A Profile-based Trust Management Scheme for Ubiquitous Healthcare Environment

Georgia Athanasiou Georgios Mantas *Member, IEEE* Maria-Anna Fengou Dimitrios Lymberopoulos *Member, IEEE*

Laboratory of Wire Communications, Department of Electrical & Computer Engineering, University of Patras
Rio, Patras, Greece
gathana@ece.upatras.gr, {gman, afengoum, dlympero}@upatras.gr

***Abstract*— Ubiquitous Healthcare environment materializes the patient-centric paradigm providing healthcare services without spatial and temporal limitations. However, the nature of Ubiquitous Healthcare services requiring exchange of sensitive personal data raises trust issues. In this paper, we propose a profile-based Trust Management scheme that enables the patient to select the most trustworthy Healthcare Provider in a Ubiquitous Healthcare environment. Furthermore, we propose an extended User Profile structure integrating trust-related information in order to enhance the functionality of the proposed Trust Management scheme.**

Keywords— profiles; recommendation; reputation; trust; ubiquitous healthcare

I. INTRODUCTION

Nowadays, the patient-centric paradigm plays an important role towards the improvement of the quality of healthcare. The notion of the patient-centric paradigm is materialized by Ubiquitous Healthcare (UH). UH exploits the ubiquitous networking infrastructure to enable the provision of healthcare services to anyone, anytime and anywhere without limitations on time and location [1]. Essentially, the ubiquitous technology enables the creation of the appropriate UH environment where UH systems can be deployed.

However, the heterogeneous and dynamic nature of the UH environment as well as the nature of UH services raises many security challenges. Particularly, UH services usually require the exchange of patients' personal information among unknown participating entities (e.g. Healthcare Provider) in the UH environment. The fact that sensitive personal information is exchanged among unknown entities raises many trust challenges.

Therefore, it is essential for UH environment the deployment of trust management mechanisms to determine the trust of the participating Healthcare Providers. Latest literature [2-7] argues that the adoption of trust in UH environment limits the uncertainty of its nature and makes it more effective in terms of reliable UH service provision. Trust management mechanisms enable the UH participants to establish the confident and secure relationships required for the provision of secure and reliable UH services.

The concept of trust defines the degree to which an entity will be trustworthy in any interaction with another entity within a specific environment [2, 3]. The assessment of trust is mainly based on entity's personal experience derived from his/her previous interactions with others [2-7]. However, in absence of personal experience, the interrelated attributes of Recommendation and Reputation should be taken into consideration [2]. Recommendation reflects the subjective opinion of an entity for the trustworthiness of another entity (i.e. trustee), as it is derived from his/her personal experience [2-4]. On the other hand, Reputation constitutes a collective measurement of the trustworthiness of the trustee as it derived by the subjective opinion of all the other participating entities within the given environment [2, 3, 5, 6].

In this paper, we propose a profile-based Trust Management scheme that enables the patient to select the most reliable and trustworthy Healthcare Provider in a UH environment. The proposed Trust Management scheme is based on the concept of the Virtual Healthcare Community (VHC), where each patient creates a community which is oriented on himself/herself.

Moreover, we propose an extended User Profile structure integrating trust-related information in order to enhance the functionality of the proposed Trust Management scheme. The extended User Profile structure is based on the proposed User Healthcare Profile structure that we presented in [10].

Following the introduction, this paper is organized as follows. In Section II, we give an overview of the related work regarding Trust Management mechanisms deployed on UH environment. In Section III, the notion of Virtual Healthcare Community in UH environment is discussed. In Section IV, we describe the structure of the extended User Profile. In Section V, the proposed profile-based Trust Management scheme is presented. In Section VI, a scenario of the proposed Trust Management scheme in UH environment is deployed. Finally, Section VII concludes the paper.

