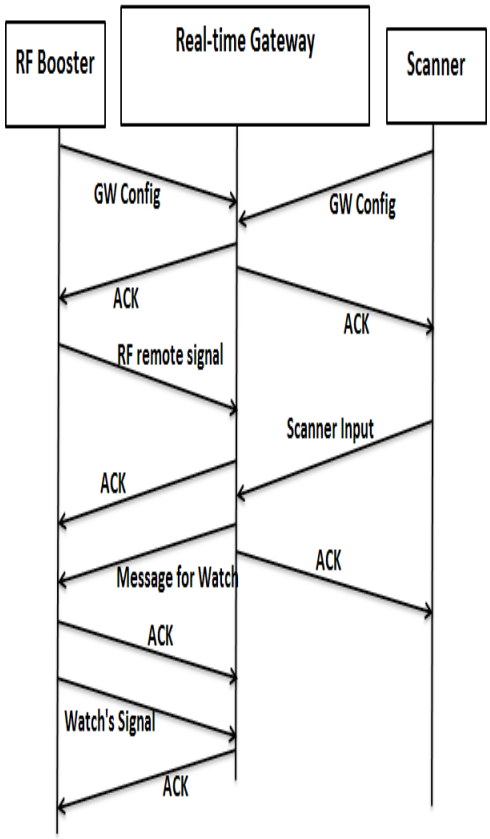

Figure 7. Message flow between modules.

4. Experimental Setup

The system has been designed and experimented in Strobilanthes Technology solutions lab. The Figure 8 shows the integrating RF modules with raspberry pi to send and receive RF signal.

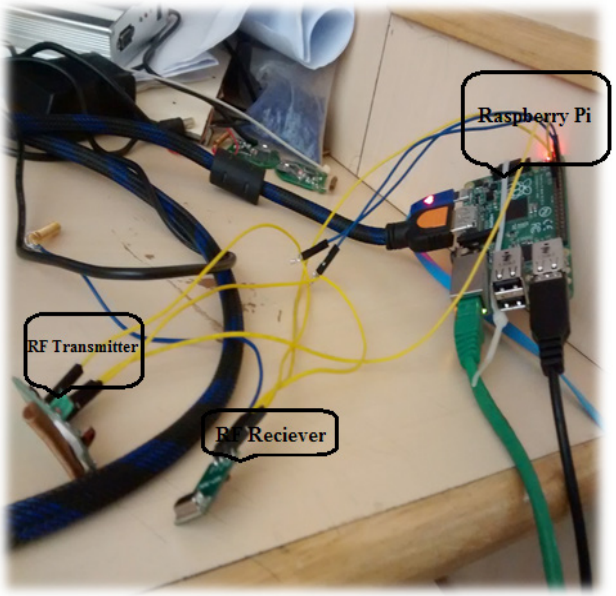

Figure 8. Experimental set-up.

5. Results and Discussion

The experimentation and evaluation resulted desired features of the system including SMS as well as emails sent by patient and received by the central console. Those feature proved credibility and robustness of the design system.

Online monitoring of the running task is required to service the gateway from remote place if it fails. It is used to monitor which script stopped and to reboot the system from remote place. Task can also be re-run from remote place. It provides GUI dashboard to monitor the tasks which is as shown in Figure 9.

Simple Mail Transfer Protocol (SMTP) is implemented to get the IP remotely through E-mail as shown in Figure 10. In this technique, an E-mail is triggered whenever the IP of system changes. This makes system dynamic and secure. SMTP can also be configured using private domain which will make it more secured.

Apart from this, the dashboard is designed user friendly which shows the situations for monitoring all the rooms at a time. In case an alert is raised, that particular room is showed with red marker indicating the need of help there along with waiting time depending on the urgency which is shown in Figure 11.

When patient presses the button, it sends to gateway and gateway directs the message to the nurse's watch,

