Journal of Information Engineering and Applications
ISSN 2224-5782 (print) ISSN 2225-0506 (online)
Vol.12, No.2, 2022

Telehealth Support System Using Wireless Technologies: The Case of Ethiopia

Tagay Mifta Aba-Bulgu
Atlas University College, PO box 30306, Addis Ababa, Ethiopia
* E-mail of the corresponding author: tagaymifta0@gmail.com

Abstract
Telehealth is an inter-disciplinary area and is basically the delivery of health and medical information and services over large and small distances using electronic information and communication technologies. Broadband wireless services available today, along with more powerful and convenient handheld devices, will enable a transformational change in health management and healthcare with the introduction of real-time monitoring and timely responses to a wide array of patient needs. Further, a network of low-cost sensors and wireless systems help in creating constantly vigilant and pervasive monitoring capability at home and at work. This paper addresses recent efforts in this growing field, including standards, system architectures, and lower layer protocols for body area networks. The paper also suggests the use of cooperative transmission-based strategies for such wireless topologies.
Keywords: Telehealth, Telemedicine, Telecare, Wireless Technology.
DOI: 10.7176/JIEA/12-2-01
Publication date: November 30th 2022

1. Introduction

Telehealth is a fast-growing inter-disciplinary area, in which electronic information and communication technology is used to deliver health and medical information and services over large and small distances. Telehealth includes telemedicine, which offers empowerment, a better quality of life, and a reduced cost of care for patients with chronic disease, such as cardiovascular disease, diabetes, chronic respiratory diseases, and cancer [1]. However, telehealth also includes applications for healthy people, who want to maintain or improve their health. The system that the researcher will propose provides ability for doctors and patients in remote locations to interact, enable health professionals in distinct locations to share information as Ill as to monitor patients remotely and give them timely health information and support. The proposed system would even include a situation in which a doctor in one hospital can get/give support with a doctor somewhere in another hospital via digital imaging between professionals. Patient charts, X-rays, and other diagnostic materials can be transmitted digitally between doctor's offices/smart devices. This potentially supports the extending of health information services available at anytime and anywhere.

2. Statement of the Problem

The population number of Ethiopia is around 110,000,000 [6]. Out of the total population, 85% live in rural areas, making Ethiopia one of the least urbanized countries in the world. Rapid growth of population with a low ratio of health professionals exacerbates critical gaps in basic health services .The healthcare system in Ethiopia can only be able to provide basic health services to 72% of the population. The ratio of medical doctors to population is one of the lowest in the world 1:35,493 .This is a big problem that affects the health of people in the country. Due to this a patient may suffer to the extent of losing of life.

The other health related problem is that resulting from lack of awareness and education. In most of the rural areas an estimate of 60-80% of the health problems is due to communicable and deficiency diseases which resulted from lack of awareness. Also the most common diseases that cause mortality among many Ethiopians are HIV/AIDS, tuberculosis, malaria, and various communicable diseases that occur due to improper sanitation and malnutrition. In addition to this, due to poor transportation and other infrastructures in the country, it has been a challenging task to deliver health services and educate the rural people; also the health professionals may not be motivated to educate remote people. As a result the rural people have to travel long distances to get proper healthcare service. Their journey is difficult as the land is characterized by mountainous terrain and there is no adequate transportation. However, uniform healthcare coverage requires that healthcare be freely available to all citizens.

A solution to this problem is to effectively utilize the existing professionals and enhance the existing health system using wireless technologies. This provides a chance to make communication between health professionals and allowing them to have adequate access to Patients, to medical information, to give health related services remotely, remote consultation,

And remote education to patients/peoples anywhere and anytime. It also enables patients to send video and high-resolution images between two distant locations, doctors can easily examine patients in offices thousands of

miles away. As a result, rural patients do not need to make long trips to urban centers to get proper health services as well as to consult specialists. This helps a patient to save lots of time and money, provide ability to healthcare providers to save patient history and valuable information in their system. Hence telehealth application supported by modern wireless technologies allows medical specialists in the underserved areas to get specialist's support from other hospitals. The importance of this is not only for rural areas; it is also important for urban area as a means to communicate with advanced specialists as well as to get support from physicians living anywhere. To this reality there are many efforts done to establish the use of wireless technology as a vehicle to improve the health domain problems and to achieve aforementioned advantages. The gap in the existing work is that, they did not include telehealth education for diseases prevention and control. Therefore, the goal in the proposed system will be to achieving the aforementioned advantages of wireless technologies on health domain by incorporating health education for disease prevention and control which aimed to solve health related problems that can be resulted by lack of sufficient health professionals and lack of awareness on how to prevent the spread of diseases and how to control diseases in rural and/or urban areas in Ethiopia.

