Evaluation of the New e-Health Signaling Model in the Ubiquitous Sensor Network Environment

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***Abstract*— Ubiquitous Sensor Network (USN) is a conceptual network built over existing physical networks. It makes use of sensed data and provides knowledge services to anyone, anywhere and at anytime, and where the information is generated by using context awareness. In 2010, the ITU-T provided the requirements to support USN applications and services in the Next Generation Network (NGN) environment to exploit the advantages of the core network. One of the main promising markets for the USN application and services is the e-Health. It provides continuous patients' monitoring and enables a great improvement in medical services. In this paper, the authors provide the evaluation of the e-Health signaling model in the USN environment, which was introduced in a previously published work. The model is based on using the IP Multimedia Subsystem (IMS) as a service controller sub-layer for the USN platform. This paper provides a USN based IMS detailed network design for e-Health implementation with emphasizes on Session Initiation Protocol (SIP) modification and middleware entities functions. The proposal evaluation was carried using OPNET Modeler for network simulation and proved its applicability and reliability.**

Keywords- e-Health; ubiquitous sensor netowrk; NGN; IMS; SIP.

I. INTRODUCTION

The ITU recommendation Section for Ubiquitous Sensor Network (USN) presents the requirements for a platform to numerous number of life services and applications [1]. The USNs consist of collaborative efforts of many small wireless sensor nodes. These nodes are small and autonomous devices capable of measuring all sorts of environmental and physical conditions (e.g., temperature, sound, vibration, pressure, motion or pollutants) forming the USN sensor layer. The Next Generation Network (NGN) capabilities can impact the service requirements of the USN. Support of USN applications and services may require some extensions and/or additions to NGN core.

One of the main emerging markets for the USN applications and services is the e-Health. It has been invented to exploit the wide use of the USNs to gather the patients' medical/non medical data for various applications. e-Health offers timely coverage of the advances in technology that offer new and innovative options to practitioners, medical centers, and hospitals for managing patient care, electronic records, and many other features.

Considerable ongoing research efforts are focusing on providing the physical design for the USN entities according to the ITU requirements. Some of these proposals are based on Context Awareness (CA), such as [2][3][4]. Also, an integration between service enablers based on the CA system is proposed to provide various services in [5]. Paganelli et al. proposed a context aware mobile service platform supporting mobile caregivers in their daily activities [6]. They have demonstrated its capability for providing an extensible set of services aiming at supporting care networks in cooperating and sharing information for the goal of improving a chronic patient's quality of life. This work was used for health monitoring and alarm management of chronic conditions in a home-based care scenario [7]. The CA service architecture proposed by Domingo [8] can also be used in order to integrate with social networks.

Another group of 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 without mentioning the consideration of the core network [9][10].

Most of these researches and standardization efforts proposed only theoretical ideas and potential scenarios. However, they did not provide a detailed signaling flow to be the roadmap for implementing these e-Services.

Apart from the ITU recommendations of USN, there are other approaches for building a platform for sensor networks services. Singh et al. [11] proposed a prototype for a global homecare monitoring system. The prototype is based on using IP-based USN in a personal area to provide sensor data. Kim [12] proposed a middleware platform including several types of sensor network for building USN services. The platform is used to build a healthcare service that is proposed to be integrated with standardized medical devices communication framework based on ISO11073/ IEEE1073 standard. These proposals introduce a healthcare service with minor capabilities offering monitoring only due to the limited core network facilities. Moreover, it did not consider the challenges of the integration between USN and existing infrastructure. Besides that, these solutions miss proposing real scenarios and its required signaling flow.

On the contrary, in [13], we proposed the usage of IMS as a service controller sub-layer in the USN environment. The IMS platform is used to utilize its benefits and features

[9] and to provide the service requirements of USN applications and services [1]. The main contribution of [13] is to develop a detailed network signaling flow for different applicable e-Health scenarios using Session Initiation Protocol (SIP).

In this paper, we provide a USN-based IMS detailed network design for implementing the e-Health service with emphasizes on the middleware layer entities functions. There is a need to modify the SIP protocol (SIP MESSAGE request) to match the features provided in the proposed e-Health service as will be discussed in details in Section III.

The rest of the paper is organized as follows: Section 2 describes the detailed proposed network architecture. Section three explains the modification of the SIP Message Request and initialization phase, as well as the different applicable scenarios. Section 4 presents the proposal evaluation using OPNET simulation. Finally, Section 5 gives a conclusion and an idea about the current and future work.

