wNext Generation Network Infrastructure Enabling Telemonitoring Services

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Abstract: In the next few decades one of the main problems to deal with in Western Europe is the aging of the population. The healthcare sector will face rising costs and increasing workload. Telemonitoring and networks of professional and voluntary health workers are promising solution directions to deal with both the cost and workload challenges. In this paper a study on telemonitoring services with a network of health workers using next generation network infrastructure is presented. Next generation network infrastructure technologies like Session Initiation Protocol and IP Multimedia Subsystem offer service enablers that help realise a telemonitoring solution that can call in a dynamic network of health workers. Content repurposing is an important component in this solution enabling the distribution of multimedia content to the large variety of devices.

1 Introduction

In the years to come the aging of the population in Western Europe will lead to a dramatic increase in the demand for specialized, and hence costly, healthcare services. For example in the Netherlands we see an increase of people above the age of sixty-five from 14% of the total population in 2005 to 19% percent in 2020 [CBS06]. Within these statistics an increase in the total working population is not seen. Pressure of work on healthcare professionals is therefore expected to rise. One of the possible solutions to deal with this problem is the use of volunteer aid, which can help healthcare professionals to lighten some of their tasks. Volunteers can perform simple care tasks and help professionals in acquiring information about the situation of the patient. This will result in a network of professionals and volunteers as health workers responsible for healthcare services to the patient [BST03].

Another problem that arises due to the aging of the population is the cost increase of healthcare services. Less people will have to pay the healthcare costs for more people. A solution direction for this problem is enabling elderly people to stay longer in their own house instead of going to a nursery home. Telehomecare services like telemonitoring can provide health services within the premises of elderly people. Additionally, it can help reducing the workload for the healthcare professionals and increase the independency of the elderly patients.

The above mentioned solution directions can result in a situation where different health workers (professionals and volunteers) are involved in a telemonitoring service offered to the patient. This requires good communication among the volunteers and the professionals and clear responsibilities of tasks, e.g. volunteers can interact quickly with the patient in an emergency situation and help professionals in giving first aid. New communication networks can provide an infrastructure which supports such a network of cooperating volunteer and professional health workers.

Mobile as well as fixed telecom operators within Western Europe are currently implementing all-IP based network infrastructures, that shall not only support data services but also various kinds of multimedia services including voice communication like Voice over IP (VoIP). Such all-IP architecture offers new possibilities for enhanced communication services and can therefore be of interest for telemonitoring services. In this paper a study on telemonitoring services with a network of health workers using next generation networks infrastructure is presented. For this research a literature study on all-IP architectures, interviews with healthcare professionals on telemonitoring and some first experimental tests with next generation network protocols were performed.

The organization of this paper is as follows. Section 2 provides an overview on the new network infrastructure and services. In section 3 a description of telemonitoring is given. Section 4 indicates how these new services can be used within telemonitoring. Section 5 proposes an infrastructure needed for the presented scenario. In section 6 conclusions and recommendations are given and section 7 contains a bibliography.

2 Next generation infrastructure

The next generation network infrastructure will be an all-IP network. Both mobile and fixed networks will be based on the Internet Protocol. Voice communication as well as data communication will be transported over the IP transport layer. The IP Multimedia Subsystem (IMS) is a key element in enabling an all-IP network. IMS enables communication services to be delivered in a standardized manner. Moreover, its layered and modular structure provides the ability to re-use components for creating new services. Not only network operators but also other parties can create new enhanced communication services on top of this infrastructure. Also telemonitoring services can make use of this advanced infrastructure.

2.1 Session Initiation Protocol

Session Initiation Protocol (SIP) is an Internet Engineering Task Force (IETF) standard for signalling and session control [Ro02]. It provides functions for creating, managing and terminating sessions between two or more endpoints in an IP based network. A session could be a simple two-way telephone call, a conference call or streaming multimedia images. SIP doesn't specify the media transport; how data exchange is performed within a session is taken care of by other protocols. In short, SIP serves four major purposes

- SIP allows for the establishment of user location (i.e. translating from a user's name to their current network address).
- SIP provides for feature negotiation so that all of the participants in a session can agree on the features to be supported among them.
- SIP is a mechanism for call management - for example adding, dropping, or transferring participants.
- SIP allows for changing features of a session while it is in progress.