3. Objective of the study

The general objective of this thesis is to design and implement a telehealth support system using wireless technologies.

4. Scope and Limitations

The scope of telehealth support system using wireless technologies include several applications like healthcare service, health management, health education, health information services, and so on. However, this covers the following: Add announcement, Update announcement, Delete announcement, Register health professionals, Add disease information, View disease information, View announcement, Create account and View Request. Work focuses on health education, on disease prevention and disease control, and health information provision. In this work the scope is also limited to some of the chronic diseases such as STIs, communicable diseases and diet-deficiency diseases.

5. Used Methodologies

System analysis is the part of the system development life cycle in which we determine how the current health system functions and assess what the user would like to see in the new system. During system development, there are expected level of capabilities like functionality of the system that are expected by the users of the system. To do this, during requirement elicitation we have gathered information and requirements of the system by using questionnaires [Annex B]. Additionally, different sites which can provide useful health related information have been visited. This Chapter describes the analysis of the existing system to determine exactly how the existing system works as well as what problems exist and finally provide a solution to the problems. Also this Chapter provides the analysis of the interactions between the proposed system and its environment.

5.1. Over view of existing system

The government is the main healthcare provider in Ethiopia. There are a number of hospitals, health centers, health posts, health stations, clinics, pharmacies, and drug shops [3]. However, the healthcare system of Ethiopia is among the least developed in Sub-Saharan Africa and at present it is not able to effectively handle the significant health problems facing the country [9]. Most of the health problems are associated with infectious diseases, communicable diseases, and nutritional deficiencies. In addition to this, issues such as widespread poverty, low education levels, inadequate access to safe water, poor nutritional status, poor sanitation facilities, and poor access to health services have contributed to the high burden of the ill health situation in the country [2]. Indicators such as infant mortality (97 per 1000), under 5 morality (140.1 per 1000), and maternal mortality (871per 100,000) speak more on the health and the general socioeconomic situation of the country [52]. Generally, life expectancy at birth is currently about 54 years and is expected to decline to 46 years if the present HIV infection rates are maintained. According to government statistics, 3.5% of the populations in the age group of 15-49 in 2005 are reported to have HIV/AIDS [53]. Malaria is the primary health problem in the country. In total, as much as 80% of the health related problems in the country are due to preventable communicable and nutritional diseases [9]. These are the major challenges the country is facing in its effort to reach the goal of universal coverage [3]. The government has chosen to strengthen primary healthcare as a strategic approach to solve the problems and to address a major gap in the country's healthcare system; lack of physical access to even basic healthcare facilities in rural areas. But, the healthcare delivery in primary healthcare facilities has been highly affected by the lack of skilled manpower and finance.

The country not only has limited number of health centers but also a big shortage of health professionals with one physician for 35,493 people and one nurse for 4206 people to cover the health services for the nation at

large [10, 3]. A shortage of health professionals and health centers influences inadequate treatment for many people, especially in remote areas.

In the existing system to get health service, the patient has to go to the nearby health center and consult the health workers at the centers irrespective of whether the workers are specialized in

The area of his/her disease or not. Particularly, this problem is more challenge full for the patients with chronic diseases, which need continuous follow up as well as specialized professional's consultation on how to prevent and manage the disease. Additionally, the patients must go to the health center early in the morning and get registered to get a card for medical services. Since the number of health workers is limited in numbers, the user is expected to stay at the center and wait until his/her turn comes to see the health workers. This process may consume many times of the patient as well as the time of the health professionals. In addition to the time wastage, the patient might be asked for a costly service fee which he/she might not afford.