II. RELATED WORK

The efficient provision of UH services, such as the location-based emergency response services or the ubiquitous access to medical data is a matter of trust [7]. Depending on the employed attributes (i.e. Personal Experience, Reputation and

978-1-4799-3163-7/13/$31.00 ©2013 IEEE

Recommendation) in Trust Evaluation and Trust Decision Making, several Trust Management mechanisms have been proposed [6].

M. Denko et al [4] propose the incorporation of Recommendation system into Trust Management mechanism in order for enabling the indirect assessment of trust, taking advantage of other users' recommendations. That mechanism is deployed on modules of "Histories of Interactions", "History Maintenance", "Recommendation Management", "Trust Computation".

On the other hand, W.Yan et al. [5] proposed the integration of Reputation system into Trust Management mechanism for enabling the aggregation and diffusion of trust-related information within UH environment. In that way, patients are assisted to select reliable Healthcare Providers, while Healthcare Providers build their trustworthiness.

The proposed in [2] Trust Management mechanism incorporates a combination of Reputation and Recommendation systems. Hence, the enhanced Trust Management mechanism not only evaluates and updates trust value based on trustor's personal experience, trustee's reputation and aggregated recommendation but also exploits it in order to perform access control.

Valarmathi et al. [3] argue that the efficiency of Trust Management mechanism is improved when the exchange of trust related information follows the community-based model.

III. VIRTUAL HEALTHCARE COMMUNITY IN UH ENVIRONMENT

We consider that UH environment includes the following main participating entities:

- *Patients*: individuals receiving UH services (e.g. ubiquitous emergency response, remote access to medical data) in order to achieve high quality level of his/her own health and wellbeing. Patients are considered as the users in the UH environment. According to the patient-centric paradigm, the patient is the core entity of the UH environment [12].
- *Healthcare Providers*: professionals (e.g. doctors, nurses, clinicians, pharmacists) providing UH services to the patients. They are trained to recommend or perform treatments as well as make use of medical devices [12].

The proposed Trust Management scheme for UH environment is based on the concept of the Virtual Healthcare Community (VHC), as it is depicted in Fig. 1, where each patient creates his/her own community which is oriented on himself/herself. Within the UH environment, the patient-centric paradigm is deployed on the concept of VHC [8, 9].

In the context of the patient-centric paradigm, the requested UH service determines the participants of the UH environment that will become VHC members. Given that UH services are usually location-based, an area of UH environment is defined for each user's request.

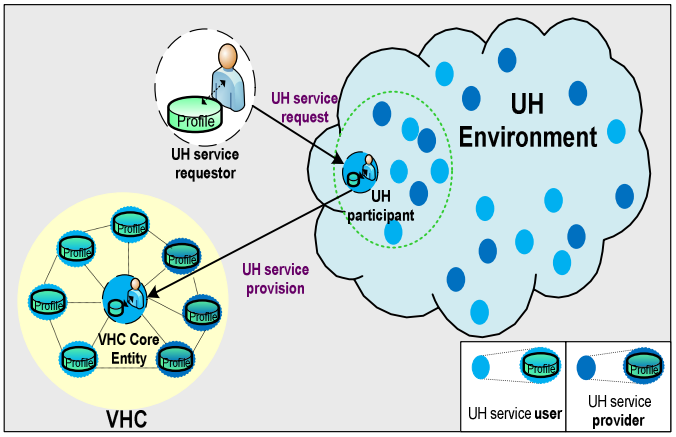

Fig. 1. Virtual Healthcare Community in UH Environment

From all different UH participants included in the defined area, the available Healthcare Providers related to the requested UH service as well as the users who requested the same type of Healthcare Providers are selected to become VHC members. Essentially, the VHC assists its core entity to discover and select the appropriate Healthcare Provider.