II. PROPOSED NETWORK AND SERVICE ARCHITECTURE

The proposed network follows the IMS-based NGN architecture and according to the requirements of the USN [1]. We implemented these requirements in the form of physical devices as described in the proposed model as shown in Figure 1. The architecture is divided into two stratums: transport stratum and service stratum.

The patient sensor network contains different types of sensor nodes with wireless capability. These nodes observe the patient and the surrounding atmosphere as well. A USN Gateway is used to translate between the network's access network protocol and that of the sensor nodes providing the connectivity requirement to the IMS infrastructure.

The transport stratum includes transport sub-layer and transport control sub-layer. The transport sub-layer contains access network and core transport network. The access network take care of end-users' access to the network as well as collecting and aggregating the traffic towards the core network. The transport control sub-layer is further divided in two subsystems the Network Attachment Subsystem (NASS) and the Resource and Admission Control Subsystem (RACS) to provide the QoS, privacy, security, and authorization, as required for the USN applications. These elements provide transport control functionalities according to the standards [14][15].

The service stratum includes IMS service control sub-layer, USN middleware sub-layer, and the IMS service application sub-layer.

It provides the platform for enabling services to the user. It includes registration and session control functions. It includes three sub-layers: the service control sub-layer, the USN middleware sub-layer, and the service application sub-layer. The service control sub-layer is based on the standard IMS [16] and controls the authentication, routing, and database of the subscribers. This sub-layer provides the USN requirements needed including service profile, open service environment, security, and authorization.

The USN middleware sub-layer consists of a set of logical functions to support USN applications and services. It contains the Application Servers (ASs) providing the different services. It interfaces with the Serving Call Session Control Function (S-CSCF) using SIP and is responsible of applications execution.

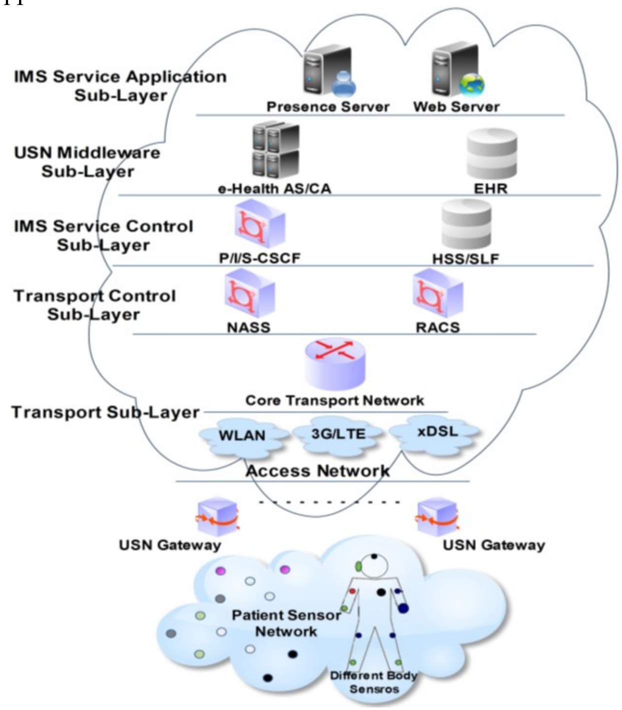

Figure 1. Next Generation e-Health Network Architecture

There is a need for a CA server to automatically adapt an application or service depending on the user current situation. 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.

The USN middleware 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, prescription, 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.

This sub-layer covers the sensor network management, service profile, open service environment, location based service support, and service privacy of the USN requirements.

The Service Application Sub-layer contains a Presence Server (PS), which is 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.

This sub-layer contains also a Web Server (WS), which interfaces the patients' records. Through the WS, patients can change in their details, upload files, contact medical centers, doctors, etc.

III. SIGNALING SCENARIOS

This section focuses on the IMS and SIP functionalities and does not cover the transport layer as there is no modification to its functions.

The 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. The standard SIP "MESSAGE" requests are designed to carry content in the form of Multipurpose Internet Mail Extensions (MIME) body parts. Therefore, in this work, we propose using a special format and data fields for the MESSAGE request body to carry data from/to AS/CA. These data may contain sensors initial configurations, sensors data, alerts, subscribers' information, etc. Figure 2 shows an example of the proposed data fields provided in the MESSAGE request body.

