

Reliable, Intelligent, and Large Scale E-Health Architecture using Wireless Sensor Networks

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Abstract

Recently Wireless Sensor Networks (WSNs) are used in many applications concerned with e-health, military among others. In this paper a new architecture for e-health is presented. This architecture uses multiple WSNs. Also, the architecture is controlled by a network management system which regulates the transmission of data between patients and doctors remotely in secure manner. Furthermore, the gathered information by sensors is analyzed and reported using an intelligent expert system. Finally, the proposed architecture is considered as large scale due to using the Internet as a connection for the WSNs.

keywords: E-Health, WSN, Network Management, Expert System.

1. Introduction

Nowadays, it's well-known that the health systems in most countries do not provide a complete service in health care. In addition, the cost of this service may represent an obstacle for the poor people. Accordingly, many people may not able to avoid the danger disease which means death. In addition, the quality of health service represents an important factor in the health system. The quality factor contains many parameters such as the time which the patients wait for service, the availability of doctors, the efficiency of doctors, the early diagnoses especially in danger cases, and the advanced instrumentations. Hence, there are many e-health applications which try to handle the health system bugs and improve its service. Some of these applications are concerned with data gathering software and using hardware such as sensors [1-2]. Also, the face-to-face monitoring of patient from a consultant is extremely difficult if not impossible. So, this paper is concerned to remote monitoring of patients using active devices such as mobiles, laptops, taps, and others.

This paper proceeds as follows; in Section 2 the paper contribution is presented. In Section 3, the related works are demonstrated. In Section 4, the proposed architecture is introduced. In Section 5, the architecture components are presented. Finally, the conclusion and future work are introduced in Sections 6 and 7 respectively.

2. Paper Contribution

One of the most important problems in the e-health systems is time consumption in the diagnoses process due to the long distances between the patients and the doctors. This may result in dangerous events especially for the patients who suffer from critical diseases. So, this paper introduces an e-health architecture using WSN. This architecture helps doctors to be up to date with their patients regardless of the time or the distance factors. Also, the proposed architecture is secure as it contains a network management system which controls the authorization and the authentication of the e-health system entering. In addition, the gathered information is analyzed using expert system which provides a filtering process to determine the urgent and the trivial data. This will decrease the load on the WSNs and the doctor efforts. Finally, the architecture can be used to construct desktop, web and mobile applications.

3. Related Works

There has been many works on e-health systems [3-7]. P. Halapeti, et al proposed in [8] a system that makes continuous monitoring for patients remotely. This system used WSN as its infrastructure. The system attaches a group of sensors to the patient to gather the required parameter values that are sent to his/her doctor. This system is not implemented. Also, it did not tackle the security issue. In addition, it is not scalable. So it cannot be considered as a long term solution. A. Lounis et al proposed in [9] an architecture to gather data using WSNs

and send it to the specified doctor. Before the sending process, data is analyzed. The security issues are described in this architecture; however, this architecture neglects the WSN management. In addition, it has no sufficient performance analysis. Furthermore, the communication between sensors is not well-defined. H. Yan proposed in [10] a system which distributes many sensors in a home environment to determine the required needs for patient. This research presented a tracking system. This system, however, is not secured and has scalability limitations. In addition, the implementation of this system is not well-defined. A. AL-Marakeby proposed in [11] an image processing algorithm for e-health systems. This system capture images for special patient activities and sends it using WSN after the analysis process. The system uses limited bandwidth as it is optimized for limited energy and memory in the WSN nodes. This technique can be considered as a special purpose solution; however, no security or management issues are discussed in the technique. V. Vaidehia proposed in [12] an e-health system, which can collect, store, retrieve, and analyze required data about patients using WSNs. In addition, the multi-agent technology is applied in this proposed system. In this system there is no security mechanism. Furthermore, the management technique is executed for the collected data and not for the WSN itself. A. Milenković et al and S. Tennina et.al, proposed in [13] and [14] respectively multiple WSN technologies to satisfy the healthcare applications requirements. In their paradigm, many problems for network coding methods and WSN communication mechanisms are solved. Their research also focused on the WSN communication problems.

4. Proposed Architecture

The proposed architecture consists of five components: WSN, expert system, multi-agent system, network management system, and Internet, as shown in Figure 1. Each component has a function to accomplish a given target in the proposed e-health system. These components worked together in harmony to provide the stakeholders of the e-health (patients, doctors, nurses, staff, etc.) system with specific requirements as well as raising the proposed architecture's efficiency. In the following subsections each component is defined and discussed.

