Cognitive Network Infrastructures and Virtualization Platforms in Support of Healthcare Applications

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Abstract. Enormous advances in medical sciences are depicted on their capability to approach previously past-cure diseases, as well as prevent other unpleasant situations. Those advances are often derived from interdisciplinary solutions to complex medical problems, supported by communications and electronics, which target fast, reliable and stable solutions to problems that are demanding in terms of velocity and accuracy. Recent findings in the world of communications, such as the systems beyond the third generation (B3G), as well as the exploitation of knowledge and experience by means of cognitive networks, can be efficiently exploited, in order to support electronic healthcare. Accordingly, the goal of this paper is to present a service-oriented management platform, based on B3G communication systems and cognitive networking principles in order to support novel, electronic healthcare services and applications.

Keywords: B3G infrastructures, cognitive networks, electronic healthcare, management.

1 Introduction

Over the last years, the world of medical sciences has met an unparalleled evolution, mainly reflected on the continuous development and enhancement of various solutions, which has been allowing the a priori diagnosis, prevention, as well as treatment of numerous, previously incurable, diseases. As an outcome of versatile research attempts at a worldwide level, novel answers to numerous medical problems have been identified. Today's advancement of e-health products and applications necessitates the consideration of building seamless information exchange networks. In particular, e-health developments are improving the right of access to quality healthcare, regardless of their personal condition and geographical location, allowing the selection of the appropriate health resource from anywhere at any time. This is especially applicable in emergency situations, where timely retrieval of necessary information might be of extreme importance [1, 2, 3, 4].

The aforementioned advances often call for interdisciplinary research and development strategies, this mainly denoting the utilization of the findings of

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telecommunications and electronics. Specifically, some recent trends in the world of communications, such as the birth of beyond the 3rd generation (B3G) systems [5], depicted on the ubiquitous provision of applications at increasingly high bit rates, have paved the way for several innovative healthcare services and applications. Additionally, the advent of cognitive networks, which exploit past interactions with the environment, in taking future decisions regarding their behavior, is expected to facilitate several medical approaches, such as patient management technologies in telemedicine and remote diagnostics, which constitute key research aspects nowadays. All above have rendered the cooperation of medicine with telecommunications, a fundamental (almost prerequisite) factor for any further steps forward.

In the light of the above, the goal of this paper is to discuss on how B3G wireless communication systems, enhanced with the advantages of cognitive network infrastructures, can serve as enablers for the effective management and direction of novel healthcare applications. For this purpose, it first presents an indicative scenario envisaged to involve medicine and electronics, which necessitates the specification of innovative, interdisciplinary solutions. Then, it provides an overview of B3G wireless communication systems and cognitive networking principles, emphasizing on aspects of interest to electronic healthcare. Aligned with the above, the paper then proposes a service-oriented management platform for offering virtualization and cognition, with the scope to facilitate existing healthcare applications. The paper concludes with some summarizing remarks and aspects of future activities.

2 Indicative Healthcare Scenario

The goal of this section is to present an indicative scenario that reveals the need to support healthcare applications with advanced B3G, cognitive networking features. This refers to the retrieval of information that is demanding in terms of quality of service (QoS), so as to ensure the effectiveness of the related application in emergency situations.

The scenario involves an ambulance carrying a patient, and moving at a very high velocity towards a District General Hospital (DGH). Throughout the ride, the ambulance's co-driver is able to collect information regarding the patient's condition, using the appropriate electronic instruments, which can analyze this information. The instruments reveal the existence of a certain danger for the patient's life; consequently, there is need for quickly specifying a treatment procedure (before reaching the DGH), according to (i) the patient's history and (ii) radiological results. The healthcare application considered is able to interchange information with the DGH (inform the DGH upon the incident, so as to enable it to be prepared for efficiently handling it) and depending on the specific need, perform any radiological procedure on the patient, by means of the co-driver. Depending on the patient's personal data, a search is performed within a database in order to (i) identify the patient's history and (ii) check whether a similar incident has been confronted in the past. The doctor inside the communicating DGH is able to watch the patient via video in order to obtain a personal impression upon the incident and thus take any necessary decisions regarding the patient. Potentially there will be need to perform a certain radiological process upon the patient. Subsequently, the doctor is able to specify the appropriate treatment procedure.