A. Initialization and Registration

Figure 3 shows the registration messages for a patient, which follows the standard IMS client registration until message 20. The messages flow starting from message 21 until the end message presents the proposed signaling flow to initialize and activate the e-health service and the modification of the SIP MESSAGE to fulfill the requirements of the service. After the registration completion, the S-CSCF evaluates the user's Initial Filter Criteria (IFC) (message 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 to the USN Gateway in the body of a SIP "MESSAGE" request (26). The next message 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, Doctors, 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).

Request Line
Header
.
Message Body

Fields of: Sensors Initial Configuration
OR
Fields of: Subscriber Information
OR
Fields of: Sensors Data
OR
Fields of: Alerts Types & Severity Degree

Figure 2. Proposed SIP Message Request Body for e-Health Services

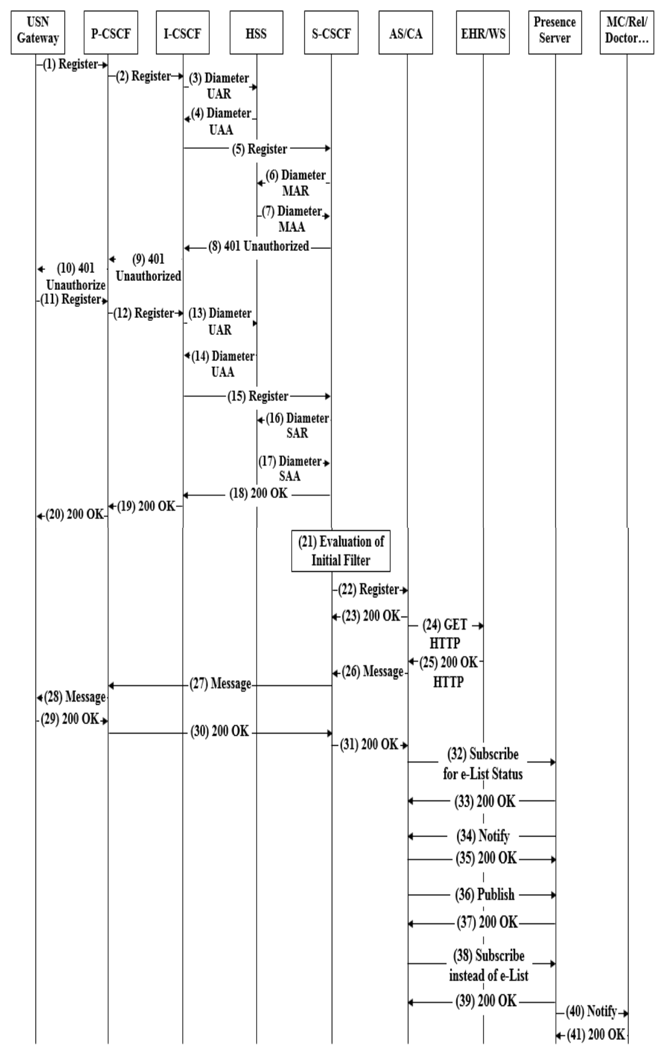

Figure 3. Registration and Initialization Scenario

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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). Figure 4 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)*

Figure 5 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 doctor, medical center, ambulance, neighbors, etc.

D. *Third Scenario*

This scenario, shown in Figure 6, 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, etc.). 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 message 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., doctor, medical center, relatives, etc.). 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 Figure 7. In that case, the uploader does not 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).