4.1 The WSN

The WSN consists of sensors groups, which are distributed in local environments to acquire specific information and

communicate with each other using multiple protocols. In the proposed e-health architecture, each group of sensors formulates simple WSNs. These WSNs communicate using the Internet to construct a large scale WSN. In the proposed architecture, multi-functional sensors such as temperature sensors, blood pressure sensors, gases sensors, and pulses sensors are used. These sensors are attached to the patient for periodically gathering the required data. After that, this data is sent to a specific responsible entity (doctor or nurse).

4.2 The Expert System

In the proposed architecture, the simple WSNs send their data periodically which overwhelm the large scale WSN with huge information. This information is required to be transmitted at about the same time of the gathering process, which may affect the WSN efficiency. So, the data which is collected by WSNs should be analyzed after collection process and before the transmission process. Accordingly, an important component should be used to accomplish this function, i.e., an expert system. This expert system retrieves the data, analyzes it, and extracts valuable reports that will be sent to the doctor. The analysis process should be based on sensitive parameters. These parameters are determined by an expert (consultant) in the medical field. Some examples of these parameters are time of sent data, amount of data, type of data, receivers of data, state of patients, type of diseases, etc. In addition, the expert system should determine report sending time and to whom. The expert system is considered as a software component. The specifications of the expert system are found in [15].

4.3 The Multi-agent System

To determine the state of each architecture component, many agents should be used for the monitoring process. These agents should work as a network because any sudden decrease in architecture component efficiency may affect other components. Each agent should have an intelligent behavior based on the network management parameters. To decrease the network load, the communication between agents should be accomplished in discrete manner (not continues). The specifications of each intelligent agent are found in [16]. The multi-agent system is considered as a software component.

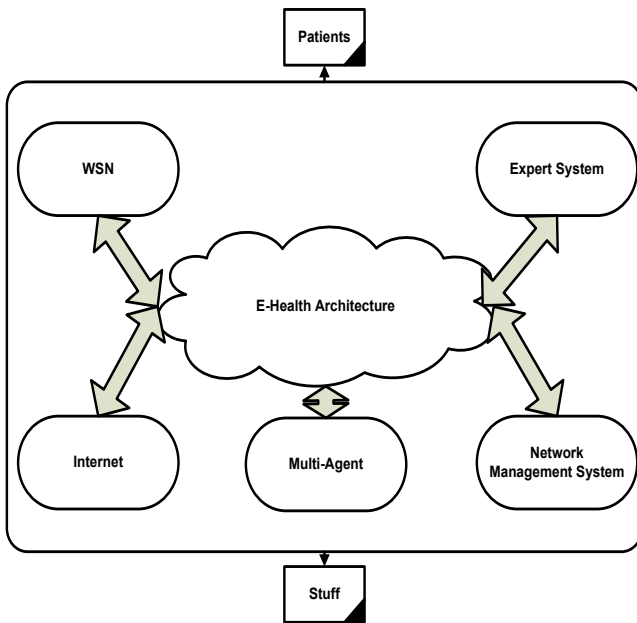


Figure 1: Components of the e-health system architecture.

4.4 The Network Management System

The network management system is considered as the second most important component after the WSN. This is because if the WSN is well-installed and not well-managed, the required data may be dropped and the e-health system cannot accomplish its target. The network management system comprises security mechanism, data transmission control mechanism, state aware mechanism, and scaling mechanism. The security mechanism determines the authorization and the authentication for the proposed e-health architecture. Also, the security mechanism is responsible for the encryption and the decryption of sensitive data that will be extracted by implementing the novel medical techniques. The data transmission control mechanism determines when the transmission process is started and ended. In addition, it determines the data that should be transmitted depending on sudden events or network state changes. The state aware mechanism periodically determines the efficiency of the network. A report describing the network state is composed for ensuring that the WSN works in full efficiency. Also, being aware of network efficiency provides safety for sensitive data transmission. The scaling mechanism determines the requirements that are needed to extend the WSNs in case of large number of patients [17]. All of these mechanisms work in one system, which is called network management system and can be considered as software.

4.5 The Internet

Simply, the internet component is used to transfer the WSNs from local environment to global environment. The Internet can be considered as a transmission medium between the simple WSNs in different locations. So, each simple WSN should have a connection to the Internet. This will delete the distance obstacle which may be faced in the traditional e-health systems. There are many requirements for using Internet in the e-health architecture such as bandwidth, routers, gateways, and availability [18].