2.2 IP Multimedia Sub System

The IP Multimedia Sub System (IMS) is a 3rd Generation Partnership Project (3GPP) standard that is heavily pushed by the telecom industry [TS 23.002], [TS 23.228]. It is based on Internet protocols and is universally seen as the step forward towards an all-IP environment. IMS is based on SIP and adds Quality of Service (QoS) control, mobility management, charging and security.

2.2.1 IMS advantages

A clear goal of IMS is to move away from vertical architecture solutions for individual services. IMS does not bring a service or a set of services, but provides basic enablers within the Control Layer that can be used to implement various services within the Application Layer (see Figure 1). An example of a service in the application layer is Telemonitoring. An important benefit of this horizontal architecture approach of IMS is that common functionality can be re-used as opposed to the approach of the traditional vertical integration model, in which functionality is replicated for each application. Therefore, the IMS service approach is potentially more cost efficient. Following the horizontal architecture approach of IMS implies that one cannot look at implementing services in isolation. For each service on its own, there is most likely a vertical architecture that is more optimal than using the IMS architecture. Only for a set of services together, the IMS architecture becomes more beneficial.

Another important aspect of IMS is that it provides a standardized overall solution. This should enable interoperability between terminals and networks from different vendors and suppliers. IMS standardization also implies that interconnection between subscribers of different operators is facilitated.

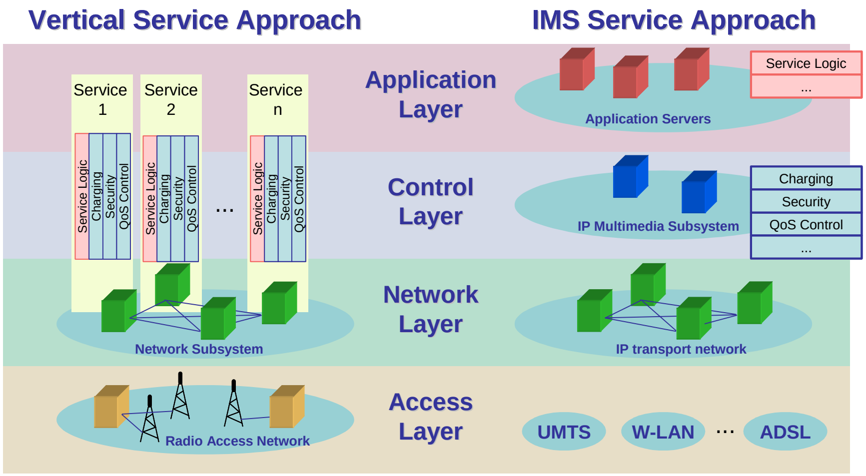

Figure 1: IMS as a horizontal service development approach (source: Frost & Sullivan)

2.2.2 IMS enablers

IMS offers basic enablers that can be used as building blocks for IMS services. Important basic enablers that are already mentioned are ‘session control’ based on SIP and QoS control. Another interesting one is media negotiation enabling parties in a session to negotiate what media type, codec and bandwidth they can and are willing to support. On top of these basic enablers, IMS also provides service enablers. These are not necessarily end-to-end services, but provide capabilities that value added services can be built upon. In this section we will shortly describe some IMS service enablers that are useful for creating and delivering telemonitoring services.

Presence: IMS supports the generation, distribution and updating of presence information of users [TS 23.141]. Presence information comprehends the availability status of a user’s contacts and may include the following parameters:

- Network connectivity (online / offline)
- Availability (e.g. “available“ or “busy“; availability status may vary for different communication channels)
- Capability (This contact can communicate using video, etc.)
- Moods (happy, sad, tired etc.)

A mobile user may choose whether or not to publicize his presence information, either to anybody or to a restricted set of others.