A business case corresponding to the aforementioned scenario is presented in Fig. 1.

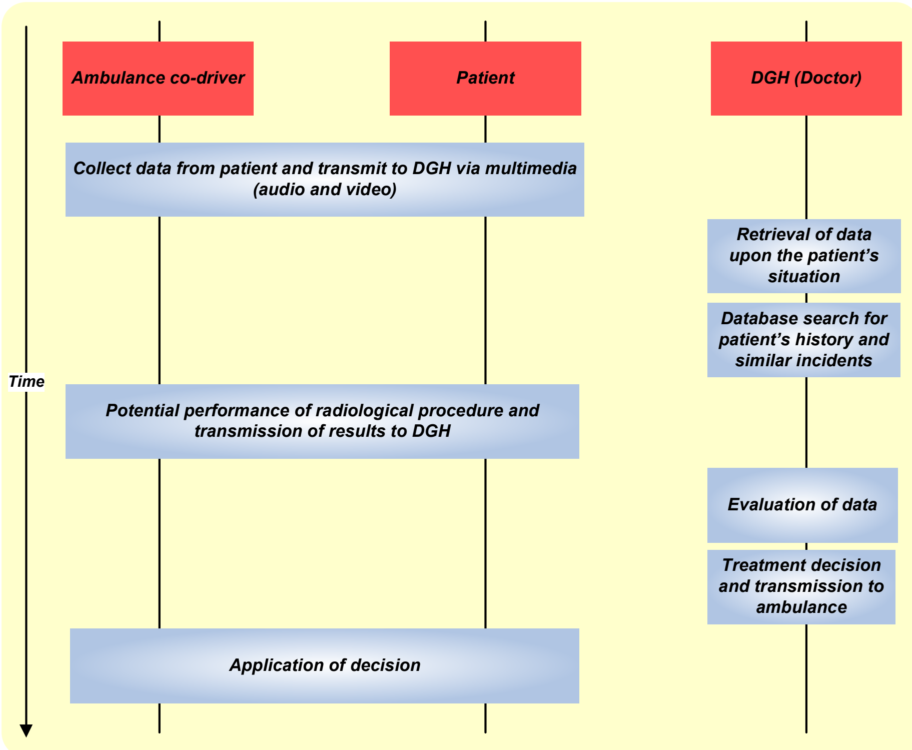

Fig. 1. Healthcare Scenario

The scenario presented above leads to twofold deductions.

First, the necessary time for taking the decision upon the treatment procedure can be significantly reduced, through the continuous communication between the moving ambulance and the associated DGH's doctor. The doctor is informed upon the patient's situation, history and also radiological results (which would be more time-consuming, if completely executed inside the DGH) and may reach to the desired decisions faster and thus more effectively. This benefit is of great significance, since it might be critical for the patient's life.

Second, the scenario assumes that the ambulance is capable of being ubiquitously connected to the DGH in a wireless manner, constantly exchanging information at very high bit rates, which might be difficult while the ambulance changes locations fast. This calls for an enhanced support by means of a telecommunication infrastructure which will allow the transmission of data at high QoS levels, seamlessly.

The next section accordingly, provides an in-depth view of the current wireless communications landscape, so as to serve as a facilitator for the scenario. Accordingly, section 4 describes the proposed infrastructure for such demanding electronic healthcare applications.

3 Wireless, B3G Systems

Over the last decade the world of telecommunications has been undergoing crucial changes, which have brought it at the forefront of international research and development interest. Creative competition among industrial manufacturers, network operators, service providers and academia, through work in research projects, fora and standardization bodies, has resulted in the advent of a multitude of innovative technologies and associated products. Special interest has been drawn in wireless communications, since they are flexible in facilitating novel features, while they also encompass the increasingly desirable concept of mobility. In this respect, today's wireless world features numerous versatile Radio Access Technology (RAT) standards, such as 2G/2.5G/3G mobile communications [5], the IEEE 802.11 and IEEE 802.16 suites of wireless local area networks (WLAN) and wireless metropolitan area networks (WMAN) respectively [6], broadcasting technologies [7], and also Software Defined Radio enabled (SDR) segments [8].

