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A Mobile Health Application Based on a Fuzzy QoS Web Service Component

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***Abstract*: M-health - the use of mobile applications for healthcare - is a dynamic recent field of research that could advance the well-being of people around the world. According to the recent developments in this area, novel medical applications have been proposed in the market to be used on tablets. This tendency has seen the light lately and it is aiming at becoming an integrated part of medical solutions. In this paper, we propose a new medical application intended for android devices. Our M-health application aims at facilitating doctors' tasks by generating an ubiquitous information system. To achieve this, we have based our application on an open source operating system, ``android'', and web services technologies. With the widespread proliferation of web services, Quality of Service (QoS) becomes a significant factor in distinguishing the success of service providers. QoS determines the service usability and utility, both of which influence the popularity of the service. Our M-health application is based on the use of a fuzzy QoS component to guarantee the selection of the most convenient service; seen as a crucial task. In addition, our application functions in a minimal space disk as we will record and get access to the needed resources via a wireless access ensuring the integrity and the security of the transferred data. Android has become more popular, flexible and more distributed; and therefore it will play a leading role in our new developed M-health system.**

***Keywords*:** Mobile-Health, QoS, Web service, Wireless, Fuzzy Set Theory, Architecture.

I. Introduction

Mobile Health, or M-health, can be defined as medical and public health practice supported by mobile devices such as smart phones, patient monitoring devices, tablets, personal digital assistants (PDAs), and other wireless devices [3]. M-health which is, also, defined as the use of wireless communication devices to support public health and clinical practice has great potential to enhance this virtuous cycle. Innovative applications of mobile technology to existing health care delivery and monitoring systems offer great promise for improving the quality of life while making the communications among researchers, clinicians, and patients easier [1].

M-health is still seen as a young and dynamic field of research as it has recently seen the light. Since its development, early in 2003, M-health has come to encompass any use of mobile technology to address healthcare challenges such as access, quality, affordability, matching of resources, and behavioral norms. Thus, it can involve a wide variety of people and products, as well as the actions that connect them. The crux of these connections is the exchange of information. Mobile technologies cannot physically carry drugs, doctors, and equipment between locations, but they can carry and process information in many forms: coded data, text, images, audio, and video [1].

During the last few years, numerous public and private initiatives were proposed addressing different mobile applications and ubiquitous M-health issues, ranging from doctor mobility -remote access to medical data - to patient mobility - such as remote monitoring of vital signals, teleconsultation, mobile medical record, etc. - up to web based medical data access. Nevertheless, these proposed approaches were designed in an ad-hoc way. As a consequence, it is not possible to integrate the different technological innovations and services into an integrated system. Additionally, various critical issues for the deployment of an integrated ubiquitous M-health system were not addressed in the proposed applications. For example, social and economic aspects are not taken into consideration, changes in medical work practices and even standardization of technologies and integration with existing medical information systems are not incorporated in the developed applications neither. It is for these reasons that most of the technological innovations were either rejected by the market or their scope and usage remained limited [4].

Today and following the wireless transmission technologies progress, the primary intention of many researches is to design and implement integrated ubiquitous M-health services systems and platforms taking into account, mainly, the socio-economic and the technological innovations aspects. More precisely, these aspects include standardization of technological innovations, development of new working practices for health professionals, supporting patient and health professional mobility by enabling cooperative working over distance and time between virtual healthcare teams and

the patients, integration of a complete service chain, ranging from medical personnel training, to device maintenance services and billing, and strategies towards the deployment of new services, i.e. personalized M-health information systems for the provision of quality services to citizens, and technologies [5].

Following the rapid growth of the technological advancements and communication platforms capacities and regarding people demands and requirements, the development of a new generation of M-health applications should not only focus on making the software available and functional on the personal computers (PCs) based Internet, in the doctor office or in the patient's home, but also examine the different broadband delivery platforms. In [6], one main development has been proposed; that will have a major impact on the further development of the M-health field. It consist mainly on the notable growth and variety of the technological mobile devices such as the 3G and 4G mobile systems, tablets and satellite handsets; that will, surely, boost and improve the development of the M-health services. A full review of these technologies and their evolution can be found in [2]. The goal of the mentioned development is to ensure that the new M-health services have to be available anytime, anywhere and anyhow through a single point of access entry. Focusing on this point, time and space have always been considered as barriers between health care providers and their patients and among health care providers as well. Telecommunication technologies have presented themselves as a powerful tool to break the barriers of time and space. And with the introduction of high bandwidth, digital communication technologies, it is possible to deliver audio, video and waveform data to wherever and whenever needed.