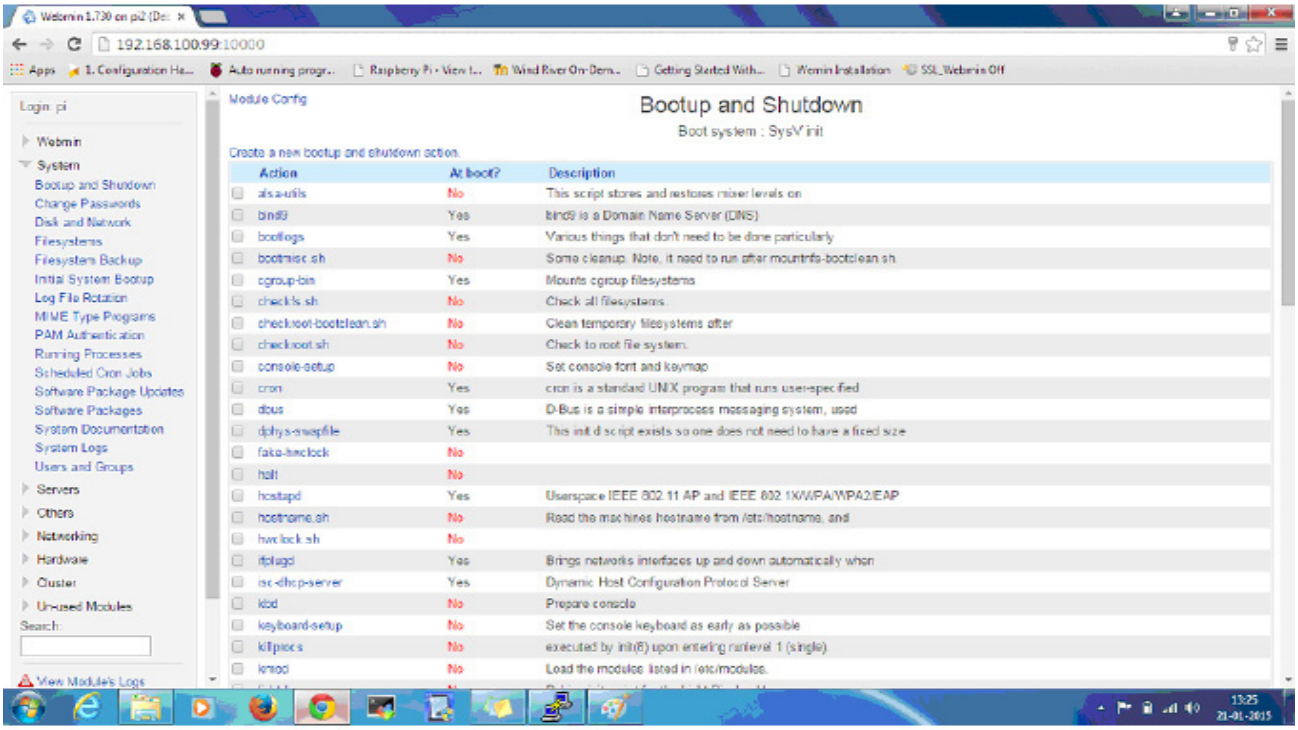

Figure 9. Online monitoring of tasks from remote place.

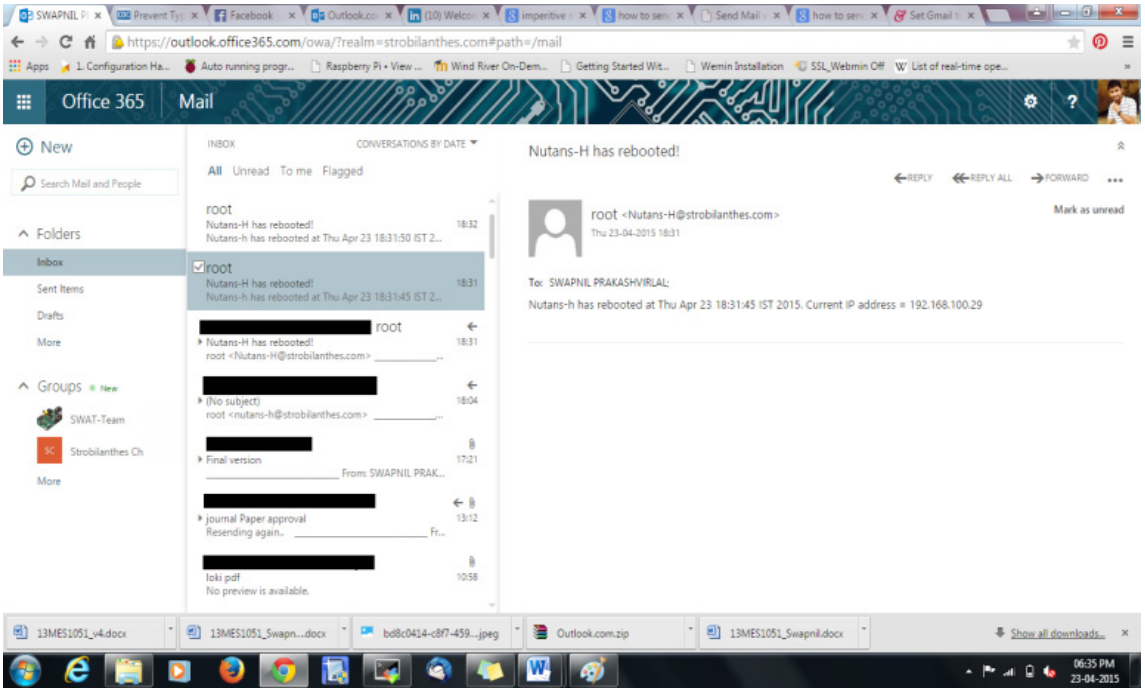

Figure 10. E-mail by using SMTP.