However, wireless systems, in contrast with traditional wired ones, suffer from several dependability problems, including reliability and availability issues [9]. In fact, no specific RAT can be considered trustworthy to confront by its own all contextual situations. Therefore, the exploitation of their coexistence, through their potential cooperation and complementary use, stands as a prerequisite for increasing the dependability of wireless infrastructures. This results in, so called, Beyond the 3rd Generation (B3G) vision [10]. In addition, constant context changes render the different RATs less predictable in terms of Quality of Service (QoS) provision. Consequently, the adaptation of B3G infrastructures to environment requisitions is a key factor that facilitates the realization of the B3G vision.

Cognitive systems [11] are seen as a major facilitator of the B3G vision. Cognitive systems, in general are capable retaining information from past interactions with the environment, transforming this information into knowledge and experience and planning their future behavior accordingly. In the case of wireless networks, this can be translated as the capability of continuously adapting to changing environmental conditions and/or user needs [12]. Adaptation is mainly realized by means of self-management and typically involves machine learning [11].

Considering the above situation, The 3rd Generation Partnership Project (3GPP) [5] has been working on the evolution of the 3G mobile system, defining the architecture shown on Fig. 2, focusing on GPRS Evolved Radio Access Network (GERAN), UMTS Terrestrial Radio Access Network (UTRAN) and Evolved Radio Access Network (RAN) base stations and controllers, also SDR segments, all connected to the, so called, Evolved Packet Core (EPC) network. Certain interfaces allow the interconnection of those versatile control and management entities.

Following the 3GPP architecture described above, several applications, novel and existing ones can be supported. In fact, versatile management and control entities may direct the operation of an infrastructure that complies with this architecture. Following this paradigm, the next section proposes a service-oriented management platform for offering virtualization and cognition, and also for supporting electronic healthcare applications, in conjunction with the scenario presented in section 2.

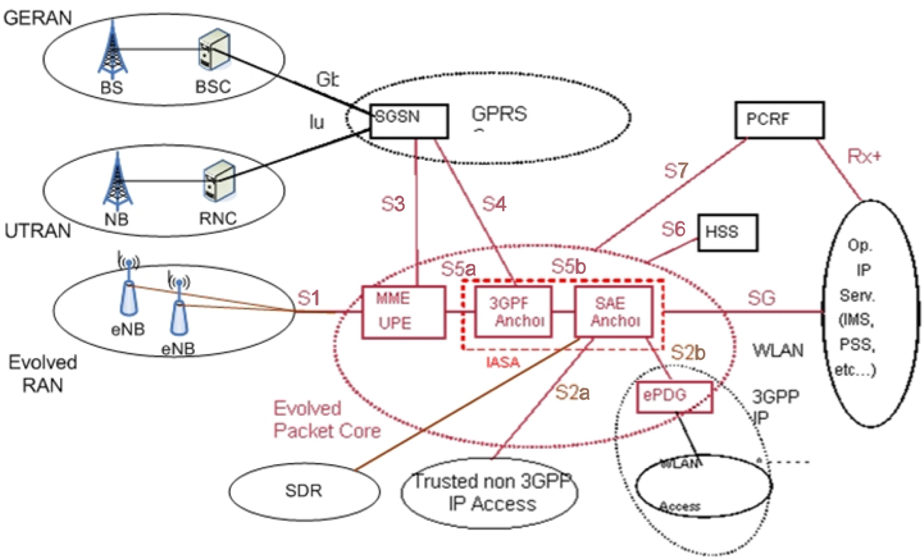

Fig. 2. The 3GPP view on the wireless B3G world

4 Service-Oriented Management Platform for Offering Virtualization and Cognition

As a general deduction from the discussion above, a generic architectural framework to support electronic healthcare applications must dispose certain characteristics of a service-oriented platform. First, it should allow the alternative utilization of various RAT standards during the communication among the ambulance and the DGH. Second, to do so, it should be adaptive (reconfigurable), so as to allow for fast responses to the varying external conditions in the wireless landscape, due to the ambulance's motion. Third, it should be cognitive, so as to retain information from previous incidents and potentially accelerate its response time, in the case that a similar incident has been anticipated in the past. Furthermore, the patient's history might drive future decisions in a cognitive manner and thus lead to the desirable results.