Messaging: The messaging enabler provides functionality that enables users to send or receive single messages immediately to and from other users i.e. page-mode based messaging, and to create and participate in a messaging conference with one ore more other users i.e. session based messaging [TS 24.247]. The messages can be plain text but can also contain various kinds of multimedia content such as images and video.

Push-to-Talk-over-Cellular: Push to Talk over Cellular (PoC) is similar to the conventional “walkie-talkie” communication. The PoC enabler provides functionality that enables users to send a voice message to one or more recipients over a wireless network by pushing a key on the mobile device [TR 23.979]. The call connection is almost instantaneous and the receiver doesn't have to actively answer the call.

Group-management: The IMS group management enabler provides functionality to manage a group of users [TS 22.250]. It includes capabilities to define a group, adding and deleting group members and modifying service-specific group properties. IMS group management can be used by multiple services and service enablers such as presence, conferencing, messaging, and PoC.

Voice-over-Internet-Protocol: Voice over Internet Protocol (VoIP), also called IP Telephony or Internet telephony, is the routing of voice conversations over IP-based networks. VoIP is essentially not a service enabler; it is considered to be one of the end to end services that will be enabled by IMS. The VoIP service can be enriched with presence, buddy lists and messaging utilizing one or more of the IMS service enablers.

2.3 Repurposing Platform

Next generation network infrastructures should assure interoperability between terminals and networks from different vendors and suppliers. Next to a large variety of terminals and networks, there exists a large diversity in types of content that is transported from and to those devices. In order to be able to distribute the correct format content to each particular device there is a clear need for a content repurposing platform. A content repurposing platform is able to transcode, adapt, and store several types of multimedia content and subsequently distributes the content in the correct format to the target device.

In this paper we present the Farcast platform as a content repurposing component enabling the telemonitoring scenario described in chapter 4. The Farcast platform is a content repurposing platform developed by TNO Information and Communication Technology [EW06]. It can be seen as an extra service on top of an SIP or IMS based network architecture.

3 Telemonitoring

Telemonitoring can be defined as the use of information technology to monitor patients at a distance. Often the monitoring is done in a dedicated contact centre [ST03]. Although telemonitoring is still at an early developmental stage, the possibilities are promising. Compared to existing monitoring services the main benefits of telemonitoring for the patients are:

- Shorter time between emergency and alarming a medical expert preventing serious disorders after an emergency.

- Less need for regular monitoring travel for both patients and professional health workers.
- Patients feel more save knowing that medical experts will be alarmed in case of an emergency.
- Patients can be nursed at home instead of in the hospital which is a more comfortable environment for the patient.

The telemonitoring of patients can be done in two ways: *actively* and *passively* [DJM06]. In active telemonitoring the patient gives explicit permission to send measurement data to the contact centre. This can only be the case when the frequency of sending information is relatively low. Active telemonitoring has the advantage that privacy sensitive information is only sent with the permission of the patient. In *passive* telemonitoring the measurements are sent without interference of the patient. The main advantage is that in case of an emergency, when the patient cannot explicitly give permission, measurements are sent anyway and an alarm can be triggered. Another advantage is that measurements can be sent to the contact centre with a relatively high frequency without disturbing the patient.

Telemonitoring with a measurement frequency that does not exceed once a day can be performed within the home environment of the patient and does not need to work outside the premises of the patient. On the other hand, telemonitoring measurements with a higher frequency rate e.g. heart rate monitoring or with an irregular character e.g. alarm triggers do require the possibility of the measurement and sending of information outside the patient’s premises. As a consequence an infrastructure is needed that supports both mobile and fixed measurement services.

Heartbeat monitoring, being one of the most promising telemonitoring services [Me05], is used within the next section as an example of telemonitoring. A heart attack occurs when the supply of blood and oxygen to an area of the heart muscle is blocked. Often, this blockage leads to irregular heartbeat or rhythm that causes a severe decrease in the pumping function of the heart and may bring about sudden death. If the blockage is not treated within a few hours, the affected heart muscle will die and be replaced by scar tissue. Within the Netherlands 1.5% of the population has a hearth or vascular disease [CBS06]. It is a necessity for heart patients to keep the heartbeat under a certain level. When a heart attack occurs, immediate reanimation in required. Telemonitoring can not prevent a heart attack, but measuring the heartbeat can warn the patient when his heartbeat is above a certain threshold. When the heartbeat is irregular an alarm message can be sent to a contact centre where further necessary actions will be taken.

