Research Article

The Intelligent Healthcare Data Management System Using Nanosensors

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We developed a design of Intelligent Healthcare Data Management System using nanosensors (IHDMS) and composed an application for mobile device. The proposed IHDMS will coordinate the healthcare data of the patients from nanosensors and transforms it into a worldwide consumed standard HL7 (Health Level Seven) for conversion of healthcare data. This converted data dispatches to a server of its system. The battery lifetime of the facility is feasible to increase, the memory usage is less than 100 KB, and it operates all data by employing few and far between resources. Moreover, the proposed system decreases the waiting time in the transposing data, and secured channel was used for the server of the healthcare center in the running HL7 format data.

1. Introduction

As with acceleration in developing technologies, intelligence healthcare systems are also moving towards novel approaches and models of healthcare based on nanosensor, smart phone, smart watch, and so on. Currently, nanotechnology is getting one of the incredible studies and plays an important role in many fields, such as electronics, telecommunication, agriculture and food, materials, energy storage, biotechnology, medicine, and healthcare system.

Intelligent Healthcare Data Management System allows a sick person or patient to use a healthcare service such as a diagnosis service, emergency management service, and monitoring service whenever and anyplace. The Intelligent Healthcare Data Management System (IHDMS) with nanosensors contains three components. Schematic of the Healthcare Data Management System using nanosensors is illustrated in Figure 1.

Component 1 involves wearable nanosensors worn by patient. Each nanosensor can recognize, represent, and process one or more physiological signals, namely, heart rate monitoring by an electrocardiogram (ECG) nanosensor, brain electrical activity observation by an electroencephalogram (EEG) nanosensor, muscle activity monitoring by an electromyogram (EMG) nanosensor, blood pressure recording by a blood pressure nanosensor, trunk position monitoring by a tilt nanosensor, and so on.

Component 2 involves an individual application, which is executing on a smart phone. This application is answerable for a considerable commitment. It greatly performs as an interface to the wireless medical sensors, which assembles the sick person or patient's health information and transfers it to a medical healthcare server. The WBAN (wireless body area network) contains network configuration and management.
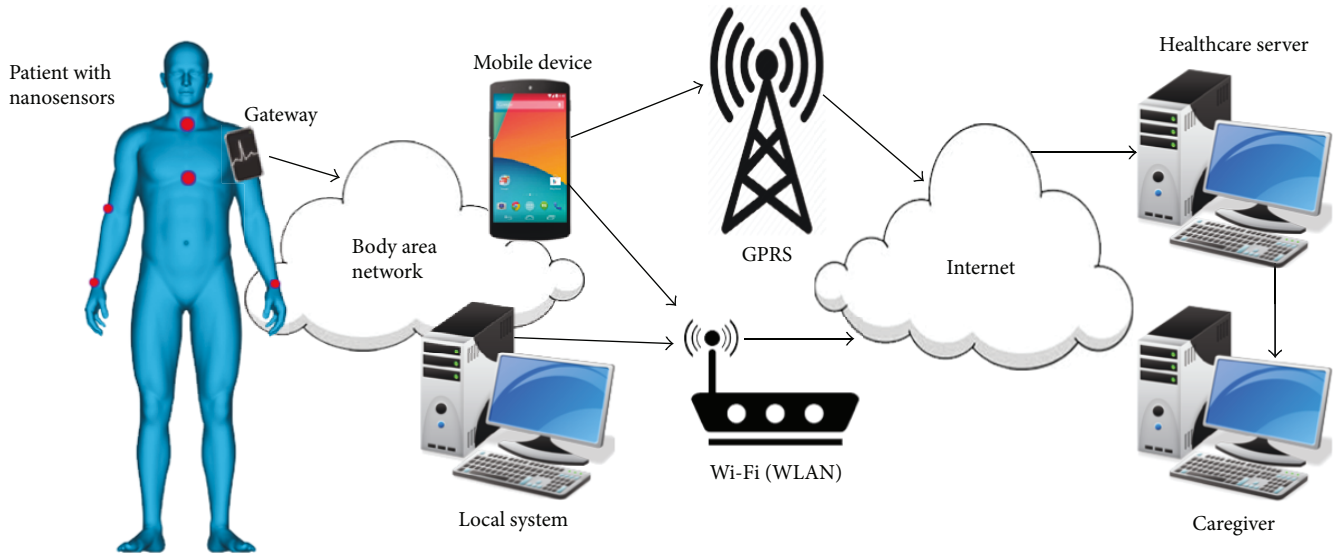
FIGURE 1: Schematic of the Intelligent Healthcare Data Management System using nanosensors.

