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NEW e-Health Signaling Model in the NGN Environment

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Abstract—**Sensor Networks are considered the heart of a wide range of applications. e-Health is one of those applications. This paper proposes a new network and Context Awareness service architecture for e-Health services. The proposal integrates the Ubiquitous Sensor Network (USN) with the IP Multimedia Subsystem (IMS)-based Next Generation Network (NGN). It provides a detailed signaling model for different healthcare scenarios based on SIP. The proposal involves modifications made to SIP to match the new e-Health features provided.**

Keywords-component; e-Health; USN; NGN; IMS; SIP

I. INTRODUCTION

Continuous advances in Wireless Sensor Networks (WSNs) made them a truly ubiquitous technology. This led to myriad of new sensor-based services [1]. e-Health is one of these new services, which exploits the wide use of the Ubiquitous Sensor Networks (USNs) to gather the patients' data for various applications. e-Health offers new and innovative options to practitioners, medical centers, and hospitals for managing patient care, electronic records, and other features. The WSN node is capable of sampling, processing, and communicating one or more vital signs (heart rate, blood pressure, oxygen saturation, activity…etc) or environmental parameters (location, temperature, humidity, light) [2].

Many recent researches concentrated on providing a network and service integration techniques for the USN with the IP Multimedia Subsystem (IMS). One of the recent solutions is based on building a service enabler over the IMS to support e-Health services [1]. Another family of solutions is proposed based on Context Awareness (CA) such as [3]. Moreover, J. Kim et al. proposed the integration between service enablers based on the CA system to provide various services [4]. ERMAHAN proposed a context aware mobile service platform supporting mobile caregivers in their daily activities [5]. A CA service architecture was proposed in [6] to integrate with social networks.

On the standardization side, the ITU proposed integrating the USN with Next Generation Network (NGN) to provide a wide range of applications without presenting a detailed architecture or specifying how to integrate with IMS [7].

Most of these researches and standardization efforts proposed only theoretical ideas and potential scenarios. None of them provided a detailed signaling flow to be the road map to implement these e-services.

In this paper, we propose to integrate the USN with the NGN service layer based on IMS to utilize the benefits and features of the IMS [1] and to provide the required QoS for these e-services as well. We provide in this paper four main contributions: i) A detailed network design for implementing the proposed service including new functional entities for the Application Layer. It is simple, flexible, and does not require great changes in the already established communication networks, ii) A detailed network signaling flow for different applicable e-Health scenarios using Session Initiation Protocol (SIP), iii) Modification of the SIP to match the features provided in the proposed e-Health service, and iv) Emergency cases detection, which is practically vital to save patients life.

The rest of the paper is organized as follows. Section II describes in details the proposed network architecture. Section III explains the initialization phase as well as the different applicable scenarios. Conclusion is in section IV with an idea about the ongoing work to evaluate the proposal's validity.

II. PROPOSED NETWORK AND SERVICE ARCHITECTURE

The proposed network follows the IMS-based NGN architecture [8]. It is divided into five layers: sensors, device, access, transport, and service layers as shown in Fig. 1.

The **Sensors layer** contains different types of sensor nodes connected together. These sensor nodes are capable of sensing data, as well as, processing and networking it. A USN Gateway is used to translate between the access network protocol and that of the WSN in order to provide connectivity to the IMS infrastructure. The Gateway is not required if the sensor element has a built-in IP capability.

The **Device layer** provides the connection between the USN Gateways and the IMS network via the access layer. The type of these devices depends on the available **Access layer**, which enables the use of any technology (GSM, 3G, Wi-Fi, xDSL…etc) since IMS is access independent.

The **Transport layer** is divided into a transport control sub-layer on top of a transfer sub-layer. The **Transport Transfer Sub-layer** provides connectivity for all components and physically separated functions within the network. While

the **Transport Control Sub-Layer** provides authentication, authorization, and access control using the Network Attachment Subsystem (NASS) and the Resource and Admission Control Subsystem (RACS) as described in [8].

