Trust and Reputation in e-Health Systems

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Abstract— **The paper studies the role of trust and reputation in e-Health communities. The trust concept is akin to a mechanism for quantifying the relationships that can be established between users. A trust and reputation module is integrated into a e-Health Service Oriented Architecture. Such a module provides a more reliable system for use. In addition, we discuss the possibility that the proposed module may be a part of the solutions that ensure the interoperability between different e-Health systems.**

Keywords— **trust, reputation, e-health, SOA.**

I. Introduction

This article studies the impact that the concepts of trust and reputation have in an e-Health community.

The paper discussions are based on the model of trust developed in [1] and on an e-Health system called Telemon [2, 3]. Telemon is an e-Health system, intended to allow real time patient monitoring by using different mechanisms.

The paper has the following structure: section II presents the main component modules of Telemon. In order to create a viable architecture, in [2] we proposed a solution based on SOA paradigm [4, 5]. We present the general aspects regarding the following components: the user-interaction, the SSO-like user authentication, the message routing, the data storage, and the overall management of the application. The paper proposes a module that extends the architecture, having as a main role the management of trust and reputation relations among users.

In section III we describe how trust and reputation are used for modeling relationships between users. Also, in this section we consider the contexts in which trust and reputation can be used in e-Health communities.

Also, the paper analyzes how the introduced trust component can help to achieve integration and interoperability between different e-Health systems.

The article ends with the conclusions and further work.

II. Telemon – general architecture

A. Service Oriented Architecture

The term SOA (Service Oriented Architecture) refers to the design of a distributed system. SOA is a design methodology, aimed at maximizing the reuse of multiple services (possibly implemented on different platforms and using multiple programming languages).

In a SOA platform, the services generally have some important characteristics [4, 5]:

- Services are individually useful - *autonomy*;
- Services must be loosely coupled. This term implies that services discover the needed information at the time they need it. The benefits offered by this characteristic are: flexibility, scalability, ability to be easily replaced, and fault tolerance;
- Services can be composed to provide other services. This promotes the reuse of existing functionality;
- Services can participate in a workflow - *service choreography*;
- Services can be easily discovered, eventually in an automatic manner. Therefore, services must expose details (and additional meta-data) such as their capabilities, interfaces, policies and supported protocols. Other details such as the programming language or the information about the platform are not useful for consumers and – usually – are not revealed.

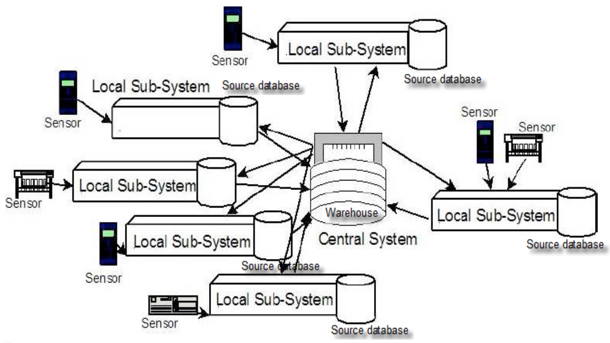

Fig. 1 Telemon – general architecture

B. Telemon Architecture Overview

In [2], a general architecture is proposed. It consists of two types of components: Local Sub-System components and a Central System component.

The local sub-systems are components that collect information from different sources (devices that observe the patient). All this information from local sub-systems is transferred (through an update mechanism) to the central system.

The general architecture of our health system platform is depicted in Figure 1. We will outline the general structure of the components – local subsystems and the central system, both of which conforming to SOA principles. The system performance will be assured due to the scalability of the architecture based on actual Web standards (XML, SOAP, WSDL, REST, WS-*, etc.) [6-8, 17].

We identify the following modules:

- *Frontend module* – guarantees the user interaction with the system, at the user-interaction level in Telemon architecture,
- *Identity management module* – assures the authentication and authorization of users,
- *Service management module* – is a component that assures the access to available services,
- *Routing module* – guarantees that a request can reach the Service module level,
- *Database module* – is a wrapper for local database and the management application module will allow operations that are not available for the customary user or medical staff – for example, log verifying or the management of update operations (this module interacts with the database component module),
- Management application module,
- Database management module (in Local Sub-Systems) /Warehouse management module (in Central System).