Incontrovertibly, this is the vision of an interoperable, transparent and secure m-health continent. This could be achieved by the use of appropriate technical tools and platforms, a most convenient architecture, and by adjusting the proposed M-health solution to the citizens' needs and requirements. Consequently, in the current research paper, we propose a novel M-health application taking into account the gap felt between the M-heath service and the outer environment; basically the communication and the interactions between the social and the economic aspects. Our proposed mobile health application presents a general framework dealing with doctors' needs and patients' requirements. Our application will, also, offer the possibility for the user to have access to specific insurance companies depending on its appurtenance, allowing doctors to have access to the online ``Vidal'' medical database [7], allowing doctors to collaborate in case of needs, etc. Our solution will, also, propose other interesting functionalities that will be later discussed. The use of all these offered functionalities, proposed by our developed M-health solution, will be achieved by no place, time or configuration restrictions and more importantly with keeping our solution lightweight in terms of storage size. Adding to these points, it is important to mention that our proposed system is based on the use of web services. Yet, it is crucial to mention that, recently, web services have become an important issue for developers. Selecting a specific service is a crucial task. Some approaches develop extensive description and publication mechanisms while others use syntactic, semantic, and structural reviews of web service specifications. It is very crucial for finding the most suitable web service from a large collection of web services for successful execution of applications. In many cases, the value of a Quality of Service (QoS) property may not be precisely defined. Recently, fuzzy set theory is considered as a dominant approach in web services which can deal with fuzzy constraints. Fuzzy set theory can be applied to represent such imprecise QoS constraints. As a part of our proposed solution, in this paper, we will focus on developing a fuzzy-based component for web service discovery.

The major contributions of this paper are to introduce the use of appropriate technical tools and technologies to develop our proposed M-health solution. We, also, aim at clarifying the functioning of the whole system from a development viewpoint; while focusing on its main characteristics and advantages. Furthermore, we will describe in details the design and the development of our ubiquitous information system for the provision of M-health adaptive services. We have, also, to mention that we have developed a part of this application in a real context. In comparison with applications and projects carried out worldwide, our application is characterized by its ability to fill the gap left between the M-health service and the exterior environment.

The rest of the paper is organized as follows: In Section 2, we discuss in brief some related works while in Section 3, we present our proposed M-health solution approach in details. Section 4 describes the technical specifications adopted by our ubiquitous system. Section 5 describes the strengths of our M-health ecosystem, and Section 6 concludes this paper.

II. Related Works

It is well-known that web service technologies provide an easy way to integrate the applications within and across organizational boundaries. Yet, with the explosion of web services available throughout the internet, it is not easy for the end users to composite the web services manually to meet their specific preferences [14]. One research direction is to study how to choose web services for the tasks for an abstract service process model [15][16][17][22].

In literature, we find some works that tried to build the foundation for the Quality of Service (QoS)-aware web service management. This includes QoS specifications such as HP's web services management Language [21] and IBM's Web Service Level Agreement (WSLA) [19]. In the other hand, Zhou [23] develops DAML-QoS as a complement for DAML-S. In order to incorporate current web service architecture, the work presented in [20] proposes a web services registration and discovery model. Another work presented by Cardoso in [18] deals with a QoS estimation model for composite web service.

Back to the works proposed in literature, we find few works

that have been done in QoS-based web service selection. For instance, the work of Zhou [23] considers QoS matching as subsumption inference in Description Logic. CMI [16] and eFlow [15] try to perform dynamic service selection based on user preferences. Conversely, all of them focus on optimizing service selection at a task level. Yet, the work of Zeng [17] proposes a global planning approach to optimally select component services during the execution of a composite service.