The configured WBAN network is conducted by an application. It services to share channels, synchronize time, and also retrieve, process, and transfer of data. Based on the information from multiple medical sensors, the application should determine the patient's health state and provide feedback through a user friendly and intuitive graphical. Consequently, if a communication channel to the medical server is available, the application sets out a secure link to the medical server and sends reports that can be united into the patient's medical record in HL7 format. However, if a link between the mobile device and the medical server is not available, the application stores the data locally and initiates data uploads, whenever a link becomes available.

Component 3 consists a medical server(s) or healthcare server, accessed through the Internet. Moreover, this component could embrace other servers, such as informal caregivers, commercial healthcare providers, and even emergency servers. The medical server commonly composes a service that establishes a communication channel to the patient's application. It assembles the data from the patient application and unites the data into the patient's medical record. The service can allowance admonitions, if reports seem to manifest an anomalous condition.

Numerous researches have been studied in intelligent healthcare system and applications of the nanotechnology. Also, genetic algorithms are already a key player in task assignment. Savić et al. [1] presented a genetic algorithm approach to solve task assignment problem. Lee and Shin [2] developed a task assignment problem in minimizing costs for execution and communication. Mei et al. [3] proposed a task distribution framework to support dynamic reconfiguration of PHMS, by means of task redistribution. This framework consists of a coordinator and a set of facilitators. Task assignment problem in arbitrary processor networks was studied in [4]. Pawar et al. [5] presented a method in optimal task assignment processing based on a genetic algorithm. Bachouch et al. [6] composed an optimization model for task assignment in healthcare.

Hu and Marculescu [7] and Alsalih et al. [8] developed models of the channel directions in processor network. Otto et al. [9] studied about the "Personal Server" in their research work. Paré et al. [10] published a review of home telemonitoring in chronic diseases.

Kang et al. [11] classified stress status based on EEG signals. Sun-Jin [12] designed a smart application that can accurately diagnose and process the current state of the local environment, objects, and persons remotely. Also, Kim et al. [13] developed mobile healthcare application based on the tongue diagnosis.

Kumar et al. [14] proposed a general real-time healthcare monitoring system architecture and summarized the need, challenges, and radio technologies of WBANs, since it is the key factor to achieve low power and low latency. Hanen et al. [15] proposed a mobile medical web service system and implemented a medical cloud multiagent system using Android operating system. Hamdi et al. [16] introduced other system in the management of medical technology. O'Donoghue and Herbert [17] presented the Data Management System (DMS) architecture, which employs an agent-based middleware to intelligently and effectively manage all pervasive medical data sources. Lee et al. [18] composed a management system, which is suitable for diabetes patients by their blood sugar level. Ketan et al. [19] developed a healthcare system for the diabetes patients. Nkenyereye and Jang [20] presented a design in the healthcare web service gateway of the healthcare monitoring system for distance runner.

Sahoo et al. [21] introduced the chief scientific and technical aspects of nanotechnology and discussed some of its potential clinical applications. Omanović-Mikličanin et al. [22] composed the perspective of the nanotechnology applications in medicine. Raffa et al. [23] summarized the progress made in nanotechnology for healthcare. Ali and Abu-Elkheir [24] overviewed a foresight of the healthcare environs and its structural challenges, which are used nanotechnology and nanonetworks.
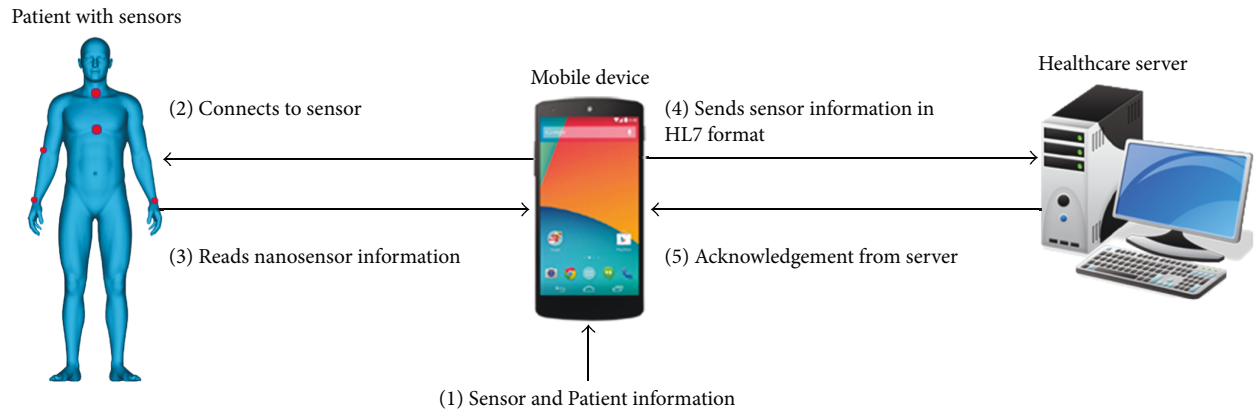
Figure 2: Design of the IHDMS.