4 Scenario description

In this section a scenario of passive telemonitoring of a heart patient is described. It is used to get a functional description of a telemonitoring service and can be used to show the possibilities of the next generation network infrastructure.

4.1 Scenario

A heart patient is subject to passive telemonitoring and suddenly gets irregular heartbeats. The heartbeats are measured and analysed locally by the device and send to a contact centre. The operator within the contact centre retrieves the alarming statistics of the measurements, opens the medical file of the patient and sees that the monitored person is a heart patient. The operator tries to call the patient, but the call remains unanswered. The operator contacts a neighbour who appears to be home, has a first aid degree, and has a key to the house of the patient. The neighbour is asked to have a look at the situation. In the meantime an ambulance is called and information is sent to these medical experts. The neighbour arrives at the location of the patient, opens the door, offers first aid and waits for the ambulance personal. The neighbour contacts the operator, who sets up a multiple person voice call with the ambulance personal. The ambulance health workers arrive with all the necessary information about the situation of the patient.

4.2 Function description

Within the scenario four main functionalities of the contact centre application can be identified: Analyse the situation of the patient, selecting the right health worker, contacting health workers and patient and providing information to the health workers.

Analyse the situation: For measuring heartbeats a device attached to the body is needed. This telemonitoring device measures heartbeats using a sensor and analyses the measured data locally. Irregular heartbeats are detected and automatically an alarm is given to the contact centre. A triggered alarm will be acted upon by an operator in the contact centre. The operator assesses the situation by requesting measurement statistics from the telemonitoring device, requesting information from the medical file of the patient and information from the patient using a voice communication line.

Selecting health worker: The contact centre operator attributes a priority indication to the report and decides what competences are needed on the spot. This can be professional health workers but might also involve voluntary health workers. Based on the condition of the patient and on the presence, location, and competences of the health workers the operator decides which health worker(s) will be contacted. Presence of the health workers is needed by the contact centre operator in order to judge whether he/she is able to contact this person and if this person is available for this emergency. In order to know which person can be the fastest on the emergency site, the location of the health worker is important.

Different competences are needed for each situation. These competences are not only that in the medical area, for instance a neighbour does not have professional medical skills, but in an emergency he/she can open the door for medical professionals. Table 1 gives an overview in order to select health worker(s).

Information used	**Explanation**
Presence	• Network connectivity; to see if it is possible to setup a communication session. • Availability; is this person available or busy. This may vary for different communication channels • Technical capabilities of the network service; what kind of information can be sent to this person and in what kind of format
Location	• The current location of a health worker, can be described in several formats such as longitude/latitude, address, cell-id or zip code
Competences	• Basic Competences like opening the door or social interaction with patient etc • Professional Medical Competences like first aid or reanimation skills etc

Table 1: Information used to select health worker(s)

Contacting health worker and patient: The operator is able to start multiple communication sessions with the patient and several health workers. Communication sessions can be with voluntary health workers such as a neighbour or family or with professional health workers such as a district nurse, a general practitioner or an ambulance. This can involve voice communication or messaging communication. Also group communication sessions can be set up.

Providing information: Persons who have entered the communication sessions are able to request information about the client's situation. Only information that is required to perform the healthcare task is made visible to this person. This can be information from the patient's medical file or the statistics of the measurements. The person will request the information using its own device. There will probably be a wide variety on communication devices used by the different persons involved within this service. It is therefore not likely that every person is able to get the same information within the same format. Depending on the type of communication device this person uses, the information is sent within the right format. It might be the case that only a simple text message is sent with location information of the patient to a mobile phone. In another situation full heart films are sent to a mobile device with more advanced capabilities.

5 Technical implementation of the telemonitoring scenario

This chapter describes the technical implementation of the telemonitoring scenario as described in the previous chapter. To get a complete picture of the functionalities and technologies needed a modular product architecture is used based on a functional refinement tree [Wi96].