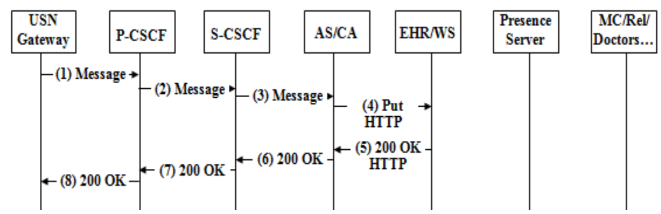

Figure 4. Periodic Transmission Scenario

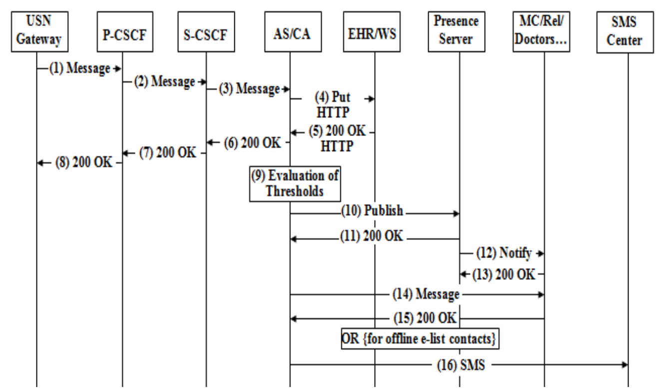

Figure 5. Emergency Scenario

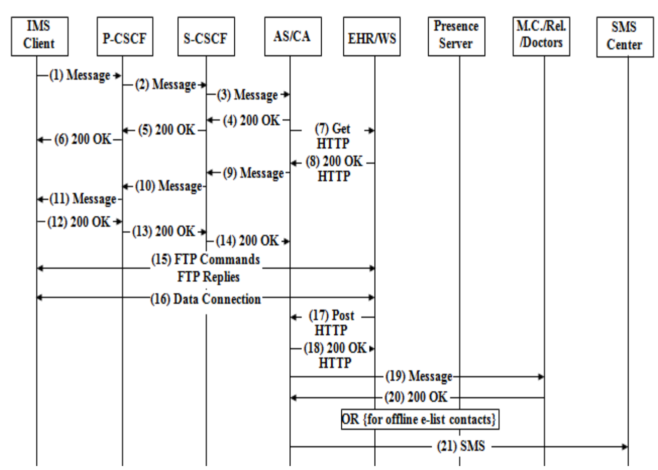

Figure 6. Uploading Patients' Files using an IMS Client

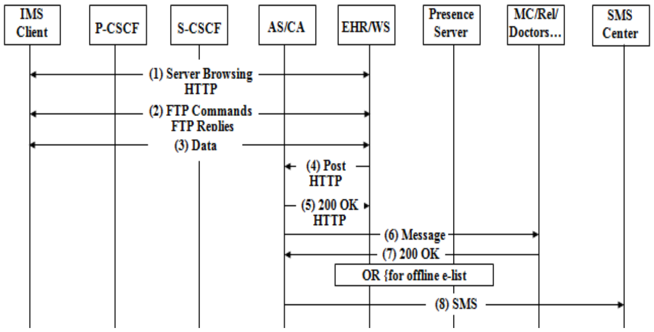

Figure 7. Uploading Patients' Files Through the Web Server

E. Fourth Scenario

This scenario is similar to the previous one. However, the uploader here is not the patient but the treating doctor or the scanning center or the tests laboratory, etc. Consider the patient's doctor 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 "MES-SAGE" request or a SMS depending on his IMS availability.

IV. Performance Evaluation

This section presents the performance evaluation of the proposal. To evaluate the system, we implemented the different scenarios using the OPNET modeler 14.0. The objective of the simulation is to study the applicability and reliability of the proposal under different conditions such as number of users and links bandwidths (BWs). As this work concentrates on the IMS and the SIP protocol and as the NGN transport layer has no change in our model, the performance Section focuses on the IMS evaluation. The simulation model passes by sequential steps as follows:

- Build the proposed network architecture (IMS servers) using the OPNET simulation tool as shown in Figure 8 and assign the transmission delay to the servers' connections according to the values of Table I.
- Create the developed signaling flow using the graphical OPNET application task tool (ACE whiteboard) as shown in Figure 9. The servers are called tiers in ACE whiteboard.
- Assign the processing time of each server (tier) in the ACE whiteboard model according to Table I in [17].
- Import the ACE whiteboard model into the main project model.
- Assign the server function of each ACE model tier corresponding to the developed signaling flows.