Earlier systems were concentrated on obtaining the patient's information irrespective of the resources been used. A raw data produced by these systems were transferred to healthcare server, which caused a lot of overhead of handling this information on the server.

Even though previous researches are composed of various methodologies in the healthcare management system, that is, [14, 17–20], the task assignment, that is, [1–6], the healthcare application for the smart phone, that is, [12, 13, 15], and nanotechnology application for healthcare, that is, [21–24], any work does not perform using these methods together. This study focuses on to developing Intelligent Healthcare Data Management System using nanosensors, which includes task assignment algorithms based on a genetic algorithm, a smart device application, and nanosensors with high sensitivity all together. In addition, genetic algorithm can decrease waiting time in data transpose and demands lower memory while providing the assignment. This paper is arranged as follows. Section 2 explains the objectives and newly proposed methodology. Section 3 presents results and discussion generated from this research work. Section 4 gives conclusions and future works form this study, like the goals achieved and efficiency of the system.

2. Objectives and Methodology

The main goal of this study was to design the Intelligent Healthcare Data Management System using nanosensors and develop an application for mobile device. In our proposed system, a device is ubiquitous, and software supplies the real-time patient health information to the caregiver using nanosensors.

An algorithm to obtain the overall methodology used in this paper is as follows:

(i) Design the Intelligent Healthcare Data Management System (IHDMS) using nanosensors.

(ii) Develop a task assignment algorithm (TAA).

(iii) Transform sensor data to HL7.

(iv) Develop an IHDMS application.

2.1. Task Assignment. In the Healthcare Data Management System, a "single task" is a connection between mobile system and a body sensor at a distinct time and assemble the sick person or patient's physiological health information.

If a TAA commends an individual task to the sensor, operation in that begins. In our composed system, the IHDMS connects to target sensor, assembles, and operates the patient's health information, then keep in present information.

In this research, the TAA was developed using genetic algorithm. The genetic algorithm is found on not complicated evolutionary process and consuming pointed option to get optimal results. In genetic algorithm, population of the chromosome was produced.

2.2. Transform of the Nanosensor Data to HL7. After operating the sensor information, it was transformed to the healthcare server by HL7 standard.

An individual HL7 message consists of MSH, PID, and OBX segments. Therefore, these three kinds of segments are produced in our proposed IHDMS.

2.3. An Application for IHDMS. An application programming interface (API) for smart device was composed in the proposed Intelligent Healthcare Data Management System using nanosensors. The IHDMS application based on Android OS and utilized Java program.

The application consists a main page and other subpages, which are unable to get and enter information about sensors, and patient's health information.

3. Results and Discussion

3.1. Design of the Intelligent Healthcare Data Management System Using Nanosensors. This section presents the design and performance of the Intelligent Healthcare Data Management System (IHDMS) using nanosensors. In this study, a sick person or patient's health information was assembled from the nanosensors. The assembled health information was operated on the phone and transformed to the HL7 format for transfer to the healthcare server. Figure 2 illustrates the design of the IHDMS for better understanding.

3.2. Task Assignment Algorithm (TAA). Task assignment algorithm (TAA) is the key component of this study. Primarily, connection between the nanosensor and the mobile device must be set up. There are several predefined nanosensors, which are the user or the caregiver can choose and connect manually to them. User, who is the first time addressed to connect to the nanosensor, should get permission to make a contact in further by an allowed passport. The allowed passport is saved in the system for user's automatic connection afterwards.