In the functional refinement tree a decomposition of all functionalities needed in the scenario is performed. The technical infrastructure is also decomposed into smaller technical components in the same way as the functional decomposition. All functions find their implementations within the technical infrastructure as reflected by the connection lines between the functions and technologies. In this way a complete overview of functions and implementation of these functions is given. Figure 2 gives the functional refinement tree of the proposed telemonitoring solution. In the white boxes the functional decomposition can be seen. The four main functions of the telemonitoring scenario described in the previous section are placed within the second row and are further decomposed.

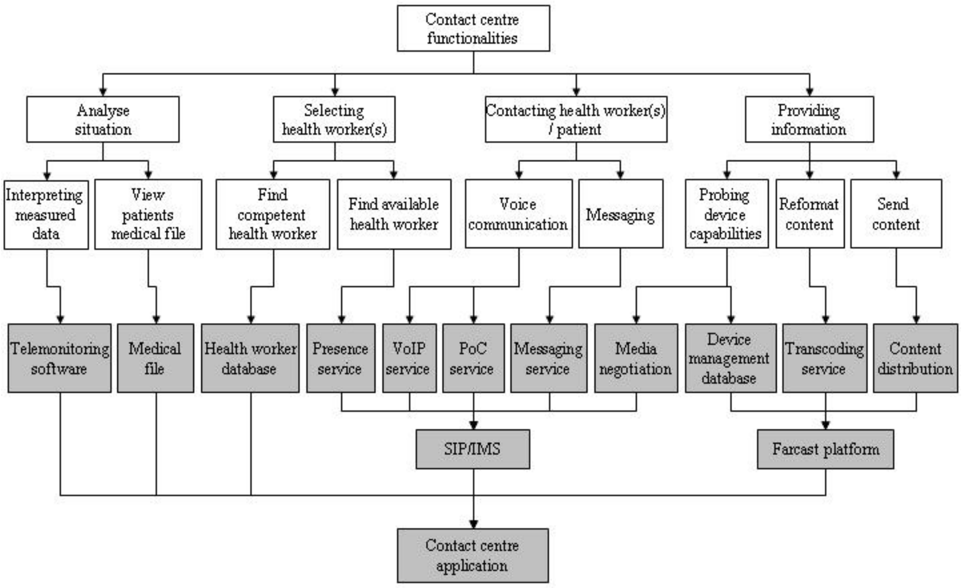

Figure 2: Functional refinement tree

The complete solution is implemented by several technical components. The *contact centre application* provides the contact centre operator with an interface that allows for monitoring patients, accessing information sources, setting-up communication sessions and distributing multimedia content. The contact centre application provides a software shell over other technical components that implement parts of the solution. Besides telemonitoring software, medical files and a health worker database, components of SIP/IMS and the Farcast platform are required to realize the proposed solution.

The *telemonitoring software* at the contact centre is in direct contact with the telemonitoring devices of all monitored patients. It analyses the data that it receives and triggers an alarm when necessary. The alarm will be presented to the contact centre operator via the contact centre application. The operator will assess the alarm and take appropriate action. The contact centre operator has access to several information sources and several forms of communication means to health workers. Next to the telemonitoring software the operator has access to the following information sources:

- *Medical files* of all monitored patients; this could be implemented by proprietary electronic patient files.
- A *health worker database*; with data on all professional and voluntary health workers that can be alarmed via the contact centre. This data includes the competences of the health worker and the SIP address. This SIP address is a unique address needed to contact the health worker using the SIP/IMS platform.

The next generation network infrastructure *IMS* provides several service enablers to the telemonitoring software. One of them is the *Presence service* providing presence information of all professional and volunteer health workers such as availability, network connectivity, and the devices in use. The presence information is combined by the contact centre application with other information sources in order to suggest a health worker to the contact centre operator.