The **Service layer** provides the platform for enabling services to the user. It is divided into: the **Service Control Sub-layer** and the **Service Application Sub-layer**.

The **Service Control Sub-layer** controls SIP sessions and is based on the NGN IP Multimedia Subsystem (IMS) core component described in [9]. The IMS controls the authentication and routing using Proxy, Interrogating, and Serving Call Session Control Function servers (P/I/S-CSCF), and maintains the subscribers' database in the Home Subscriber Server (HSS).

The **Service Application Sub-layer** contains the Application Servers (ASs) providing the different services. It interfaces with the S-CSCF using SIP and is responsible of executing the different applications.

In this proposal, a new AS integrated with a CA server is developed to provide e-Health services. This integration eases services control and reduces the signaling required between both of them. There is one centralized server, which provides a coherent environment and is responsible of services control. This server can be owned by the network operator or hosted by an external service provider. A Presence Server (PS) is also used to follow and publish the patients' status in real-time to their emergency contacts as explained later in details. This addition allows informing selected persons by the emergency situation as soon as it occurs.

The service application sub-layer contains also a private database for the e-Health services' subscribers. We call it the Electronic Health Record (EHR). It contains the initial sensors configuration settings, the collected monitored vital signs, the different patients' data files such as (X-Ray, tests results, prescriptions…etc), emergency contacts, medical supervisors, medical history, and any other information related to the patient health. The proposal allows the patients to access the EHR. This enables them to change their details, update their emergency contacts, and upload files. Access to the EHR is provided through a Web Server (WS), which is implemented in the service application sub-layer or via an IMS client.

III. SIGNALING SCENARIOS

This section describes in details the initialization phase as well as the different applicable scenarios. It is to be noted that the SIP "MESSAGE" requests in these scenarios are used differently from their original use. Standard SIP "MESSAGE" requests are designed to carry content in the form of Multipurpose Internet Mail Extensions (MIME) body parts. In this work, "MESSAGE" requests are used to deliver data from/to AS/CA. These data messages may contain; sensors initial configurations, sensors information, alerts, and information to subscribers as well. Therefore, the original "MESSAGE" request package has been modified to adapt for the new use and to add the new functionalities.

A. Initialization and Registration

Fig. 2 shows the registration steps for a patient, which follows the standard IMS client registration detailed in [10]. After the registration completion, the S-CSCF evaluates the user's Initial Filter Criteria (IFC) (step 21) and accordingly, it forwards the register message to the AS/CA (22). Based on the e-heath algorithm saved in the AS/CA, it downloads the initial configurations, measurements thresholds, possible diseases' situations, and patient's emergency contact list from the EHR using the HTTP "GET" request (24). HTTP is proposed to be used between the EHR/WS and the AS/CA server. It is to be noted that every patient (e-Health subscriber), via the WS interface, can build his own contact list to be notified in case of emergency as mentioned before. The AS/CA forwards the downloaded initial configurations and a copy of the measurements thresholds to the USN Gateway in the body of a SIP "MESSAGE" request (26). The next step is that the AS/CA sends a "SUBSCRIBE" request (32) to the PS to be notified by the presence status of the persons in the downloaded patient's emergency list. The PS sends back a "NOTIFY" message (34) containing the current status. The PS sends a "NOTIFY" request to the AS/CA every time there is a status change. At the same time, the AS/CA sends a "PUBLISH" request (36) to the PS containing the current patient's status. It is to be noted here that the patient's status is not meant to be online or offline. Instead, it reflects the patient's health condition (normal, critical, emergency …etc). Another important issue arises; the contacts in the patient's emergency list (MC: Medical Center, Rel: Relatives, Physicians ….etc) have to follow his status automatically and without their intervention. To solve this, the AS/CA subscribes on behalf of them to the patient's status by sending a "SUBSCRIBE" request (38) to the PS. Accordingly, they will be continuously notified of any status change via "NOTIFY" requests (40) from the PS.
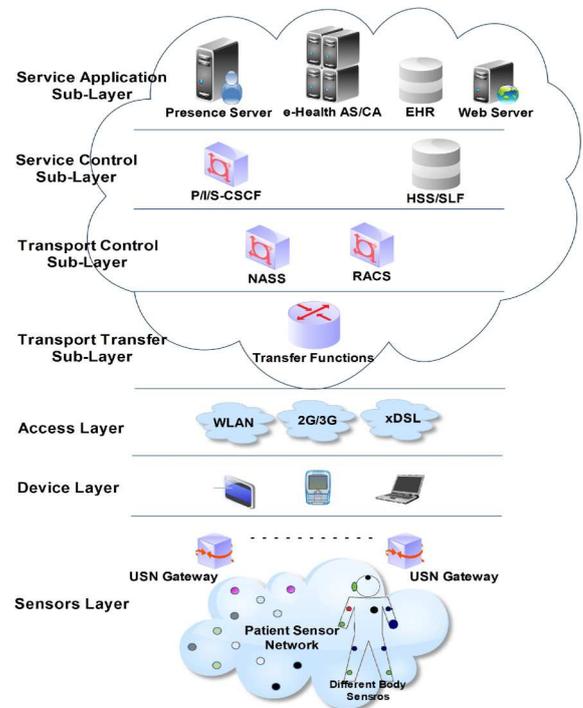