IV. PROPOPOSED USER PROFILE STRUCTURE

We propose the integration of trust-related information into User Profile. In particular, we carry on the work from [10], in which a generic structure of User Profile is proposed. Essentially, we enhance the generic User Profile structure by integrating an additionl profile attibute, called Trust. The attribute Trust consists of the following three profile fields:

- *Trust Historical Records*: This field stores the trust scores for the entities that interacted with the user in the past. The user interacts with other users (i.e. patients) and Healthcare Providers in the UH environment. The trust scores for these entities derive from the user's trust evaluation process based on the past interactions that they had with the profile's owner.
- *Trust List*: This field contains the IDs (i.e. identities) of the Healthcare Providers that the user considers as trustworthy based on his/her previous interations with them (i.e. personal interaction experience). Furthemrore, this field contains the IDs of Healthcare Providers that the coordinator of the UH system considers as trustworthy based on their generic behavior. The UH system provides these IDs in order to facilitate the user's trust evaluation process.
- *Untrust List:* This field contains the IDs of the Healthcare Providers that the user considers as untrustworthy based on his/her previous interations with them. Additionally, this field contains the IDs of Healthcare Providers that the coordinator of the UH system considers as untrustworthy based on their generic behavior. These IDs are provided by the UH system to facilitate the trust evaluation process.

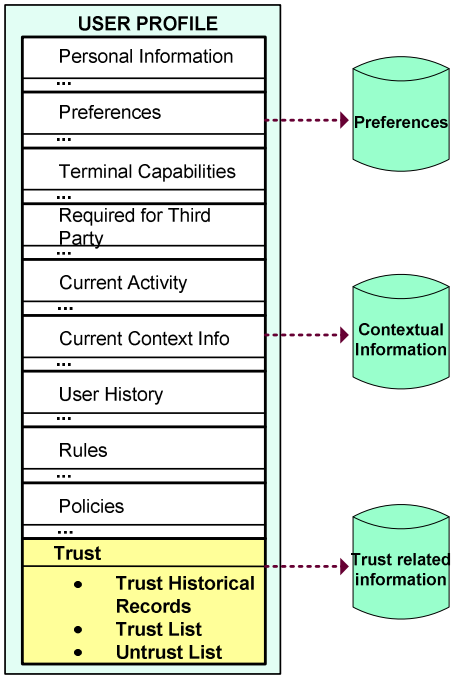

Fig. 2. Extended User Profile Structure

The proposed User Profile structure includes not only information characterizing the user, such as his/her personal information, preferences and capabilities, but also trust related information in thefollowing fields: Trust Historical Records, *Trust List* and *Untrust List*. The data incorporated in each User Profile are stored in distributed databases in the UH environment [10, 11, 12]. The proposed user profile structure is shown in Fig. 2.

V. The Proposed Profile-Based Trust Management Scheme

In this paper, we propose a profile-based Trust Management scheme enabling the user (i.e. patient) to select the most reliable and trustworthy Healthcare Provider in a UH environment for UH service provision. The proposed Trust Management scheme is deployed on the concept of the VHC. The proposed Trust Management scheme integrates the use of the proposed User Profiles structure with the three main notions of Trust Assessment that we meet in the most current existing Trust Management schemes; Personal Interaction Experience, Reputation and Recommendation. The materialization of these three notions constitutes the Trust Assessment of the proposed profile-based Trust Management scheme depicted in Fig. 3.

The Personal Interaction Experience, which is the core component of the proposed Trust Management, makes use of the trust-related information stored in the *Trust Historical Records* field of the proposed User Profile. Each user has Personal Interaction Experience for each entity in the VHC that interacted with him/her in the past. It is derived from the user's trust evaluation process based on his/her transcation history with a given entity. The Personal Interaction Experience can be represanted as a trust score calculated by the trust evaluation process.