Nanosensor information page for connected nanosensors was displayed. In this page, the user can choose scan time and scan daily inputs. Entered information is saved and required in the TAA to produce chromosomes. In our system, input scan time was determined between 10 to 60 seconds, and scan daily input was limited 24 scans daily. This limitation of the scan time and scan daily is reasoned from the current research demands, such as reduce memory usage and save battery of the mobile device.

If there are no nanosensor inputs (scan time and daily scanned inputs) of the system, any chromosome would not be produced by the TAA in the IHDMS. In this case, default values for every inputs are equal to zero (0). Instantly, the application is operated by the user; the TAA is created.

The chromosomes, which are produced by the TAA, consist two variants of chromosomes with distinct bit sizes. These chromosomes are scanned daily and a single hour. In order to produce the chromosomes, the TAA serves two different functions.

The first function operates once in around the clock and produces the daily scan for each sensor. The second function operates every hour and produces the scan per hour chromosome for the whole activated sensors in the current time.

This scan information can be used to produce the scans per hour chromosome for all nanosensors. Twenty-four bit chromosomes will be produced during this process for each sensor. These produced chromosomes create nanosensor's scan information for every hour of the single day. As a single day divided by twenty-four hours, the size of the scans in each day chromosome is equal to twenty-four bit, and the maximum number of the scans in each day for each nanosensor is also twenty-four. So a cell of the chromosome represents a single hour of the day. The cell of the chromosome can get a value 1 or 0. When the process of the sensor information in the current hour finished, the cell gets a value of 1 bit. When the sensor information will not be processed in the current hour, the cell gets a value of 0 in the chromosome.

Producing these chromosomes is little various from the genetic algorithm-based chromosome generation. In the genetic algorithm, a population of the chromosome was generated, and their fitness was evaluated. Then a novel population through the genetic operations was created. This algorithm is convenient on a powerful system, and there is no limitation on system resources such as memory and battery. The proposed TAA is a genre of the genetic algorithm.

According to the genetic algorithm theory, randomized population of the chromosomes was produced and the chromosomes were rejected based on its fitness. Genetic
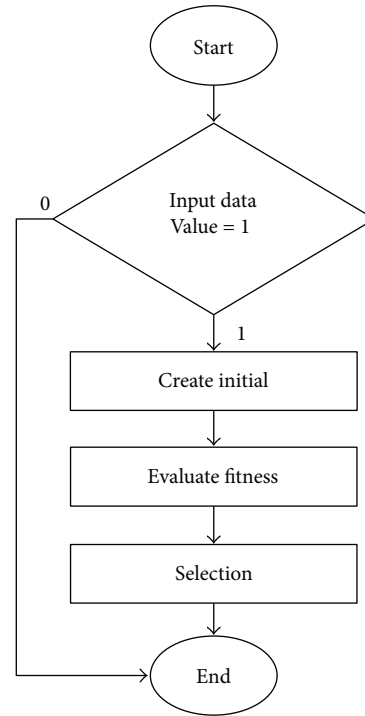
Figure 3: Genetic algorithm for task assignment.

1 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0
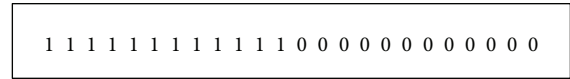
Figure 4: Chromosome before randomization.

0 0 0 0 1 1 1 0 1 0 1 1 1 1 0 1 0 0 1 1 0 0 0
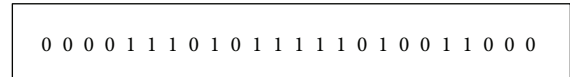
Figure 5: Chromosome after randomization.

algorithm for the proposed task assignment is presented as a flowchart in Figure 3.

This process consists n number of iterations, randomizations, and adoption. In order to reduce the n number of iterations, randomization, and selection, the TAA was started working from the fitness function of the system.

Figure 4 presents produced chromosomes before randomization.

According to the requirement of the system to obtain randomized health information of the patient, the produced chromosomes were randomized in this study. Figure 5 illustrates produced chromosomes after randomization.

The proposed TAA does not have an assumption of crossover and mutation as in the genetic algorithm. The genetic algorithms generally consist of three fundamental operators: reproduction, crossover, and mutation. The crossover and mutation are utilized to produce a new population of the chromosomes, and a fitness function is used to reject unfit chromosomes. The genetic algorithm is utilized to get the best solution after n number of population generation, fitness selections, crossover, and mutation without specifying

BP nanosensor

| 1 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 |

SPO2 nanosensor

| 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 1 |

ECG nanosensor

| 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 |

Temperature nanosensor

| 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 |

FIGURE 6: Result of scan chromosomes a day in all nanosensors. BP: blood pressure nanosensor; SPO2: saturation of peripheral oxygen nanosensor; ECG: electrocardiogram nanosensor.

any rules. The task assignment algorithm just produced chromosomes. A single chromosome provided by the scans every single day and various chromosomes are produced on all process.