Figure 1. Next Generation e-Health Network Architecture

B. First Scenario (Periodic Transmissions)

This Scenario proposes a simple case for transmitting periodic sensed information. The period to transmit regular collected data is determined from a timer value in the initial configuration received from the AS/CA during the initialization phase. The USN Gateway collects the sensed data from the sensors. When the data is ready for transmission, the USN GATEWAY puts the collected sensors data in the body part of a SIP "MESSAGE" request (1) and sends it to the AS/CA. the request is routed normally to the AS/CA, which stores the data in the EHR using HTTP "PUT" (4). Fig. 3 shows the scenario's signaling flow. The USN GATEWAY transmits the data to the EHR through the AS/CA and not directly, because the collected data has to be assessed and compared to specific thresholds to determine emergency cases (more details in next scenario). These thresholds are set in the initial configuration file downloaded from the EHR during the initialization. This task has to be done by the AS/CA and not the EHR as this later is only a database, and it has no control or service algorithm as in the AS/CA. Another reason is security as the EHR must be hidden from non-trusted users' devices.

C. Second Scenario (Emergency Case)

Fig. 4 shows the emergency scenario. The emergency case is determined if the collected data values are out of the threshold range set in the initial patient's file stored in the EHR and downloaded to the AS/CA. After saving the users' data into the EHR, the AS/CA evaluates the collected values to the preset thresholds. If an emergency case is identified, it updates the patient status in the PS using a "PUBLISH" request (10) to be critical or emergency. The PS updates, in turn, the emergency status in the patient's contacts list by a "NOTIFY" request (12). Simultaneously, an alert message is sent to these contacts. The AS/CA has two options to do so depending on the contacts' IMS status: online or offline. In case the contact person is online, the alert is sent using a SIP "MESSAGE" (14) containing the current patient's data. In case the contact person is offline, the alert is sent using a SMS message (16) through the mobile network. The contacts' IMS status is known since the AS/CA has already subscribed to their status during the initialization phase. The emergency contacts could be relatives, treating physician, medical center, ambulance, neighbors...etc.