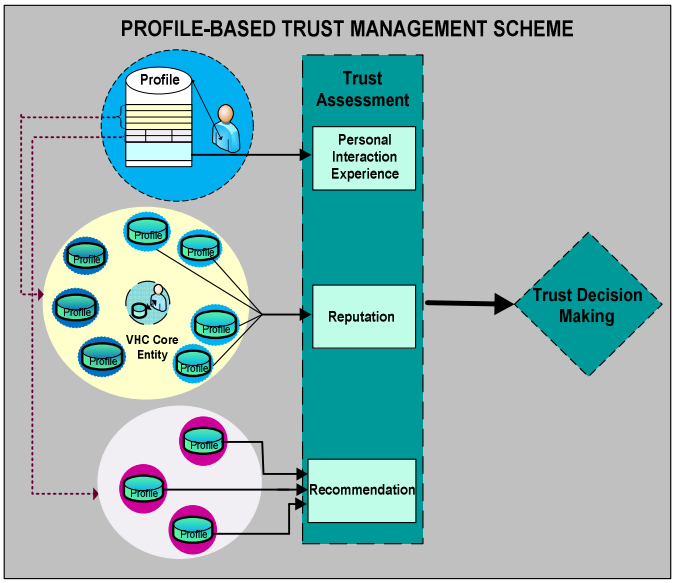

Fig. 3. The Proposed Profile-based Trust Management Scheme

On the other hand, Reputation is the collective measurement of the trustworthiness of an entity (i.e. trustee). This measurement is derived from the subjective opinion of all the users participating in the VHC. In the proposed Trust Management scheme, a reputation score is calculated for all the users and the Healthcare Providers participating in the VHC.

The notion of Recommendation constitutes the subjective opinion of a user for the trustworthiness of another entity (i.e. user , Healthcare Provider) in the VHC. Recommendations are based on the Personal Interaction Experience of the user that provides the recommendation. The main concern regarding Recommendation in UH environment is the determination of the users that the given user can trust their recommendations. In the proposed profile-based Trust Management scheme, the users whose recommendation the given user can trust are those users with the highest reputation scores.

In the proposed profile-based Trust Management scheme, when a user (i.e. patient) sends a request for a Healthcare Provider, the trust decision making process takes into consideration a lot of information in order to extract the most trustworthy Healthcare Provider. The trust decision making process exploits not only the Personal Interaction Experience of the user for the Healthcare Provider, the reputation score of the Healthcare Provider and the recommendations for the Healthcare provider, but also the information included into the User Profile fields *Trust List* and *Untrust List*. The use of information included in these fields facilitates the trust decision making process when the user, who requests for a UH service, is located in an unfamiliar UH environment.

In case that the user is located in a familiar UH environment, the trust decision making process for choosing the most reliable Healthcare Provider is based on the user's Personal Interaction Experience. Thus, the Healthcare Provider with the highest trust score, which is stored in the Trust Historical Records field of the user profile, is selected. Furthemore, the ID of the selected Healthcare Provider should be checked if it is included in the *Untrust List*, since the

information in this list is updated not only by the user but also by the coordinator of the UH system based on the generic behavior of the Healthcare Provider. If the ID of the selected Healthcare Provider is included in the *Untrust List*, then he/she is rejected and the Healthcare Provider with the next highest trust score is selected and the *Untrust List* is checked again. This process is being continued until the ID of the selected Healthcare Provider based on the highest trust score is not included in the *Untrust List*.

In case that the user is located in an unfamiliar UH environment, the trust decision making process for choosing the most reliable Healthcare Provider includes more phases, since it is the most challenging case. In the first phase, the Healthcare Providers with the highest reputation scores are selected. In the second phase, the IDs of the selected Healthcare Providers are checked if they are included in the *Trust List* or the *Untrust List*. If there are Healthcare Providers, whose ID is included in the *Untrust List* they are rejected. If there are Healthcare Providers, whose ID is included in the *Trust List*, they are selected and the Healthcare Provider with the highest reputation score among them is the most trustworthy. Finally, the trust decision making process exploits the selected Healthcare Providers from the previous phases as well as the recommendations from the users with the highest reputation score in order to determine the most reliable Healthcare Provider in the VHC. We present the scenario in the following Section VI in order to describe in more details the trust decision making process for an unfamiliar environment.