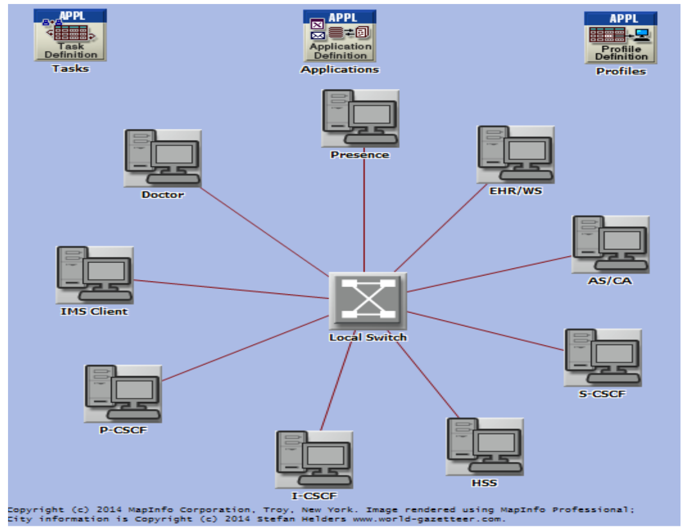

Figure 8. Network Architecture Built using the OPNET Simulation Tool

TABLE I: IMS ENTITIES PROCESSING AND TRANSMISSION TIMES

Parameters		Duration
Process time (microsecond)	UE P/S/I-CSCF HSS	200 200 10
Transmission delay (microsecond)	UE/P-CSCF other links	5,000 200

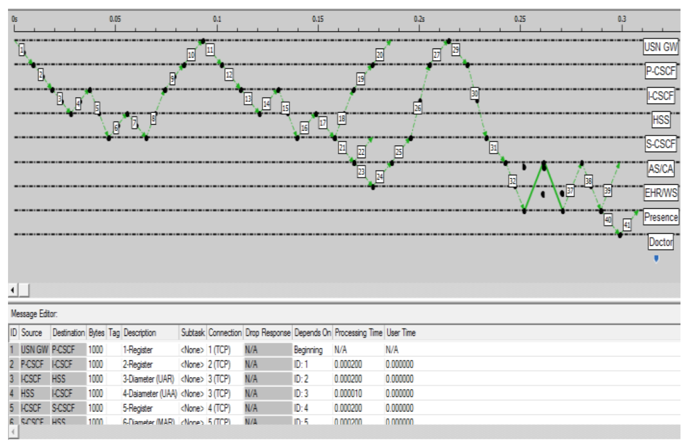

Figure 9. ACE Whiteboard Model for the Registration and Initialization Signaling Flow

Simulation 1: for the first scenario (initialization and registration), we studied the effect of increasing the BW of the link between the USN Gateway and the network on the initialization time. The initialization time is defined as the time spent between the register message (1) and the 200 OK message (41). We repeated the simulation several times increasing the BW from 50 to 500 Kbps in steps of 50 Kbps. The connection BW is chosen to be low to assure the reliability of the proposed scenarios.The initialization time was calculated for different number of users varying from 100 to 1000. Figure 10 shows the collected results. The simulation shows that the delay of the initialization time decreases with the increase of the connection BW. On the other hand, the number of users has a negligible effect for bandwidths higher than 150 kbps and a small effect for bandwidths less than 150 kbps. This is because the connection bitrate required for each user to register and activate his e-health subscription is low according to the signaling proposed in Figure 3.

Simulation 2: the emergency detection scenario is evaluated by simulating the signaling flow shown in Figure 5. The simulation was run for different USN Gateway connection BWs ranging from 50 to 500 Kbps for 100, 500, and 1000 users respectively. The collected results are shown in Figure 11. The simulation shows that the maximum detection time of an emergency case is 0.21 seconds. This time decreases exponentially as the BW increases and is not affected significantly by the number of users. As shown in the figure, the number of users has a minimum effect on the delay. This is because the BW needed for the process is low, which proves the reliability of the developed signaling flow. Moreover, the delay is within an acceptable margin for implementing the emergency scenarios as they do not require high connection bitrate.

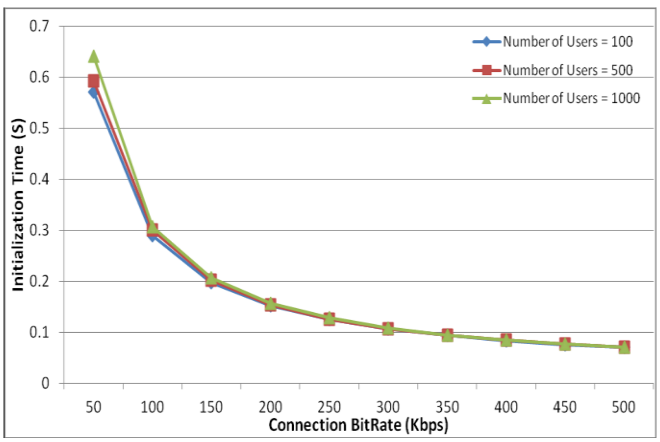

Figure 10. The Registration Time at Different Connection Speeds

TABLE II: UPLOADED FILES SIZES

File Type	Purpose	Average File Size
Text	Sensed Information Medical Analysis, etc.	A few KB
Image	X-Ray Magnetic resonance, etc.	0.5 MB
Video	Ultrasound, etc.	5.0 MB