D. Third Scenario (Patient Uploading Files)

This scenario, shown in Fig. 5, provides the case of a patient uploading a file (scanned X-Ray, ultrasound, magnetic resonance ...etc) to his EHR record. There are two options for doing this. The first option uses an IMS client. When the uploader (patient) needs to upload a file, he transmits a SIP "MESSAGE" (1) containing in its body part a request for the necessary upload information (URL, username, password …). Once the request arrives at the AS/CA, it asks the needed information from the EHR by a HTTP "GET" (7). The AS/CA forwards this information to the uploader in a SIP "MESSAGE" (9). The uploader can now upload the file according to the received settings using FTP (15). The username and password sent in the previous step are temporary and will change the next time for security. After uploading the file successfully, the EHR informs the AS/CA of the upload termination using HTTP "POST" (17). According to the patient's customized service algorithm, the AS/CA informs the concerned persons (e.g.: physician, medical center, relatives….). This is done, depending on the contacts' IMS status, using a SIP "MESSAGE" request (19) or a SMS (21) as explained in the previous scenario. The second option is shown in Fig. 6. In that case, the uploader doesn't use an IMS client. He uses HTTP to browse the WS (1), and submits his file directly by FTP (2, 3) without using the IMS network. As in the first option, the EHR informs the AS/CA of the upload termination using HTTP "POST" (4). The AS/CA, in turn, informs the concerned persons using a SIP "MESSAGE" request (6) or a SMS (8).

E. Fourth Scenario (Physician Uploading Files)

This scenario is similar to the previous one. However, the uploader here is the physician or the scanning center or the laboratory…etc. Consider the patient's physician would like to send or update the prescription of the patient or the lab wants to send the test results. They will connect directly to the WS using their accounts credentials and upload the new file or update the existing information. The sender can also identify the urgency of this data. The EHR informs the AS/CA of the new upload or the information change. The AS/CA, in turn, informs the patient using a SIP "MESSAGE" request or a SMS depending on his IMS availability.
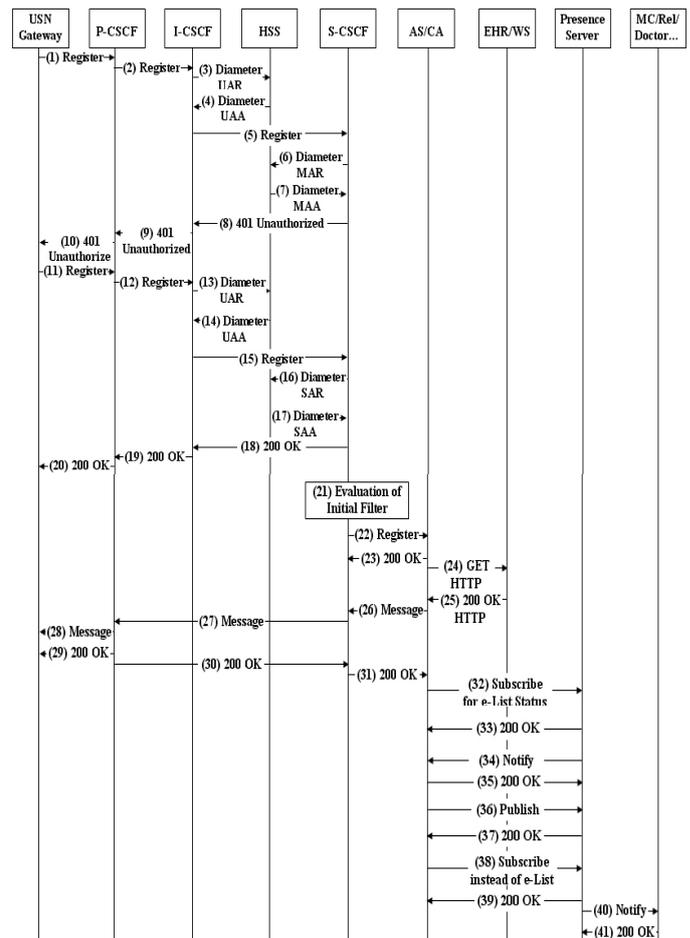
Figure 2. Registration and Initialization Scenario
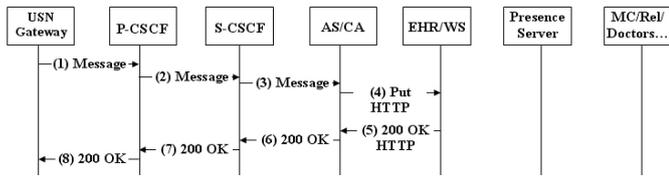
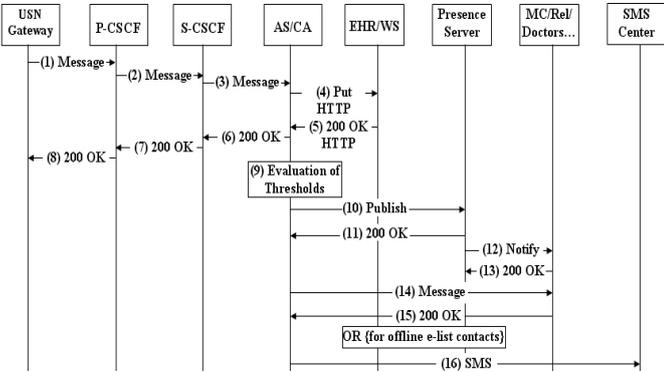Figure 3.   Periodic Transmission Scenario