An actual produced chromosome presents the hour information. The chromosomes were produced for each nanosensor based on their input of scan daily. Some produced chromosomes for each nanosensor are shown in Figure 6.

Nanosensor scan information is presented as an array of vectors in Table 1. The array size is 24 (hour) in each vector consisting nanosensors name. This produced array was consumed for the production of second unit of chromosomes.

The second function operates each single hour and produces a chromosome of size 60. It produces a chromosome, which has 60 cell size using the information from array of vectors. Each cell consists a value of 0 or nanosensor name. When the cell value is equal to nanosensor name, the IHDMS operates the nanosensor information.

The produced chromosome at the fifth hour for ECG nanosensor is presented as below.

[ECG Nanosensor, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0]

Next step of the production of primary chromosome is to randomize as below.

[0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, ECG Nanosensor, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0]

In the proposed IHDMS, time suspension worked for the chromosomes. Then the system was stopped over until continuation of that process. Due to this stopover in the system, battery life and memory were saved of the device.

The produced chromosomes, which are used for the scan of the nanosensor information, are exclusive, and the nanosensors scan at an exclusive time every single day. It also saves the memory usage and battery and more efficiently operates the nanosensor information on the mobile environment.

3.3. Transform Nanosensor Data to HL7.
The nanosensor information was converted into the lab HL7 format. Inbound lab messages can be received as ORU (observational report—unsolicited) messages and will be sent to the "Labs" tab on patient's profile in healthcare records. Each HL7

TABLE 1: Nanosensor scan information per hour.

Hours	Nanosensors
1	SPO2 nanosensor
2	SPO2 nanosensor, temperature nanosensor
3	Temperature nanosensor
4	BP nanosensor
5	ECG nanosensor
6	SPO2 nanosensor, ECG nanosensor, temperature nanosensor
7	BP nanosensor, ECG nanosensor, temperature nanosensor
8	
9	SPO2 nanosensor, ECG nanosensor
10	
11	SPO2 nanosensor, ECG nanosensor, temperature nanosensor
12	BP nanosensor, ECG nanosensor
13	SPO2 nanosensor, ECG nanosensor, temperature nanosensor
14	ECG nanosensor, temperature nanosensor
15	BP nanosensor, SPO2 nanosensor, ECG nanosensor
16	BP nanosensor, SPO2 nanosensor
17	ECG nanosensor, temperature nanosensor
18	SPO2 nanosensor, temperature nanosensor
19	
20	BP nanosensor, SPO2 nanosensor, ECG nanosensor
21	ECG nanosensor
22	BP nanosensor
23	BP nanosensor, SPO2 nanosensor
24	BP nanosensor, temperature nanosensor

TABLE 2: HL7 lab messages format.

Segment	Description
MSH	Message header
PID	Patient identification
PV1	Patient visit identification
ORC	Common order
NTE	Notes and comments
OBR	Observation request
OBX	Observation/result
NTE	Notes and comments

message consists of one or more segments (see Table 2). A segment is a group of fields, which contain different data types.

MSH field information is illustrated in Table 3: Seq. is a sequence, in which each field information has to be entered and each field is separated by delimiter. Opt. is options, which is optional field by user. Each involved field information is obligated and cannot be left blank. Len. presents the maximum length of the each field.

TABLE 3: MSH segment field information.

Seq.	Len.	Fmt	Opt.	Field name
0	3		R	Segment ID = "MSH"
1	1	ST	R	Field separator
2	4	ST	R	Encoding characters
3	20	HD	R	Sending application
4	20	HD	R	Sending facility
5	20	HD	R	Receiving application
6	20	HD	R	Receiving facility
7	14	TS	R	Date/time of message
8	40	ST	O	Security
9	7	CM	R	Message type
10	20	ST	R	Message control ID
11	3	PT	R	Processing ID
12	8	ID	R	Version ID
13	15	NM	O	Sequence number
14	180	ST	O	Continuation pointer
15	2	ID	O	Accept acknowledgment type
16	2	ID	O	Application acknowledgment type
17	2	ID	O	Country code
18	6	ID	O	Character set
19	60	CE	O	Principal language of message

TABLE 4: PID segment field information.