VI. Description of Scenario

In this section, we describe how the proposed Trust Management scheme is applied in an unfamiliar UH environment for assisting a user to discover and select the most reliable Healthcare Provider. For that purpose, we consider George, a 35 years old man, who visits the city of Athens (unknown environment) as tourist. Suddenly, he feels pain in his chest and sends a request via his mobile device to the local UH system for a cardiologist.

The UH system exploits contextual information stored in George's User Profile to determine his location. Based on George's request and location, all available cardiologists and their corresponding reputation scores are listed and returned to his mobile device. In addition, the system returns a list of users (i.e. previous patients) with their corresponding reputation scores, who requested for cardiologists, within the same area, in the past. The listed cardiologists and users build a VHC, where George is the core entity. Since George is a tourist in Athens, we consider that he is unacquainted with the cardiologists and the users of the VHC. Thus, there are not *Trust Historical Records* related to the cardiologists and users in George's User Profile. Consequently, the trust decision making process of the proposed Trust Management scheme is based on reputation scores, recommendations and trust lists. The trust decision making process, which is depicted in Fig. 4, consists of the following three phases:

- In the *First Phase*, the cardiologists with the highest reputation scores are selected.

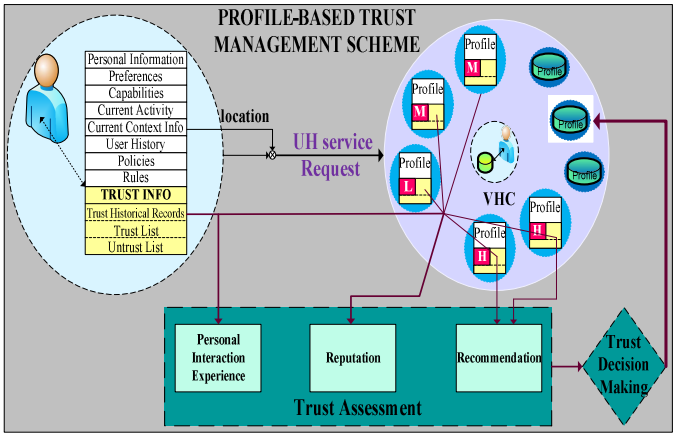

Fig. 4. Trust Decision Making Process in an Unfamiliar UH Environment

- In the *Second Phase*, the IDs of the selected cardiologists are checked if they are included in the *Trust List* or the *Untrust List* of George's User Profile. This phase includes the following three steps:
  - *Step 1:* It is checked if there are one or more cardiologists whose ID is included in the Untrust List. If there are cardiologists, whose ID is included in the Untrust List they are rejected automatically. Otherwise, the trust decision making process is forwarded to Step 2.
  - *Step 2*: It is checked if there are one or more cardiologists whose ID is included in the *Trust List*. If there are cardiologists, whose ID is included in the *Trust List*, they are selected and the cardiologist with the highest reputation score among them is the most trustworthy cardiologist for George. Otherwise, the trust decision making process is forwarded to Step 3.
  - *Step 3*: There is not any cardiologist whose ID is included either in the *Trust List* or *Untrust List*. Then, the trust decision making process is forwarded to the Third Phase.
- In the *Third Phase*, the trust decision making process makes use of the selected cardiologists from the previous phases is order to determine the most trustworthy cardiologist for George. To achieve that, the proposed scheme exploits the recommendations for selected cardiologists given by users participating in the formed VHC. However, since George is located in an unknown environment, the proposed scheme takes into consideration only the recommendations derived from the users with the highest reputation score. The provided recommendations of these users are based on their Personal Interaction Experience with the specific cardiologists in the past. The cardiologist who receives the best recommendations from the users with the highest reputation score is the most trustworthy cardiologist for George.

VII. Conclusion & Future Work

In this paper, we have proposed a profile-based Trust Management scheme enabling the patient to select the most trustworthy Healthcare Provider in a UH environment. In addition, we have also proposed an extended User Profile structure integrating trust-related data in order to enhance the functionality of the proposed Trust Management scheme. The extension of User Profile structure with trust-related data paves the way for deployment of more efficient Trust Management schemes for UH environment. Particularly, the introduction of the profile fields *Trust List* and *Untrust List* facilitates the trust decision making process when the patient is located in an unfamiliar UH environment.