For the proposed telemonitoring solution the location of the health worker would be of great value. This is however not covered by the current specified version of the presence server [TS 23.141]. The reason for this might be in the fact that presence information is rather static compared to the location. Presence updates of a user are pushed to all the users that have subscribed to that presence information. It imposes a heavy load on the infrastructure if location information is also pushed every time the location of the mobile devices changes. We suggest further research in a “pull method” of location updating the presence server: only when necessary the presence server checks with the client for a location update. This method promises benefits in both the load on the network as on the privacy of the mobile device owner.

When the telemonitoring software triggers an alarm the contact centre application will suggest the operator what action to take. The telemonitoring software will base this suggestion on information from various sources:

- The type of alarm that has been retrieved from the telemonitoring software (only a small irregularity or a major stroke?).
- The medical file of the patient (has the patient a history of major strokes?)
- The health worker database (when the patient needs to be visited in his house, which person can open the door for a professional health worker?)
- The presence server (what professional health worker is available AND within 5 kilometres of the patient?)
- The device capabilities of the nearest voluntary health worker retrieved from the *device management databaset* (is the device in use capable of setting up a PoC session?)

Based on the suggestion of the contact centre application the operator will decide which persons, patient and/or health worker(s), to contact and how to contact them. The contact centre operator has various options of contacting the patient or the health worker(s): starting a “walky-talky” voice service to several health workers at the same time using the *PoC service*, sending text messages via the *Messaging service* or starting a ‘regular’ voice call over *VoIP*. All these communication sessions are supported by the IMS platform as described in section 2.

Also data communication sessions are supported by IMS enabling multimedia content to be distributed to the health worker(s). In order to be able to determine in what format the content should be send, *media negotiation* is used; a session to the health worker device is set up to negotiate what media type and bandwidth it supports. Additional parameters and capabilities are retrieved from the device management database. The Farcast platform has a device management database describing the capabilities of a large variety of mobile and fixed devices in terms of screen size, colour depth, image format support, codec support, network support, etc. Based on this information the platform will decide what kind of multimedia content will be sent to the health workers device in use. E.g. when the health worker has a laptop connected via WiFi, he will be able to receive high quality video content. However when, at the moment of the alarm, he uses a regular mobile phone that is not capable of playing video the information could be sent via text and images. Based on the same device management database information and using media negotiation it is decided in what format the content will be sent to the device, e.g. the video will be sent in the mp4 codec or on the 3gp codec. When necessary the Farcast platform will use its *transcoding service* to transcode the content into another format and/or different resolution, etc. Based on the network capabilities of the device the content will be pushed over the most appropriate network to the health worker. Upon reception, the device will display the content on the device.

At the moment of writing this paper several parts of the actual implementation are realised. These include distribution of content, including device management, transcoding and push via SIP. This paper presents the results of the telemonitoring solution exploration phase and the architectural study phase. In the next phase the implementing and piloting of the described solution will be executed.

6 Conclusion & recommendations

The trend of an aging European population results in a growing need for healthcare for elderly people which in turn lead to increased healthcare costs. It is not expected that there will be a growth in professional health workers causing an increasing workload for professional health workers. Telemonitoring and the means to call in a network of professional and voluntary health workers is a promising direction to solve both the cost and workload problems stated above.

Next generation network infrastructure technologies like SIP and IMS offer service enablers that help realise a telemonitoring solution that can call in a dynamic network of health workers. Furthermore, there is a clear need for content repurposing in next generation network infrastructures in order to be able to distribute the correct format content to each specific device. In this paper a solution is presented that implements an application allowing a contact centre operator to telemonitor several patients, access and combine various information sources and set-up different communication channels to a flexible network of professional and voluntary health workers. At moment of writing this paper several parts of the actual implementation of the proposed solution are realised including distribution of content, device management, transcoding and push via SIP.

We recommend further research in the area of IMS service enablers and their application in realizing flexible health worker networks. One of the topics that need specific attention is the combining of location information and an IMS presence service. At this moment a presence server uses a "push method" to be notified of presence state changes that is not practically applicable for location information. We propose a "pull method" for location information allowing for less network load and more privacy for users of such a presence service.

Authors of this article will start with implementation and piloting the described telemonitoring solution in the next phase of their project.

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