Due to the aforementioned and other problems, the existing health system is not a motivating system for patients to diagnose from time to time and to consult health professionals when needed. Not only for patients, health professionals also do not motivated to diagnose, treat, consult, etc. the patients using the existing system. Also a number of health centers are inadequate to provide health services within a short period of time with low cost. For both health professionals and patients in underserved areas with the lack of access to specialized medical centers, the only preferable way is to use new technologies to deliver as well as to access health services for all populations living in both rural and urban areas as well. Hence, wireless technology is the powerful tool to use.

The vastly growing of wireless technology has given rise to many applications which aimed to reach the wide population at large. Therefore, in consideration of the problems in the current system and the improvement of this highly developing wireless technology including PDAs, laptops, mobile phones, and Internet services, we have proposed to design Wireless Telehealth Support System which aims to solve the problems.

5.2. Over view of the new proposed system

The proposed Wireless Telehealth Support System enhances the existing healthcare system by introducing various telehealth applications including remote health education on disease prevention and disease control/management (what to do and how to act during the increase of disease) as well as the system enhances the provision of health information service to the public at large. Also, the system recommends the patients to get more sophisticated treatment or consultation from specialized professionals as well as recommend any health professionals to get support from other specialists by informing where the specialized person is working or located and by allowing mailing or teleconferencing with the specialized person. This will help the users to save their time as well as make them to get the services easily being at the home or anywhere with low or no cost and high privacy. In addition to this, the system is user friendly by providing the users with some easily selectable features to select as they need and send it to the specialist or to any health professionals to get any support in different manner easily by using the proposed system.

5.2.1. Functional Requirements

From the requirement elicitation, we have gathered the following requirements. The system shall allow the health professionals including health extension workers, clinicians, nurses, specialists, medical doctors, etc. to:-

- Send request for support on cases that they want a specialist's or other professional's support/advice.
- Update or delete the previous request.
- Receive the recommendations/advice made by a specialist for the request.
- Give/get support to/from other specialists and discuss concerning a certain case if the case is somewhat difficult as well as if the available data cannot lead to definitive diagnosis in real- time interaction using teleconferencing or in store and forward telehealth system.
- Exchange the patient's medical data securely for more clarifications.
- The system shall allow:-
- The users to register themselves with the telehealth system through means of Internet facility either at home or at anywhere anytime with their mobile/wireless devices.
- Any registered user to get the privilege of accessing the telehealth system for any service like health education on disease prevention and management, consultation, accessing any clarification related to different diseases, etc.
- A registered user to maintain any requests using their devices.
- Patients based on their request to get response that suggests suitable tests which have to be carried out by the patient through the Internet.
- Patients with the assistance of a health professional to undergo the prescribed test.
- The system shall allow the Coordinator (may be MOH or Administrator) to:-

- Manage announcements of different information.
- Manage user accounts.
- Maintain detail information of health professionals.

5.2.2. Non Functional Requirements

The non-functional requirements also known as quality requirements specify the quality of system attributes such as reliability and response time.

Usability: The system shall be developed in a way to be easy to use. Taking into consideration of the effectiveness of the usage of the system both for health professionals and patients, the system shall be designed to have easy navigations and some easy look and feel buttons/links with supportive tooltip and is easy to use. For those who will face a problem by using the system, a user manual [Annex C] shall be prepared along with tutorials.

Performance: When the system is a wireless mobile system which is available at anywhere, it might be accessed by hundreds or even thousands of users in a concurrent way. So, performance is the most important thing in the system and it shall be designed with high performance. It should also handle multiple users' requests at the same time and be responsive to the users' requests concurrently as well as the system should perform the tasks within a limited amount of time.

Security: To prevent unauthorized access of the system, it shall ensure that only authorized users access the system so that one cannot access a page which is beyond his/her privilege.

Availability: The system is a wireless system and it shall be available at any place and anytime.

Error handling: Invalid input from the users shall be handled in an interactive manner and appropriate messages would be displayed to the users.

5.2.3. Implementation methodology

To develop the proposed system the following tools and technologies are use full

Java 2 Enterprise Edition (J2EE): the Java programming language is used to develop both server side and the personal computer client side application of the system.

Java Server Pages (JSP): Java Server Page is used to design the web interface for the server side application of the system.

Java 2 Micro Edition (J2ME): the J2ME is a CDLC/MIDP platform which is used to develop and demonstrate MIDlet applications running on mobile clients. In order to run MIDlet applications on the target small computing device, the .JAR and .JAD files are installed in mobile devices.