Seq.	Len.	Fmt	Opt.	Field name
0	3		R	Segment ID = "PID"
1	4	SI	O	Set ID—patient ID
2	12	CX	O	Patient ID (external ID)
3	16	CX	R	Patient ID (internal ID)
4	20	CX	O	Alternate patient ID—PID
5	48	PN	R	Patient name
6	48	PN	O	Mother's maiden name
7	14	TS	O	Date/time of birth
8	1	IS	O	Sex
9	48	PN	O	Patient alias
10	1	IS	O	Race
11	106	AD	O	Patient address
12	4	IS	O	County code
13	20	TN	O	Phone number—home
14	20	TN	O	Phone number—business
15	20	CE	O	Native language
16	1	IS	O	Marital status
17	3	IS	O	Religion
18	12	CX	R	Patient account number
19	11	ST	O	SSN number—patient
20	25	ST	O	Driver's license number—patient
21	9	CX	O	Mother's identifier
22	3	IS	O	Ethnic group
23	20	ST	O	Birth place
24	2	ID	O	Multiple birth indicator
25	2	NM	O	Birth order
26	4	IS	O	Citizenship
27	60	CE	O	Veterans military status
28	80	CE	O	Nationality
29	8	TS	O	Patient death date and time
30	1	ID	O	Patient death indicator

Practically, all information is entered by the user on primary setup of the application in the IHDMS. A representative result of the MSH message according to Table 3 is shown as below.

MSH||IHDMS|IHDMSMobilePhone|IHDMSMobile Phone|Lab|11101026914414||ORU^R10001075067129 |P|2.4|1|||NE||ASCII|||

The next segment in the HL7 is the PID (Patient Identification) segment. This segment contains 30 different fields (see Table 4), such as patient ID number, sex, address, phone number, marital status, primary language, nationality, citizenship, and religion.

A representative result of the PID segment in a manner corresponding to Table 4 is shown as below.

PID||6804010117||Lee^Malrey|||||||||||||0803738490 ||||||||||||

The next segment after PID is the OBX (Observation) segment. The OBX segment is a part of multiple message types that transmit patient clinical information. 17 different fields of the OBX segment are detailed in Table 5.

A sample result of the OBX segment in a manner corresponding to Table 5 is shown as below.

OBX||ST|ECG Nanosensor||2.675^2.925^2.855^|ECG Nanosensor|||||||||||

Each segment information of the MSH, PID, and OBX are mandatory to produce an accomplished HL7 message that can be delegated to the healthcare server. An individual HL7 message consists of MSH, PID, and OBX segments, which are produced by IHDMS. HL7 messages was transferred to the healthcare server afterward producing process.

3.4. The IHDMS Android Application. Once the task assignment algorithm assigns the task to a particular nanosensor, then "Personal Server" is solely responsible for collecting data and events from the wireless body area network (WBAN). The "Personal Server" provides the user interface, controls the WBAN, fuses data and events, and creates unique session archive files. The software is implemented in Java for Android Mobile Operating System. It runs on Mobile Phone with Android OS. The Intelligent Healthcare Data Management System (IHDMS) Application was developed and implemented in this study. Android OS was used in our developed application. Figure 6 illustrated Start Page of the Android application for IHDMS.

A current user's health information can be seen by clicking button "View Information," if it is allowed already. At first time, it will be blank, because there is nobody, and any nanosensor was not allowed. User or caregiver permeates to the system through enter mandatory information by

TABLE 5: OBX segment field information.

Seq.	Len.	Fmt	Opt.	Field name
0	3		R	Segment ID = "OBX"
1	10	SI	O	Set ID—OBX
2	2	ID	R	Value type
3	20	CE	R	Observation identifier
4	20	ST	O	Observation Sub-ID
5	10	NM	R	Observation value
6	20	CE	R	Units
7	10	ST	O	References range
8	5	ID	O	Abnormal flags
9	5	NM	O	Probability
10	2	ID	O	Nature of abnormal test
11	1	ID	O	Result status
12	14	TS	O	Date of last normal values
13	20	ST	O	User defined access checks
14	14	TS	O	Date/time of the observation
15	60	CE	O	Producer's ID
16	80	CN	O	Responsible observer
17	60	CE	O	Observation method

FIGURE 8: Start page of the Android application in Health Monitoring System.