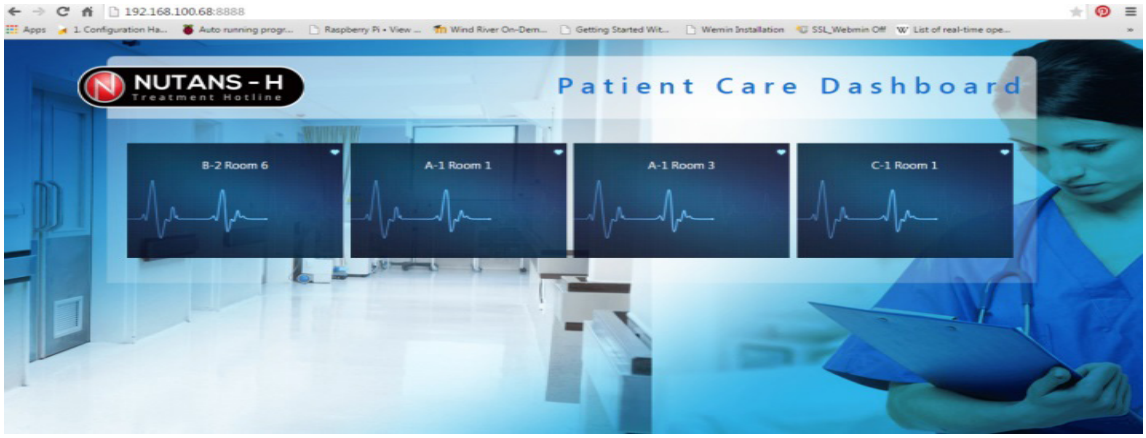

Figure 11. Dashboard view for real-time monitoring.

Figure 12. Message on RF Watch.

to attend the patient. Message on RF watch is shown in Figures 12 and 13. This technology uses the RF communication mechanism. It happens instantaneously without any delay. For SOS signal, their special by passing mechanism is there, for which gateway does not need to send the signal to nurse. It goes directly from remote to watch. Gateway just receives that message to store in database and to update its dashboard as shown in Figure 14.

Figure 13. RF watch and RF Remote.

The gateway is configured with necessary SMS handling scripts which were integrated as a part of user API's to provide SMS notification on care-giver mobile as shown in Figure 15. This makes the system centralized where system behavior can be dynamically monitored by user.

Figure 14. Updating the signal to Real-time Dashboard.

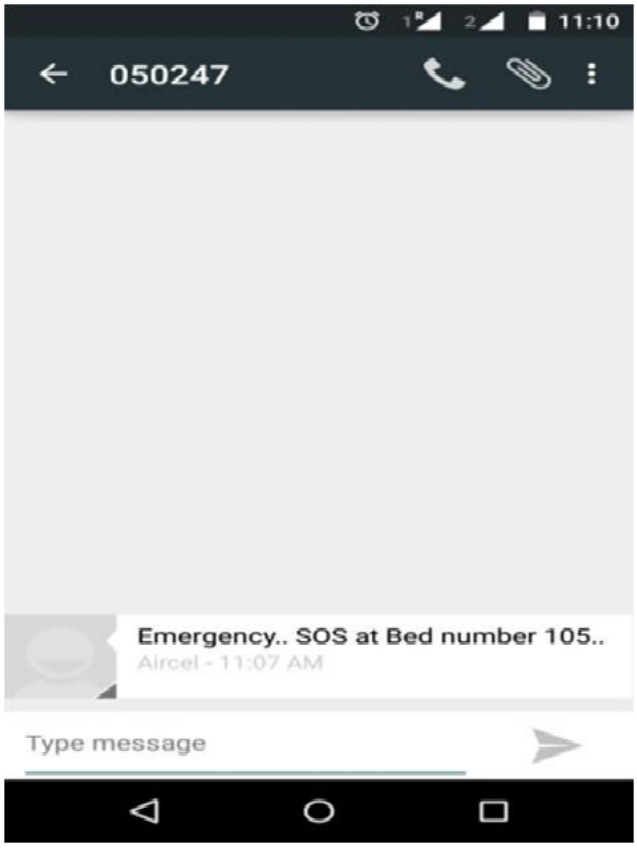

Figure 15. SMS to phone from gateway.

6. Conclusion and Future Scope

In this paper, the gateway has been used as a central monitoring system for the improvement of hospital management which provides a worthy addition to present systems which includes RF remote and watch. Both hardware and software design of gateway were undergone in this work. A series of output and its set up proves that this system is efficient and feasible in real-time scenario.

The work provides base to many possible applications dedicated to serve the problem discussed. It invites further research and expansion of techniques which were proved efficient and robust using the received outputs during testing and evaluation of the design.

In future, the project is being expanded using own cloud, which is under development to include the data analytics report in form GUI for the hospital management staff.

Mobile based APIs are to be interfaced to this system in order to monitor through phone. Security issues will also be considered in future work.

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