Wireless Toolkit 2.5.2: this is a plugin that is used to facilitate the development of the mobile client side application of the system. The J2ME Wireless Toolkit is a comprehensive set of GUI tools that automates some of the tedious details of building and packaging MIDlets and providing a simple path from source code to running MIDlets. J2ME Wireless Toolkit also can be used as standalone or incorporated into many popular Integrated Development Environments (IDEs) as well as it provides the byte code pre-verification tool, implementation of API class libraries, and a device emulator [8].

NetBeans 7.3: the NetBeans 7.3 IDE is used as integrated development environment for both the client side

6. System model and Design

6.1. System Model

System model is used to correct and captures all functionalities as well as to eliminates the unnecessary requirements. Analysis model mainly contains three models [2]. The first model is functional model that can be described by use case diagram, the second model is object model which is described by class diagrams, and the third one is dynamic model that can be described in terms of sequence diagrams, state chart, and activity diagrams. Regarding to this fact, we aim to construct the model analysis based on formalized requirements of the system. In the work, the analysis model will be described in terms of functional model, object model, and dynamic model using use case diagram, class diagram, and sequence diagrams respectively.

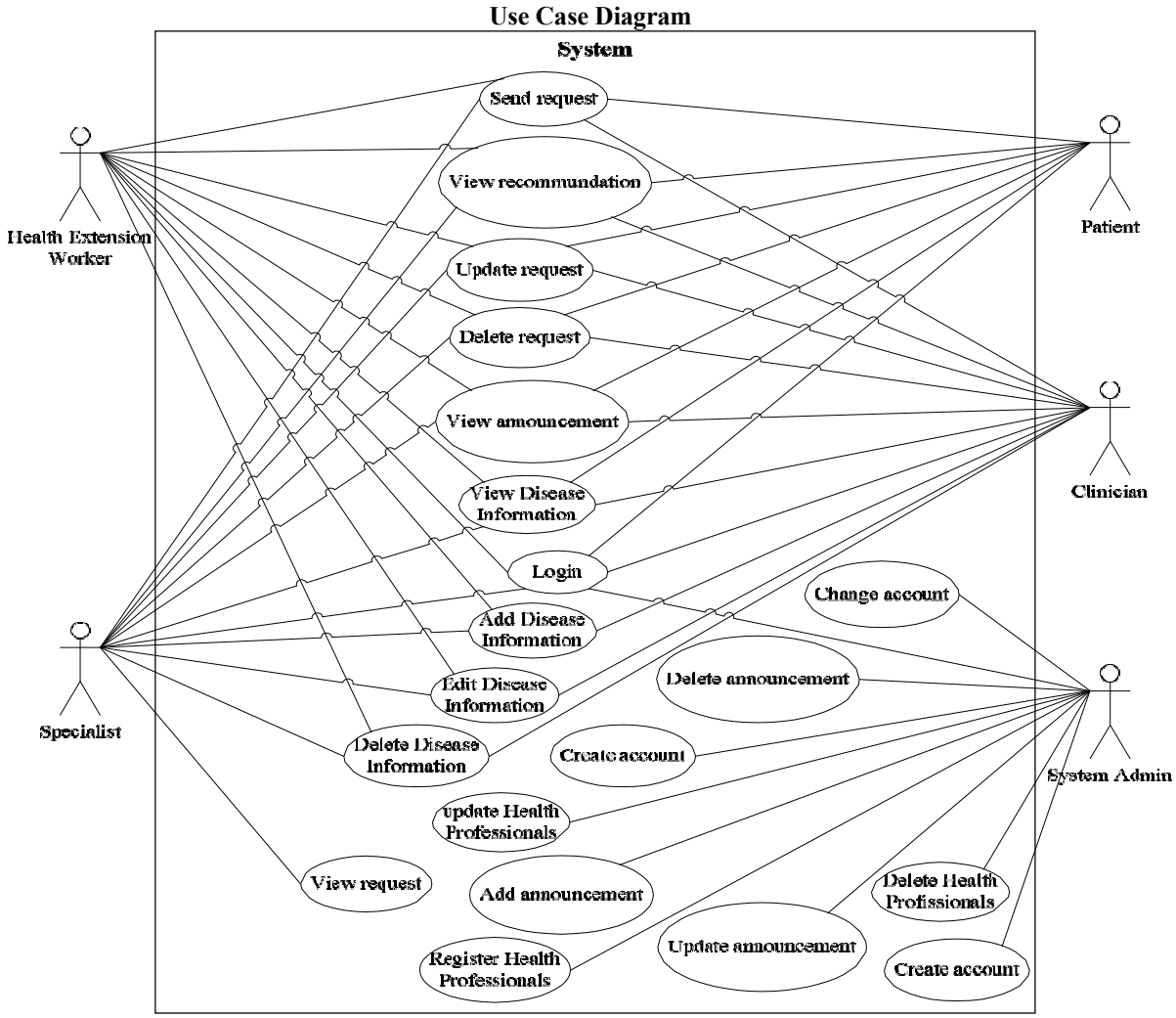
Perhaps the most fundamental concept in systems modeling is abstraction, which concerns hiding unimportant details in order to focus on essential characteristics. Systems that are worth modeling have too many details for all of them to reasonably be modeled. Apart from the sheer size and structural complexity that a system may possess, a system may be behaviorally complex as well, with emergent properties, non-deterministic behavior, and other difficult-to-characterize properties. Consequently, models must focus on a few vital characteristics in order to be computationally and intellectually tractable. Modeling techniques address this complexity through various forms of abstraction. For example, a model may assume that structural characteristics of many individual components of a particular type are all the same, ignoring the small order differences between individuals in instances that occur in real life. In that case, those differences are assumed to be unimportant to modeling the structural integrity of those components. Of course, if that assumption is wrong, then the model could lead to false confidence in that structural integrity. There are two key concepts that are applied in regard to modeling different levels of abstraction, which are: view and viewpoint, and black-box and