5. How the Proposed Architectural Components Work

The components of the proposed architecture communicate to accomplish its tasks in higher efficiency. In the beginning, sensors are distributed in the target environment and attached to the patients. After that, the sensors collect predetermined information. The consultant should determine and prioritize the collected data. The data should be inserted in the expert system for the analysis phase. The expert system filters the collected data depending on the prioritization parameters. Also, the expert system determines the interval in which the data should be sent. Accordingly, the expert system extracts formatted reports and sends it to the right receiver (either doctor or nurse). Before the sending process, the expert system should monitor the parameters of the network management system to determine if it can send the data or not. The network management system periodically monitors the large scale WSN to determine its efficiency. The network management system contacts the expert system in case of huge number of sent reports or low WSN efficiency. Consequently, the expert system can decrease the data in the final report that can be accomplished using data prioritization. Furthermore, the network management system determines the trap events that may occur within the WSNs sessions. In discrete time, the agents provide the network management system with the state of each component. This state can be described using many parameters depending on the component type. For example, as regards to the Internet component, the bandwidth - the number of active nodes, and the size of data transmission are considered as scaling parameters to describe the Internet state. Also, the network management system is responsible for the security issue in the proposed architecture. The security issues include the authorization and the authentication processes in addition to the

encryption and the decryption processes [19]. Furthermore, handling of the backup recovery process is accomplished using the network management system. Figure 2 depicts the model components and their interactions.

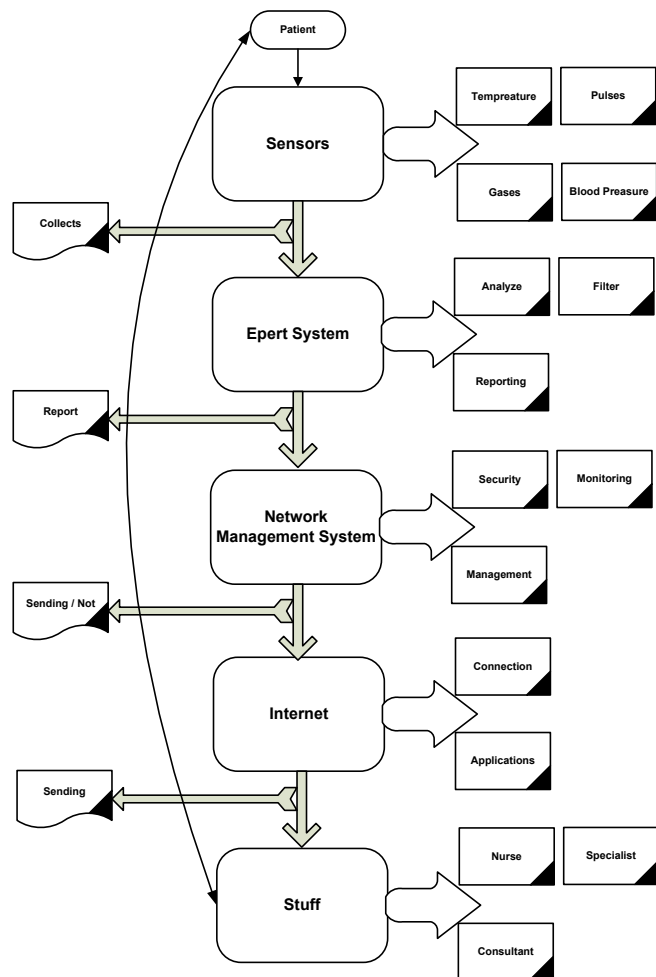


Figure 2. How the architectural components communicate.

6. Conclusion

In this paper, a new architecture for e-health system is proposed. This architecture comprises five components. These components are the WSN, expert system, network management system, multi-agent system, and the Internet. Each component function is defined. In addition, how these components communicated to each other is described. Our proposed architecture is considered secure due to applying authorization, authentication, encryption, and decryption, and the intrusion detection processes. Also, our proposed architecture is considered large scale due to the using of the Internet as a communication medium between the

simple WSNs. Furthermore, our proposal can be considered as reliable because there are many overlaps between components functions, which mean if any component fails, the other components can achieve the latter's tasks.

7. Future work

Further work includes building a simulation environment for the proposed architecture to test the WSN parameters. In addition, we plan to prototype the proposed e-health system to test its efficiency in large scale environments.

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