Service selection is formulated as an optimization problem, which can be solved by linear programming methods. Although it is ok that service selection should be done in a global manner, the work proposed in [14] tackled the point that there may be a doubt on the previously mentioned approaches for the following reasons [14]:

First, in computing the aggregated reliability and availability for composite services, they only consider the services in the critical path, which is determined by execution duration. Second, they claim that the user's preference can be set by adding constraints into the Linear Programming. Yet they require that the constraint's related criteria must be with linear aggregation function, which excludes some Qos criteria such as reliability, availability, etc.They, also, point out that doing this could make the problem become NP-hard. This kind of constraints is crisp. Third, the solution generated by their approach is to maximize the objective function, which is set by applying Simple Additive Weighting (SAW) technique. It's really hard for the user to set the weights. Fourth, Linear Programming approach requires the aggregation of the supporting criteria should be linear or can be translated into linear.

Therefore, in [14], a novel approach has been proposed dealing with a fuzzy way to express user's QoS preferences for composite web service. The user's preferences are formalized as fuzzy sets and the trade-offs among QoS criteria are expressed as fuzzy expressions. Service selection is solved as a fuzzy constraint satisfaction problem.

The proposed work - named the Fuzzy Multi-Phase Matching mechanism - [14] is seen as an easy process offered to the user to express the preferences and more extensible to the new QoS criteria. The proposed work contributes to it by introducing a fuzzy way to solve the selection of web services in a global and flexible manner. Based on this study, our proposed M-health android solution is based on the Fuzzy Multi-Phase Matching mechanism. More details about the incorporation of this component will be later discussed in this paper.

III. Highlights of the Proposed M-health Solution Approach

In this Section, we highlight the functioning of our proposed M-health solution. A global synopsis of the solution approach is presented in Figure 1.

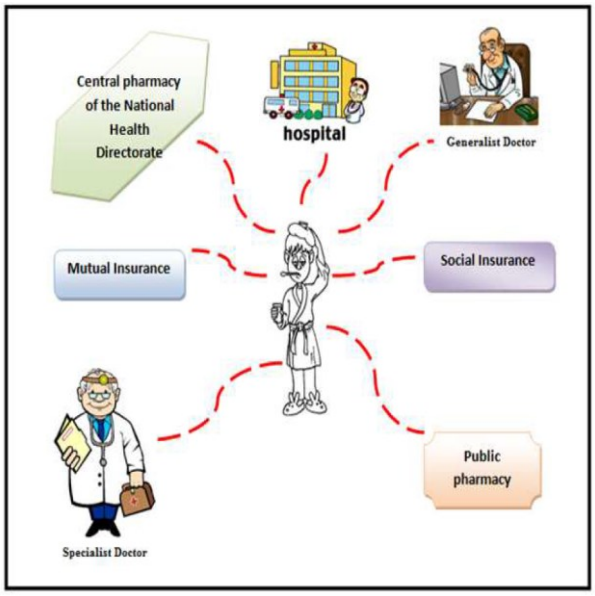

Figure 1. Global Overview of the M-health Ecosystem

Figure 1 shows that the patient is in the middle of an ecosystem composed of seven main agents. More precisely and in case of sickness or a simple consultation, the patient has to interact with these different agents. Usually, for such communications and interactions, the medical patient's file - which is in the form of papers - has to be brought in every consultation or in every therapeutic appointment. Adding to this, the patient is obliged to explain each time his current health state to the rest of the agents in case of consultations. Nevertheless, these are seen as undesirable restrictions for the patient. To solve these issues, we propose our M-health application which is based on the idea of sharing patient's files, between different agents, via mobile devices and networks. In this way, there will be no constraints such as the mandatory presence in the office to check patients' files. Checking patient's files, for example, will be achieved via mobile devices connected via networks anywhere and anytime. A detailed description of the functioning of our proposed M-health ubiquitous system and the interactions between the agents are given in what follows:

As stated previously, in case of illness, the patient has to identify himself in the doctor's office. Such identification is performed via mobile devices. More precisely, the patient's mobile devise, including his identifier (ID), will be recognized by the doctor's mobile/tablet device; allowing the doctor to have access to the patient's medical file which is already saved on the web. Once the recognition is made with success, the doctor will edit the patient's medical file either by adding more information about the patient's health statue or by adding a prescription or by dispatching the patient either to a specialist doctor in case of need or to the hospital in case of an emergency case. These changes will be automatically saved in a centralized system. In other words, if an authorized agent in the hospital, for example, has to check the same patient's file then he will have access to the latest modifications or updates made on the concerned patient's file.