white-box modeling, which are described below. Although these two modeling methods are the most widely recognized, different modeling languages and tools employ other techniques as well.

Systems design is the process of defining elements of a system like modules, architecture, components and their interfaces and data for a system based on the specified requirements. It is the process of defining, developing and designing systems which satisfies the specific needs and requirements of a business or organization.

Table 6.1: Actors List with Descriptions

Actors	Descriptions
Health Extension Worker	A person who is assigned at kebele (village) level to provide basic health service for the community especially in remote/rural areas.
Clinicians	A health professional that is not specialized in a specific area, but trained in a medical disciple which may include health officer, nurses, non-specialist medical doctors, senior staffs, and the like.
Specialist	A health professional that has specialized in a specific area that can provide support or consultation to other specialists or health professionals.
Patient	An authorized user of the system that can access the system through his/her mobile devices to get telehealth services at any time anywhere.
Administrator	This is a person who is responsible for administering the whole system.



The use case diagram that depicts the overall description of the telehealth support system is shown in Figure 6.1.

Figure 6.1: Use Case Diagram of Telehealth Support System

6.2. Class Diagram

Class diagram is a mechanism of depicting the different classes and their activities together with the relationship that exists among classes and connect each other to their contents. It describes the system in terms of objects, attributes, and operations with their association. Moreover, class diagram shows the overall structure of the system. The class diagram of Telehealth Support System (TSS) is shown in Figure 4.2.