A platform that is envisaged to host diverse electronic healthcare applications, by offering virtualization and cognition (Healthcare Services Oriented – Cognition Management Platform - HSO-CMP), is depicted on Fig. 3.

In general, the proposed platform is expected to be composed of a number of functional elements.

First, hospital (DGH) services which exist also today might need some improvements / enhancements, so as to enable fast transmissions of data at real time, in conjunction with the latest trends in the wireless world. Second, a picture archiving and communication system is needed, for keeping record of incidents, as well as for being responsible for providing the correct information regarding the specific condition of a patient. Third, a radiology information system is needed in the case that certain radiological operations need to be immediately performed upon the patient,

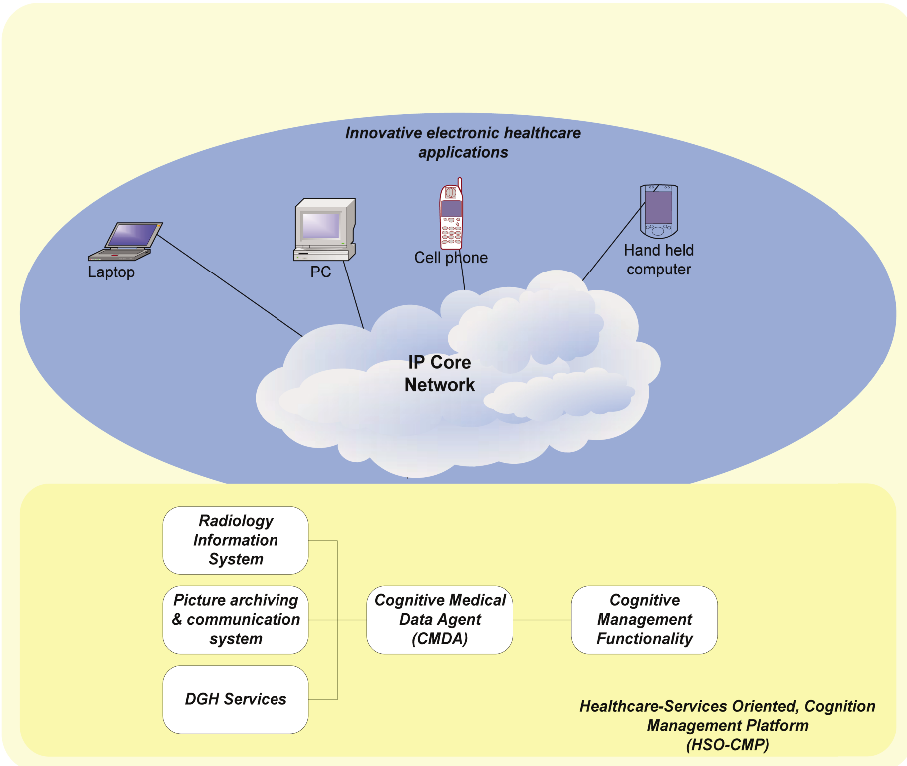

Fig. 3. Healthcare Services Oriented – Cognitive Management Platform (HSO – CMP)

before the doctor is able to reach a decision. Fourth, a cognitive medical data agent (CMDA) might act s a broker, unifying the platform's components. In particular, all data transferred through the platform are recorded by the MCDA, enabling it to locate them fast, if and when needed.

The aforementioned components are managed by an overarching management functionality component. This component should support cognition, in terms of disposing the necessary machine learning equipment that could judge whether an incident anticipated in the past might serve as a guide in deciding upon the appropriate treatment scheme, by proposing potential solutions to the DGH doctor. In fact, this component should be in continuous contact with the DGH doctor, so as to enable the doctor exploit its cognitive features.