Once the patient has finished his consultation, doctor has to write a prescription. To do so, he will have an automatic access, depending on his ID, to the medical database. In fact, it will be

possible to check the latest added medicines with their details and needed descriptions; which will ease the doctor's task. In the proposed application, we have used the online Vidal medical database, as an example, which can be replaced by any other international online medical database form [12] such as the Havas MediMedia's Global Drug Database. Once the prescription is typed, via the tablet, it will be saved; and the patient can check his prescription in any pharmacy and take his medicines via a simple identification in that pharmacy. As we can see, all the process is made via a simple mobile device identification (authentication) phenomenon and data will be automatically transferred between agents.

Let us don't forget, that the patient has to get ``some'' fees back as he is registered in an insurance; either a social or a mutual one. So, if the patient will pay the doctor or the specialist or the hospital or even the pharmacy, the amount of money paid will be automatically saved in the centralized system and once the patient identify himself near his insurance and depending on his type of insurance affiliation, he will get his charges back. We have, also, to note that this process is controlled by specific technologies which will be discussed in the next Section.

IV. Technical Specifications

A. Description of the User Requirements

The fact of getting the needed information at the right time and in the right place; is neither a simple task nor an easy one; especially for the agents dealing with the health care field. This is because they are obliged to check their needs in their offices and desktops. Trying to handle this issue, M-health solutions were incorporated as an urgent need to ease the health care task.

Despite that there are various proposed M-health solutions in the market; we have to mention that these present systems give only partial solutions to the agents. More precisely, there are no interactions between agents such as communications between insurance companies and doctors, between pharmacies and doctors, between hospitals and insurance companies, etc. Unfortunately, there is still a need to check prescriptions written in papers, a need to bring a medical file to the hospital and a need to manually check how much the patient have paid during his treatment process and how much should he be paid in return near the insurance companies.

Notably, citizens' interactions with the needed services have to be improved, and a serious analysis of user requirements in the area of M-health has to be undertaken. As we remark, there is an urgent need to merge a new and more global M-health ecosystem dealing with all these parts ensuring an automatic collaboration and communication between agents/users. This is to design an effective and personalized M-health information system that will provide quality M-health services. This is the main contribution of our paper as we suggest a new ubiquitous mobile health system capable of handling all the mentioned points. More details about our solution approach are presented in what follows.

B. System Architecture

In this Section, we give more details about our proposed solution. We will focus now on the technical aspect of our proposed ubiquitous mobile health ecosystem where its architecture is described in Figure 2.

Let us remind that to launch the system; the patient has to identify himself near one of the mentioned agents; i.e., the hospital, the doctor, the specialist, the pharmacy or near one of the two insurance types. This identification is achieved via a mobile device recognition phenomenon and more specifically via the Near Field Communication (NFC) [8] standard/sensor or via a digital certificate. Once the patient is identified, a HTTP request is sent to the web service which is responsible for the identification task. Both IDs - the patient ID and the agent ID - are transferred with the HTTP request. The web server will interact and communicate with the centralized database, Relational Database Management System (RDMS), via a JAVA query [9] in order to verify the IDs. Once verified, a message will be send back to the doctor application interface in his used mobile device/tablet. The message will be transferred via the Simple Object Access Protocol (SOAP) [11] in the form of an Extensible Markup Language (XML) format [10]. More precisely, the message sent to the agent will include the possible accesses that the agent is authorized to deal with; which are in the form of different interfaces depending on his needs. If the agent, for example, has to type a prescription then he will have access to the prescription interface.

To type a prescription, the agent needs to have access to the medical database. Therefore, once he wants to search for a specific drug or type the first letters of a drug then an automatic HTTP request will be sent to a second web server dealing with the medical database Vidal. The web server will communicate with the Vidal base in the centralized system and gets the needed answer. Finally the message is sent back, via the SOAP protocol, to the prescription interface and the doctor will get a list of the drugs depending on the letters that were typed.