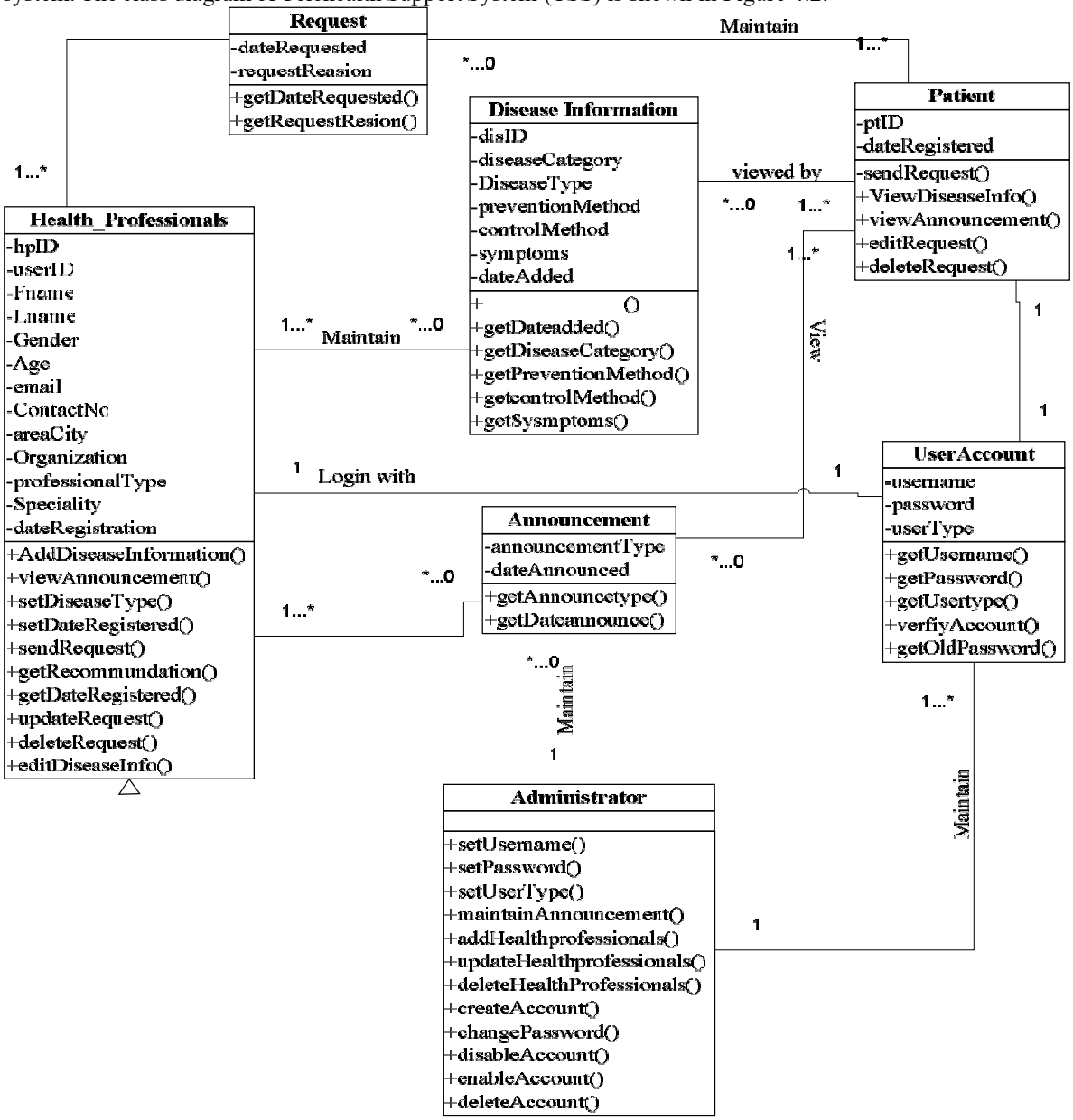


Figure 6.2: Class diagram of Telehealth Support System

6.3. System Design

System design is the process of defining the architecture, components, modules, interfaces, and data for a system to satisfy specified requirements [7]. During the design phase, we must transform the analysis model into a system design model. The objective of design is to model the system with high quality. This Chapter will discuss the details that need to be defined in order to run the requirements stated in the previous section to a final implementation, i.e., there is a shift from the application domain to actual implementation.

The task of system design includes the definition of design goals of the system, decomposition of the system into subsystems (categories) which refers to the process of breaking down the system into manageable pieces to understand the complexity of the system, hardware/software mapping showing the deployments of the components, and persistent data model that describes the database structure.

6.4. Design Goals

Design goals describe many of the quality aspects of the system that should be satisfied for the final product. It can be identified from the non-functional requirements of the system. System qualities are often expressed as non-functional requirements, also called quality attributes. These are requirements such as reliability, usability, maintainability, cost, development time, and the others which are crucial for system quality. Some of these design goals of the telehealth support system are discussed as follows.

Performance

Most of the time performance may be defined in terms of response time, memory, and concurrent user support. In the case of hardware or network failure, the users should be informed immediately. To increase the performance of the system, we shall develop the system to the best possible algorithms which take fewer amounts of time and memory to process a task. The system should transmit as minimal data as possible.