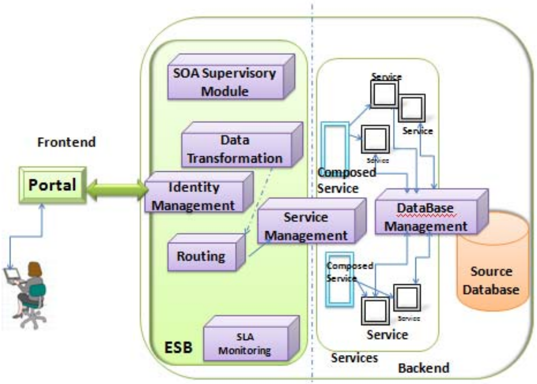

Fig. 2 Local Sub-System architecture

In the next paragraphs we will describe the overall process from the user's point of view.

When a client needs a generic service, the following general steps must be performed:

- Authentication and authorization realized by the identity management module – this module is using OpenID [14-16];
- The request of the user is routed (through the routing module) to the service management module;
- Sometimes, certain transformations are necessary to change data from one format to another format supported by the system; in this case, the data transformation module is used.

The local sub-system architecture is depicted in Figure 2.

The warehouse management module is a wrapper for the central system warehouse. This module interacts – using special services – with the database management modules from every local subsystem. Therefore, in the warehouse we can find consistent data from any local sub-systems.

All this data came from services like *consumer services* such as update services or a particular request data service. The source databases feed the warehouse with data. Our system, partially decentralized, ensures the data transfer from the local sub-systems to the central system.

To optimize the data traffic, we design two different types of warehouse updates: instant updates and periodical updates. Periodical updates are done on a regular basis and they apply to all the data. The instant updates depend on an emergency threshold, which refers to the severity of the patient's condition. In the cases where the severity is above the emergency threshold, an instant update is applied in the warehouse.

This is crucial when an emergency case occurs and the doctor can consult the specialists that are logged in the central system at that time. These specialists are automatically logged on to the local Sub-System. In this manner, they can give assistance – following the model of the social Web applications – in the patient treatment directly in the local Sub-System in whose proximity the patient is situated.

The information concerning the treatment synchronizes back with the central system via the periodical or instant updates. Furthermore, when there is a serious case of a similar type in another sub-system, the doctor could access the warehouse to get the previous treatment in order to make a decision with respect to a health problem.

III. Trust and Reputation Management Module

The use of SOA approach is useful for our system since it allows easily adding new features without modifying the existing ones. We propose in this section a new module to be integrated into the SOA architecture.

In the first part we argue why a trust and a reputation module is useful, and it can play a major role in e-Health. In the second part, we present the general principles underlying the mechanism of computing the trust. In third section, we analyze the potential role that our model can play in general in the interoperability mechanism.

A. Using Trust And Reputation In E-Health Environments

Trust and Reputation

In the present paper we rely on such an intuition on the concept of trust: an entity A (user agent) has confidence in another entity B if done on a belief that future action of B will lead to achieving some good results [9].

User feedbacks can be aggregated to obtain a graph called *trust network*.

A so-called trust metric can be attached to such trust network. This kind of metric is actually an algorithm that receives in input information from the network and calculates potential trust values between users [10].

Most systems are using global trust metrics (e.g., Google, Slashdot, eBay). Global trust metrics approximate calculation of the value, which semantically represents community general view on an entity (for example, a resource).

Thus, this value known as the reputation of an entity is seen in the same way by all community members.

A local trust metric calculate the trust from subjective opinion of an entity of the community. Thus, the trust score associated with an entity varies for each agent from the system.

In the following section we present the mechanism for calculating the trust and reputation on which proposed module is based.

Functionality and the Role of Trust and Reputation Module in e-Health

In our discussion, we consider two directions in which a trust and reputation module would stimulate the growth of services offered by the health system.

Case 1. We consider Telemon system is available in a certain geographical region.

Into the SOA architecture of the Central System, we consider a new module of calculating the trust and reputation for system users (e.g. patients, medical staff). We named this module TR-Health.

As we shall see in next section, TR-Health module will allow an assessment of the resources which patients interacts (e.g., technical equipping of a medical center, the existing competence of medical personnel). On Local Sub-System and the Central System will be especially services to collect user evaluations. Having users as patients or medical personnel, we consider several situations and for each of them we will specify the ultimate goal.

Modeling 1. The aim is that TR-Health can recommend to a patient, according to his preferences, a hospital or a doctor located in the given region. As input data will be used following assessments: evaluation of patient-patient and evaluation of patient-resource, where resource is defined according to [11]: a resource is anything that has identity (e.g., electronic documents, image, and eventually a collection of other resources), by a URI. Resources are considered and those which cannot be accessed directly via the Internet (e.g. human beings, organizations).

For our particular case, a resource can be a medic, a medical center, a service provided by a particular hospital.

Modeling 2. The aim is that TR-Health can provide to a user a personalized view on the medical community. Concurrently TR-Health module has a service that provides a global vision on each member from the medical community.