TABLE III: HSUPA CATEGORIES SPEED

HSUPA Category	Max Uplink Speed
Category 1	0.73 Mbit/s
Category 2	1.46 Mbit/s
Category 3	1.46 Mbit/s
Category 4	2.0/2.93 Mbit/s
Category 5	2.0 Mbit/s
Category 6	2.0/5.76 Mbit/s

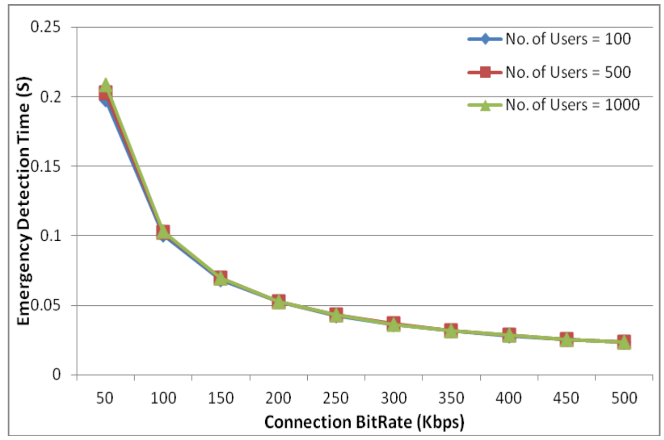

Figure 11. The Emergency Detection Time at Different Connection Speeds

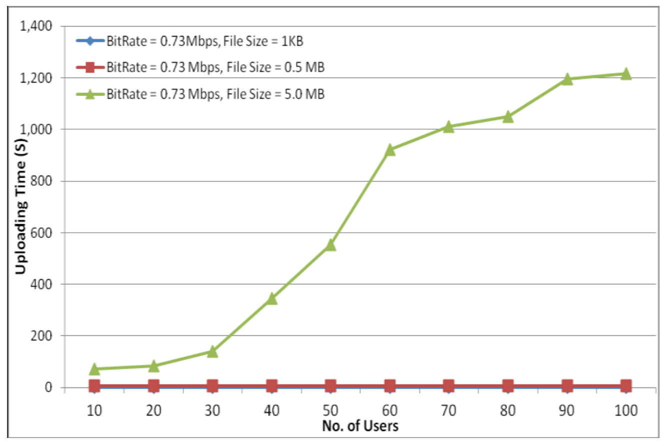

Figure 12. File Uploading Time at Different Number of Users

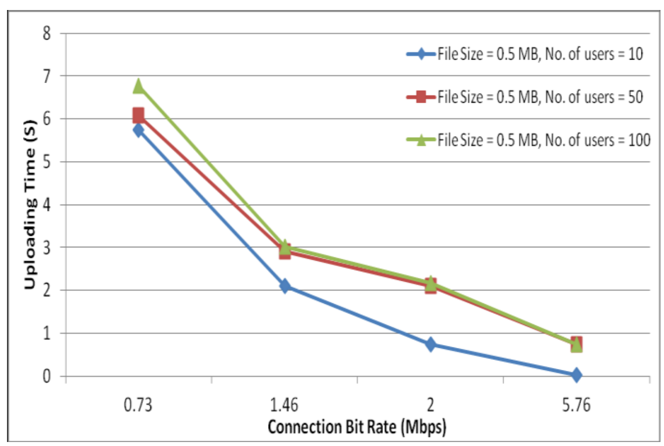

Figure 13. File Uploading Time at Different Connection Speeds

Simulation 3: to investigate the time required to upload a patient's file. We simulated the flow shown in Figure 7 increasing the number of users from 10 to 100 in steps of 10 and the simulation was repeated for different file sizes as shown in Table II. The BW of the link between the USN Gateway and the network was set to 0.73 Mbps corresponding to HSUPA-category 1 connection rate. Figure

12 shows the output results. The figure clearly shows that at small file sizes of 1KB and moderate file sizes of 0.5 MB, the delay is almost constant with the number of users. These files sizes represent the USN sensed information or patient analysis files and the average size of the x-ray or image files respectively. On the contrary, for large file sizes (5.0 MB), which represent an average video file size, the delay increases with the number of users. Hence, the proposed solution is very effective in case of small or medium files representing data and radiography files. On the other hand, video files will suffer of delay depending on their sizes.