Maintainability

If there is anything that is necessary to add on the system, the system should be easily extensible and modifiable to incorporate additional functionalities and changes without causing any problem to other systems functionality. Since the system is designed with object oriented approach and with different modules, any developer can easily maintain and modify without affecting the other functionalities.

Security

Privacy issue of the users is very sensitive. Specifically in telehealth since the information transmitted over the network contains personal medical information both the mobile client and the server should protect the transmitted content during communication. Therefore, the database which stores passwords should be encrypted with MD-5 algorithm which is difficult to decrypt. This system user's authentication with username and password play pivotal role in ensuring security. Also the J2ME platform supports HTTPs for MIDP. As a result, the system uses secure HTTP to send and receive information like patient medical history, requests and others. User Interface

Since the system is expected to be user friendly, it should have a simple user interface that can be easy and used by users without difficulties since the users may have less experience in using computing technologies. The interfaces encompass different buttons and links with tool tip which are very simple to use and make users feel comfortable during the use of the system. Also the user interface on the wireless devices like mobile phone should have to be compatible and simple as it will be displayed on small screens.

Error handling

The system shall be developed not to accept invalid input in any way and both client side and server side form validation will be made to ensure this.

Availability

Since the system is a wireless system, it should be available and provide its service at any time and
Anywhere as the users need to access it. The probability of unavailability of the system to users is in times when there is system maintenance and these tasks will be conducted when users are not supposed to be accessing the system (for example at mid night). The system will be available to the users through a wireless Internet connection using various types of wireless network. Moreover, the system prototype is developed using Connected Limited Device Configuration (CLDC) of J2ME platform. The "Connected" simply refers to a network connection that tends to be intermittent and probably not very fast. Therefore, if there is intermittent connection to the Internet or the failure of Internet connection, the system tries to

Overcome the problem or it tries to store the request locally and recovers from a temporary Occurrence of connection failure and retries sending the data automatically without requiring the user to input the data again when connection is re-established automatically.

Portability

The health professionals and system administrator can access the system through web browsers and the system should have to support requests coming from different platforms via standard web browsers. The patients can access the system via any wireless device which supports Java programming and the system should have to run on any wireless device like mobile phone which is capable of running Java programming.

6.5. System Architecture

The system architecture shows the overall organization and communication between the users and the system. The main components of the system architecture include mobile client, web client, and system server. Figure 6.3 shows the general architecture of the system.

Figure 6.3 : The General Architecture of the Proposed System

Mobile Client

The mobile client component is the client side application of the system which runs on small wireless hand-held devices like mobile phones. This component helps the users of the system to get different telehealth services such as enabling the patients to communicate with their respective health professionals and vice versa, as well as health professionals with other health professionals through their wireless devices. It contains different forms, procedures and settings which are filled by patients based on their needs and by health professionals regarding their desired support. Mobile client component communicates with web server side of the system through the use of different wireless communication technologies including mobile communication networks ranging from 2G (GSM) to 3G (W-CDMA, CDMA2000, TD-CDMA),WLAN GPRS, WiFi, and other networks.

Web Client

This is the other client side application of the system which helps the users of the system who use laptop or desktop computers to get telehealth services. Through this component, the system administrator can manage and access the system, health professionals can support patients and

6.6. Subsystem Decomposition

In order to make the system design and development easier, the system is decomposed into manageable smaller components/parts called subsystems which contain the group of the classes with similar functionality. This also helps to understand the problem better. During system decomposition, achieving strong coherence within the subsystem and loose/low coupling between subsystems were taken into consideration. The major subsystems of the system are shown in Figure 4.11.

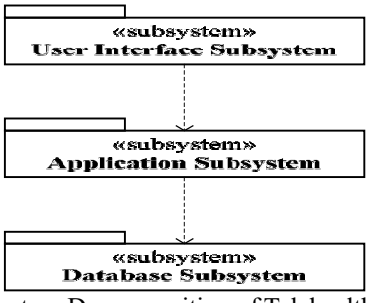


Figure 6.4: Subsystem Decomposition of Telehealth Support System

6.7. Hardware/Software Mapping

The hardware/software mapping model of the system describes the relation between the hardware and software components and nodes as well as the communication technology that can be used for the system. The system client application is deployed on mobile devices and personal computer, the server-side web application is deployed on web server, and the database application is deployed on MySQL database server. Figure 6.5 shows the hardware/software mapping (deployment) of the telehealth support system.