In general, the HSO-CMP is under continuous evolution and can be significantly elaborated, so as to be put into effect in realistic emergency situations. After the specification of its fundamental features, the detailed operation of its components, as well as the interfaces that enable their interactions, should be thoroughly analyzed. An indicative message sequence chart (MSC) that can represent the platform's operation is depicted in the following figure.

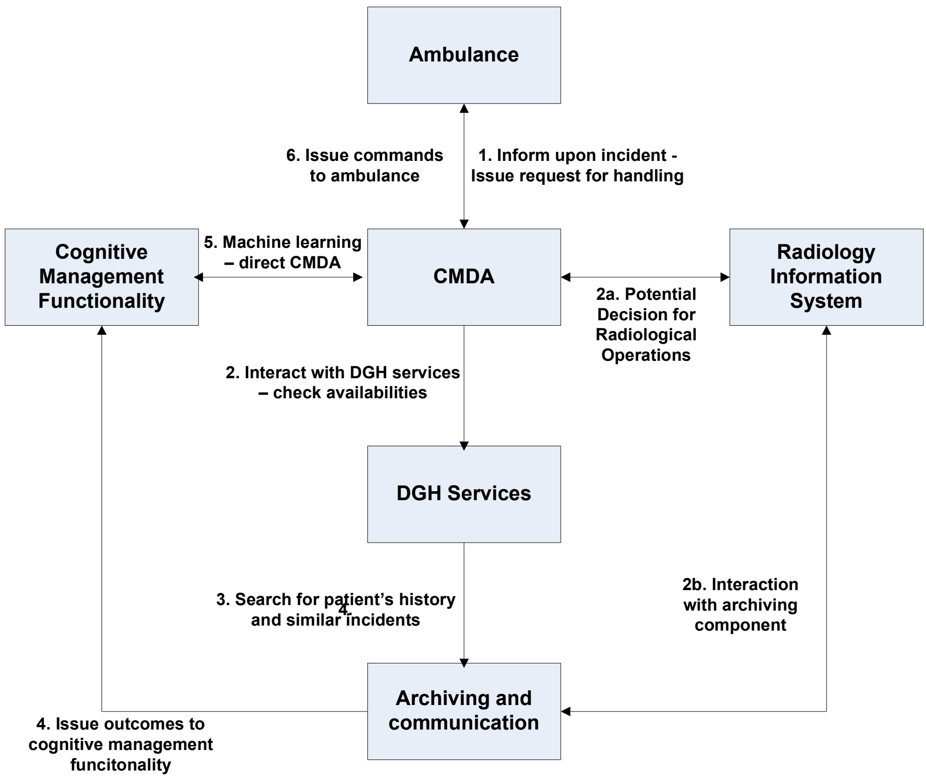

Fig. 4. Indicative Message Sequence Chart

First, the ambulance issues a request regarding the specific incident, towards the CMDA. The CMDA then interacts with the DGH services component, in order to check their availability. The identification of the available services is performed with the help of the archiving and communication component. In addition, there might be need for radiological procedures, so a message exchange been the CMDA, the radiology information system and the archiving and communication components, takes also place. Then, the outcomes of the aforementioned interactions are transferred to the cognitive management functionality component, which issues directives towards the CMDA, exploiting past knowledge and experience. Finally, the doctor is in position to decide upon the suitable treatment scheme and the ambulance is notified accordingly.

5 Summary and Conclusions

Electronic healthcare applications constitute a finding of medical sciences which can significantly facilitate their evolution, by contributing to the prevention as well as treatment of several unpleasant situations / diseases. In this respect, the goal of this paper was to propose a service-oriented management platform for offering virtualization and cognition in support of electronic healthcare applications. The paper has presented an indicative scenario envisaged to be associated with healthcare, which calls for support on behalf of telecommunications, and it has presented such an architectural framework as a manner to direct such an (emergency) scenario, with the general goal to efficiently, transparently and securely manage electronic healthcare applications. It is expected that several electronic healthcare applications can operate on top of such a generic infrastructure, emphasizing on applications that are demanding in terms of QoS levels, usually associated with emergency situations. The further elaboration of the architectural framework presented, as well as the identification and development of even more innovative electronic healthcare applications that could be supported, will form part of our future activities.

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