Simulation 4: for the same scenario of Figure 7, the effect of the USN Gateway connection BW on the upload time is studied. The simulation was run several times for different connection bit rates corresponding to the different HSUPA categories as stated in Table III. It is to be noted that the HSUPA Category 4 speed is not simulated as it is not being widely implemented. The file size was assumed to be 0.5 MB in this simulation. Figure 13 shows the results. The simulation proves that for a fixed number of users and file size, the delay decreases with the increase of the users' connection speed.

Simulation 5: the initialization process of Figure 3 and the upload scenario of Figure 7 were combined together in one final simulation to study their effect on each other. We simulated 10 users performing the initialization process simultaneously with 10 other users uploading files of 0.5 MB. The USN Gateway connection BW is 1.46 MB/S (HSUBA Category 2). The simulation was repeated for 50 and 100 users. The results are shown in Figure 14 along with the results of the initialization and upload times collected from the previous simulations where the two processes were simulated separately. The results show a slight effect on the upload time, which could be neglected. On the other hand, there is no congestion effect on the users registering to the network even when there are other users uploading files. This is because the registration process does not mandate high connection speed.

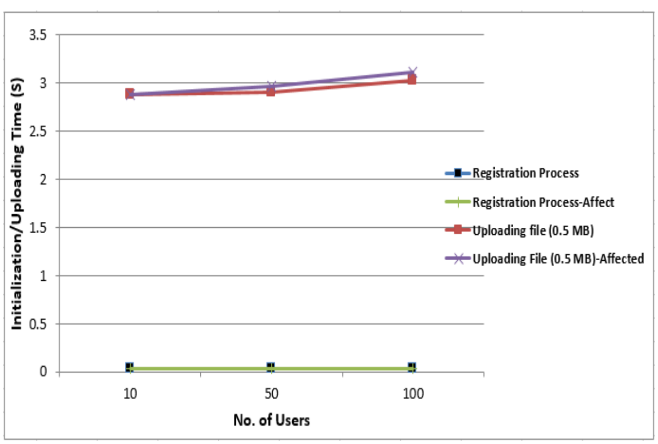

Figure 14. The Effect of Uploading FilesScenario on the Registration Scenario.

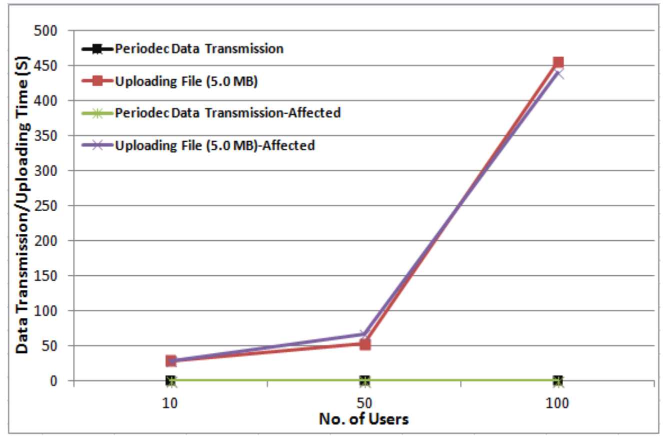

Figure 15. The Effect Uploading Files Scenario on Periodic Data Transmission Scenario

Simulation 6: finally, the mutual effect of combining the traffic of uploading files of size 5.0 MB and the periodic sensors' data transmission according to the signaling flow of Figure 5 is investigated. The USN Gateway connection BW is 1.46 MB/S (HSUBA Category 2). Each type of traffic was simulated separately and then combined together. The results are shown in Figure 15 for separate and combined traffic types. We can conclude that there is almost no mutual effect as the periodic data size is very small and does not require high bit rate. Therefore, the emergency scenarios reliability will not be affected by the simultaneous transmission of other files.

V. CONCLUSION

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 the SIP protocol to fulfill the service requirements of the USN applications according to the ITU recommendation. 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.

The evaluation of the proposal proves the ability to implement the proposed e-Health scenarios and the reliability of the new signaling model. The results show: first, the initialization time and the emergency detection time are very short (0.64 S, 0.21 S), respectively, even under low BW and high number of active users. Second, the file uploading time is affected essentially by the file size and the available BW. However, since file transfer is not delay sensitive, this is not a major issue if high BW connections are not available. Finally, combining different types of traffic together does not have a significant effect on the performance of the system.

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