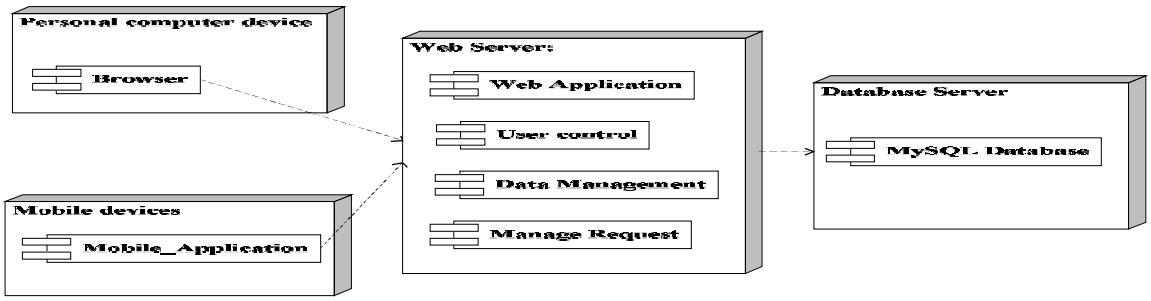


Figure 6.5: Deployment diagram of Telehealth Support System

7. Conclusion and Recommendations

7.1. Conclusion

The Telehealth field is currently an extremely active inter disciplinary research area. The Thesis includes modeling physical, link, and network layer protocol development, and the creation of new applications for healthy and sick people. Using the this system, both health professionals and/or patients can access the health services while on the move or while they are away from their living or working site to give and/or get better treatment and guidance. This is very important and practical in the areas with very high shortage of medical professionals. The researcher believe that this empowers the health professionals to have adequate health services access from anywhere and to give effective services to the patients. Therefore, this helps to effectively utilize the insufficient resources, infrastructure and health professionals in the country. Also, this improves the quality of patient care, awareness around the people, since it enables both health professionals and patients to have adequate access to the health services and information.

7.2. Recommendations

Adoption of telehealth is growing across the world rapidly, the virtual healthcare system is becoming to be important in the world. Despite the obstacles, healthcare will look much different from what it is today for the future, with innovations like virtual doctor visits and the near elimination of wait times. Therefore the researcher recommends to include such features in future works.

References

[1] E. Jovanov,“Wireless Technology and System Integration in Body Area Networks for m- Health Applications,” IEEE Engineering in Medicine and Biology 27th Annual Conference, 2005.
[2] Grady Booch, “Object-Oriented Analysis and Design”, The Benjamin/Cummings Publishing Company, 1994.
[3] Health Facilities and Human Resources, available at, http://cnhde.ei.columbia.edu/healthsystem/facilities_capacity.html, last accessed on Nov 20, 2014.
[4] Health Problem, available at, http://cnhde.ei.columbia.edu/healthsystem/health_problems.html., last accessed on Nov 15, 2014.
[5] J. Donoghue and J. Herbert, “Prole Based Sensor Data Acquisition in a Ubiquitous Medical Environment,” Proc. of 4th Annual IEEE Pervasive Computing and Communications Workshops, 2006. [2] East York Tele home Care Project, final report.
[6] J. K. Kumekawa, “Emerging Trends in Telehealth,” Business Briefing: Next Generation Healthcare, pp. 62-64.
[7] System Design, available at, http://en.wikipedia.org/wiki/Systems_design, last accessed on, January 16, 2015.
[8] T. Gao et al,“Wireless Medical Sensor Networks in Emergency Response: Implementation and Pilot Results,” Prc. IEEE Conference on Technologies for Homeland Security, May 2008.
[9] The Health System, available at, http://cnhde.ei.columbia.edu/healthsystem/, last accessed on Nov 28, 2014. [54] Grady Booch, “Object-Oriented Analysis and Design”, the Benjamin/Cummings Publishing Company, 1994.
[10]. World Health Organization, “Working Together for Health, Global Distribution of Health Workers in WHO Member States", the World Health Report 2006.