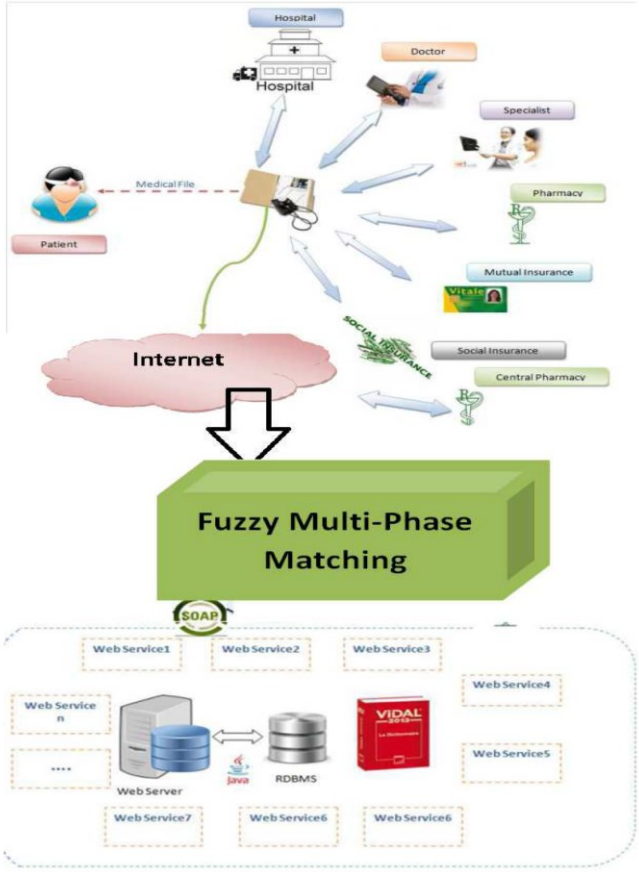

Figure 2. System Architecture

Depending on the agents' roles and depending on their needs, the application will send specific messages to specific web services and communicate with the centralized system and deliver the specific answers to the agents. Various web services can be defined for our proposed solution such as the identification based NFC web service, the medical base edition web service which is needed by the central pharmacy to add/delete new/old drugs, the use medical base web server needed by the doctors or hospital to check the drugs or to type prescriptions, the charges recovery web service needed by the doctors/hospital/pharmacy to get their fees back from the mutual/social insurance, the dispatching web server and many other web services can be defined for the proposed solution. We have, also, to mention the case where the agents want to check their patients' files when they are out of office or in case of doctors' meetings, then all of them will have access, depending on their IDs, to the needed files independently from time and place restrictions.

It is obvious here, that in such context the system is in front of a plurality of web services. Yet, it is very crucial for finding the most suitable web service from a large collection of web services for successful execution of applications. In many cases, the value of a Quality of Service (QoS) property may not be precisely defined. Recently, fuzzy set theory is considered as the dominant approache in web services which can deal with fuzzy constraints. Therefore fuzzy set theory can be applied to support the representation of such imprecise QoS constraints. We, therefore, suggest to use a fuzzy-based approach for web service discovery. Technically, our system is based on the use of the Fuzzy Multi-Phase Matching mechanism. In fact, web service discovery has become increasingly more important as the prevailing use of web service. The similarity between service consumer's request and services in terms of software signatures, the capabilities, and syntax and semantics of services is a common measurement for matching [14].

The adopted Fuzzy Multi-Phase Matching mechanism is divided into two main phases which are the filtering stage - composed of Category Filtering and Area Filtering - and two-level matching stage as Capability Matching and Fuzzy Matching.

Matching is an important mechanism for automation of web service composition. The main advantages of the proposed discovery method and matching mechanism are listed as follows:

- It can formally describe not the capability information, but the vague information of web service, and implement approximately reasoning based on ontology semantic, linguistic variable and fuzzy logic;
- The multi-phase matching are executed on different service abstract level, which can improve the efficiency and accuracy of service discovery.

For a detailed description of the Fuzzy Multi-Phase Matching mechanism, we kindly invite the reader to refer to [14].