(a) Patient Settings page   (b) Patient Information page
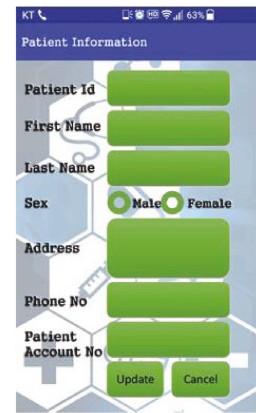
FIGURE 9: Patient Settings and Patient Information pages.

FIGURE 7: Settings Authentication page.

FIGURE 10: Pages of the set nanosensors and nanosensor settings.

"Options" button. Figure 7 shows a Settings Authentication page by clicking "Options" button in Figure 8.

After updating the patient information, the current page Patient Information is redirected to the previous page of Patient Settings, as illustrated in Figure 9. Next step is to set the nanosensor information. A Page of the Set Selected Nanosensors in Android Application is illustrated in Figure 10. Figure 11 presents Nanosensor Settings Page and result of the ECG nanosensor.

Acquired nanosensor data is sent to micro gateway, and the micro gateway data is sent to mobile device. Mobile device application displays received information to the user. Figure 12 illustrated data receiving structure and result of the Blood pressure, oxygen saturation in the mobile device.

4. Conclusions and Future Works

The proposed Intelligent Healthcare Data Management System dynamically assembles the nanosensor information of the sick person or patient and operates it on the smart phone.

(a) Nanosensor settings page
of the EGG nanosensor
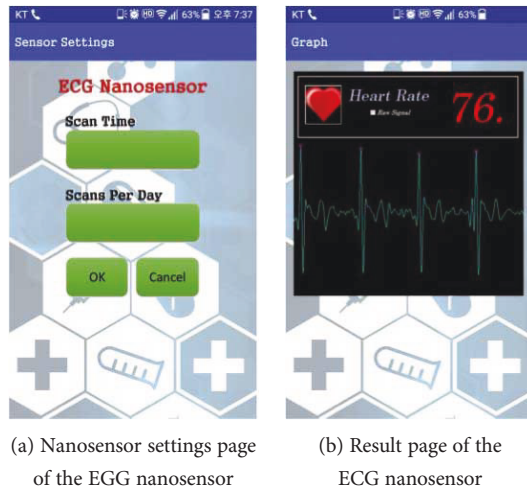
(b) Result page of the
ECG nanosensor

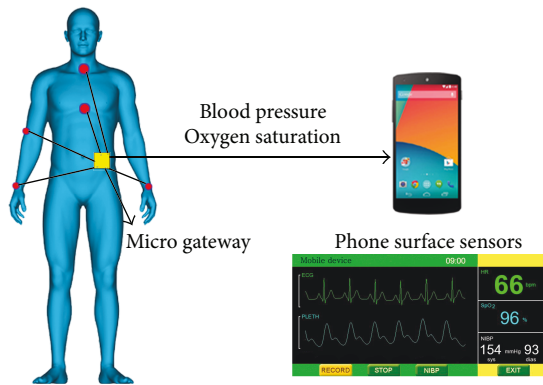FIGURE 11: Nanosensor settings and result page of the ECG nanosensor.

FIGURE 12: Data receiving structure and result of the Blood pressure, oxygen saturation in the mobile device.

It conducts the patient's health information in a superior prolific process.

This system also transforms raw data of the user from nanosensors to HL7 format and transfers the encrypted HL7 data to a remote healthcare server.

The main challenge faced by this system is in terms of the limited resources on the mobile environment. Similar to other applications operating in a mobile environment, the IHDMS could be deeply affected by context changes and scarcity of mobile platform's resource like network bandwidth, battery power, and computational power of handhelds.

This converted data dispatches to a server of its system. The battery lifetime of the facility is feasible to increase, the memory usage is less than 100 KB, and it operates all data by employing few and far between resources. Moreover, the proposed system decreases the waiting time in the transposing data, and secured channel was used for the server of the healthcare center in the running HL7 format data.

In the future, we will carry on this research in order to consummate the main point interfacing facilitator, to relate with other varying types of patient care devices that appear in medical industry. Also, the task assignment algorithm (TAA) can be amplified to utilize the motion nanosensor of the mobile device and apply this information in assigning task. We desire that the HL7 middleware library package will be maturing, to become embedded software that can be used in ubiquitous healthcare devices.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

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