Finally, as future work, we plan to deploy a prototype based on JADE platform. For the prototype, we intend to use current existing algorithms for computation of trust and reputation scores. Our main objective is going to be the evaluation of different scenarios using the trust related information integrated into the User Profile in order to determine the most efficient scenarios for Trust Management in unfamiliar UH environment. In addition, we intend to continue our research in order the trust decision making process to make use not only of patients' profiles but also Healthcare Providers' profiles. Towards, this direction we should also introduce anonymity techniques for the proposed Trust Management scheme for enhancing its objectivity.

References

[1] U. Varshney, "Pervasive Healthcare: Applications, Challenges And Wireless Solutions," Communications of the Association for Information Systems, AIS Electronic Library, vol. 16, no. 1, article 3, pp. 57-72, 2005.

[2] W. Yuan, D. Guan and S. Lee, "Trust Management for Ubiquitous Healthcare," in Proc. International Symposium on Parallel and Distributed Processing with Applications, 2008, pp. 63-70

[3] J. Valarmathi, V.R. Uthariaraj, G.A Kumar, P. Subramanian and R. Karthick, "A Novel Trust Managment Scheme in Pervasive Healthcare," in Proc. 2nd International Conference on Information Management and Engineering (ICIME), 2009, pp. 141-145.

[4] M.K. Denko, I. Woungang, M.S. Obaidat, "Trust Management in Opportunistic Pervasive Healthcare Systems,"in Proc. of IEEE 16th International Conference on Electronics, Circuits and Systems (ICECS), 2009, pp. 832-835.

[5] W. Yuan, D. Guan, S. Lee and H. Lee, "Using Reputation system in Ubiquitous Healthcare," in Proc. 9th International Conference on e-Health Networking, Application and Services, 2009, pp. 182-186.

[6] W. Yan, D. Guan, S. Lee and Y-K Lee, "The Role of Trust in Ubiquitous Healthcare," in Proc. 9th International Conference on e-Health Networking, Application and Services, 2009, pp. 312-315.

[7] Kai Wang, Yan Sui, Xukai Zou, A. Durresi and Shiaofen Fang, "Pervasive and Trustworthy Healthcare," in Proc. 2nd International Conference on Advanced Information Networking and Applications - Workshops (AINAW), 2008, pp. 750-755.

[8] Kui Meng, Xu Zhang, Xiao-chun Xiao and Geng-du Zhang, "A Bi-rating Based Personalized Trust Management Model for Virtual Communities," in Proc. of IEEE International Conference on Networking, Sensing and Control (ICNSC), 2006, pp. 260-265.

[9] G. Demiris, "The diffusion of Virtual Communities in Health Care: Concepts and Challenges," in J. Patient Education and Counseling, Patient Education and Counseling, vol. 62, issue 2, pp. 178-188, 2006

[10] M. -A. Fengou, G. Mantas, D. Lymberopoulos, and N. Komninos, "Ubiquitous Healthcare Profile Management Applying Smart Card Technology," in Proc. 2nd International Conference on Wireless Mobile Communication and Healthcare, 2011, pp. 248-255.

[11] M. -A. Fengou, G. Mantas, D. Lymberopoulos, "Group Profile Management in Ubiquitous Healthcare Envrionmnet," in Proc. 34th IEEE Annual International Conference of the IEEE Engineering in Medicine nad Biology Society (EMBC), 2012, pp. 2120-2123.

[12] M. –A. Fengou, G. Mantas, D. Lymberopoulos, N. Komninos, S. Fengos, N. Lazarou, "A New Framework Architecture for Next Generation e-Health Services," in IEEE Journal of Biomedical and Health Informatics, 2013, vol. 17, no.1, p.p. 9-18