V. Characteristics of the Solution Approach

Our proposed solution is characterized by four main characteristics which are:

- **Flexibility:** Anyhow, Anytime, Anywhere : The flexibility of our m-health system can be measured in two ways. Firstly, using mobile devices and tablets have introduced the possibility to consume services irrespective of location. Secondly, by using the mobile technology, many service delivery processes consist of more than two interaction sessions between the agents. For example, in case of emergency, the doctor (generalist) can dispatch his patient to a specialist and at the same time communicating with the hospital in order to prepare his patient for a specific diagnostic. This will ease the habitual interaction process and make it faster and simpler.
- **Accessibility:** Our application allows agents to identify themselves to access the service they need. Once a service is located and accessed, agents will be able to consume the information provided by the service.
- **Quality:** There are many situations in which an agent needs more than just one service to deal with a particular situation. Our application offer the possibility to address all requirements with a single interaction, thus saving the agent's considerable amount of time. Furthermore, our m-health system is regulated by means of strictly defined specifications. Quality can be described as satisfactory if the service is provided in conformance with the relevant specifications; a task handled by our application. For instance, by recognizing each agent, once identified,

specific services will be allowed to be used by each specific agent. In addition, our application ensures that services are offered pro-actively. In other words, services are offered at the moment an agent may need them, even though he may not yet be aware of it. Moreover, our application ensures a fast delivery of the offered services.

- **Security:** A trusted exchange of information depends on an assured security level. In fact, to ensure security, our application uses the most convenient technologies and protocols, mainly, SOAP.

Adding to these, our system offers the possibility to manage the imprecision found in the right selection of the most appropriate web service. This was handled by the application of the Fuzzy Multi-Phase Matching mechanism.

VI. Strengths of the Current M-Health Ecosystem

Adding to the characteristics presented in the previous Section, we try to shed more light, in this Section, on our application's strengths. More precisely, our application is capable of personalizing the web services by assigning specific services to specific agents. Traditionally, the issue of personalization is a rather complex one with many aspects and viewpoints that need to be analyzed and resolved. Some of these issues become even more complicated once viewed from a moving user's perspective, in other words when constraints of mobile channels and devices are involved [13]. Such issues include, but are not limited to, the following: what content to present to the user, how to show the content to the user, how to ensure the user's privacy, or how to create a global personalization scheme. Nevertheless, these issues are solved via the configuration of our centralized m-health ecosystem. More precisely, using the NFC technology can guarantee, first of all, a simple and ease recognition form between the agents, and, secondly, a secure identification process [8]; which is seen as the most important aspect. Adding to this, transferring data between agents relies on a secure process as it is based on the use of the SOAP protocol [11].

On the other hand, and with respect to the limited memory and storage size of the users' mobile devices, our m-health application has to take this point into consideration. In fact, our application is based on a centralized system where all components are stored in the web and only the needed data are transferred depending on the identified agent and his needs. In addition, using the JAVA based platform is interesting due to the inherent advantages of JAVA, namely, platform independence support, highly secure program execution, and small size of compiled code. One further advantage is added to this is the reduction of the network load. More precisely, instead of relying on numerous communication protocols to achieve network interaction, which would increase the network traffic, our application is based on a simple but powerful and secure protocol, SOAP, that can carry data that are required for an interaction and processes it locally.

In the end of this Section, we can note the interesting advantages and strengths expressed by our proposed mobile health application. Our m-health system, which is capable of taking into consideration different agents, allows the communication and the interaction between several users. This is achieved via our ubiquitous system where there are no more restrictions related to place or time, while satisfying the users' requirements and ensuring secure, flexible and accessible services.

VII. Conclusion

In conclusion, this paper presents a complete architecture for a more robust M-health ecosystem.

The growing demands of the citizens for ``anytime, anywhere and anyhow'' information and services delivery as well as the mobility and wireless platforms and devices emergence, intensified the imposition of the development of common standards and protocols as well as technologies that could be used for the design of interoperable, ubiquitous, secure, adaptive, personalized and transparent M-Health information systems. Recent works focusing on these aspects can be found in [24] [25] [26]. Eventually, in this context we have proposed our solution dedicated to the M-Health field.

By using our application, we believe that we could satisfy major citizens' requirements including doctors', patients' and insurance companies' needs. Our M-health application is based on new rigorous tools and communication protocols to guarantee an overall M-health information system capable of ensuring interoperability, ubiquitousness, security and adaptively.

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