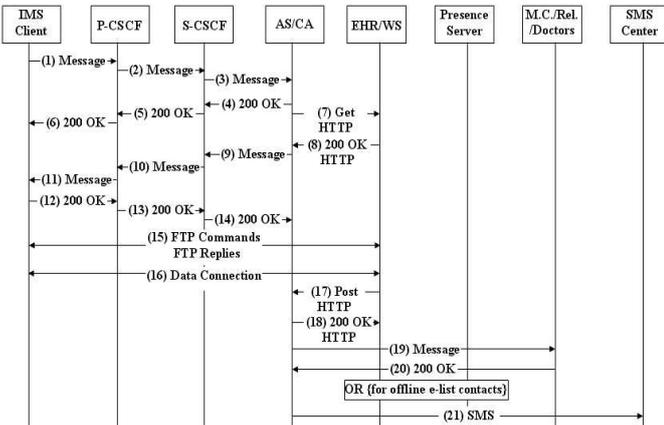Figure 4.   Emergency Scenario

Figure 5.   Uploading Patients' Files Through the Web Server
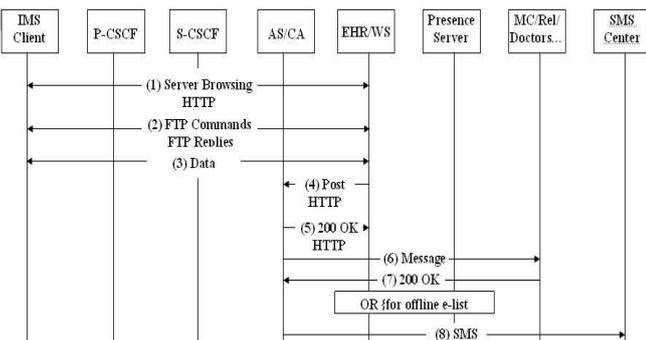

Figure 6.   Uploading Patients' Files using an IMS Client

F.   Potential Applications

Another application for such a service could involve the pharmacies, insurance companies, and hospitals. The patient can ask for the medicines from the AS/CA. this later would search the database for the nearest pharmacy to the patient and inform him or order it automatically. The service can also be used to set an appointment for the patient with his physician or at the medical center. In case he needs to be transferred to the hospital by an ambulance, he can ask for that and the AS/CA will reserve the ambulance for him to the nearest medical center or hospital. All these application require that the EHR should contain a complete database for patients, hospitals, insurance companies, pharmacies … etc.

IV.   CONCLUSION AND FUTURE WORK

Despite that e-Health is one of the promising services in NGN; there is no complete or detailed solution to provide this service. In this paper, we tried to propose a complete solution, including both the architecture and the inter-entities signaling to provide e-Health services in NGN based on the IMS and using SIP. A new architecture is introduced. It uses the existing IMS-based NGN functional entities adding to them new ones such as the e-Health AS integrated with a WS and the EHR. Detailed scenarios are presented showing the complete execution of the service and the interaction between the different entities. We are currently working on implementing this solution in our NGN testbed to evaluate its validity and performance. Most of the work is focused on the development of the AS/WS and the EHR. Once the implementation is done, we will evaluate the solution and publish the results.

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