Medical community may be divided in groups of different types: doctors group, nurses group, medical staff administrative group.

In this case, as data input will be used doctor-doctor evaluations, nurse-nurse evaluations etc.

Case 2. We consider a generalization of the first case, and consider *Telemon systems are available* in several regions that cover a country area. In this case, different types of evaluations could be collected, in a centralized manner, from the instances of Telemon systems, which exists in different regions. There will be a medical authority that will centralize the data and will thus enable the aggregation of a medical community that will reflect a number of real aspects of health system.

Such a center we call *mashup evaluation* of e-Health services center. In Figure 3 is depicted the case 2.

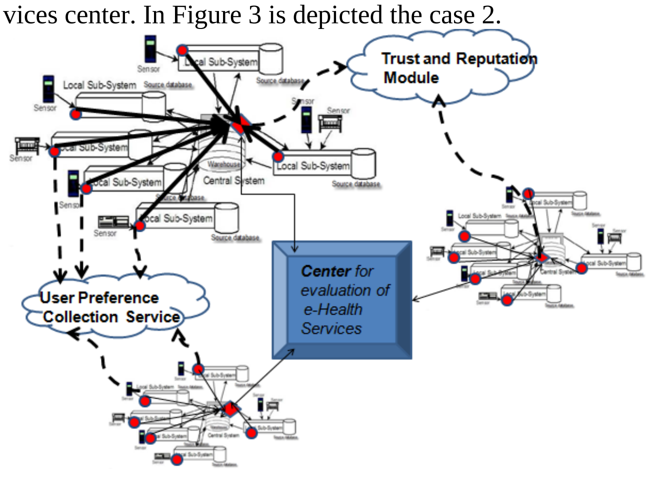

Fig. 3 Mashup evaluation of e-Health services

We can remark that the formation of such communities can participate any e-Health system that can integrate a TR-Health module.

B. Trust and Reputation Core of TR-Health Module

Trust Computation Service

In [1] we proposed an evaluation system whose goal is to assure users (e.g., patients, doctors) a personalized view over e-Health community.

In this way, a user that is member to a community based on our model will dynamically see information that he/she is most interested in.

We will shortly consider the vocabulary:

- Users – members of a community;
- Worth – this parameter is a measure of a trust statement that a user associates to another user. This measure signifies a given rating, given by a user to another user. In addition, the worth can be obtained (quantized) indirectly. In our case, we consider five evaluation levels. Users can give ratings to other users from these intervals:

N_1	N_2	N_3	N_4	N_5
(0,1]	(1,2]	(2,3]	(3,4]	(4,5]

We consider a set of constructions, which have the following semantics:

Explicit worth of a user: *WE_UU* (*user, user*) represents the rating for a user, and this rating is given manually by the user to another user.

Implicit (deducted) worth of a user: *WI_UU* (*user, user*) measures how close are his/her preferences to the others.

In the context of e-health, the preference could be: the accepting degree of a point of view concerning an opinion about a doctor, the appreciation degree of a medicine.

We consider the function *WU* (*user, user*) for each pair of (*user, user*) from a Web community:

$$WU(U_x,U_y)=\begin{cases} WE\_UU(U_x,U_y), \text{if } U_x \text{ evaluates explicitly } U_y \\ WI\_UU(U_x,U_y), \quad \text{otherwise} \end{cases}$$

We will define the manner of computation of the implicit values introduced above.

We also consider two users U_i, U_j from the community. The value of ***WI_UU*** (U_i,U_j) indicates the deducted worth based on explicit evaluations made by users to each other. Let the users, whom we have ratings from user U_i to be $\{U_i^1,...,U_i^k\}$. In addition, we consider having explicit ratings from U_i^l to U_j, $l \le k$ so *WE_UU* (U_i^l, U_j) is defined (see Figure 4).

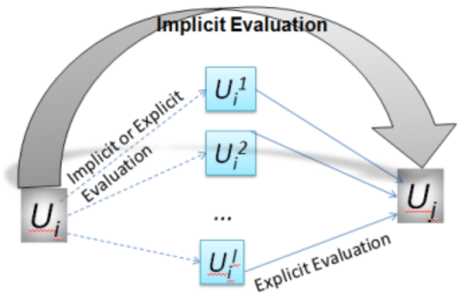

Fig. 4 WI_UU Computation

We consider the matrix *R* which contains elements that have the following meaning:

$$R(i,j) = \text{rating given by } U_i \text{ to } U_j, \forall i,j \in [1,n]$$

Line *i* in matrix R represents the personalized view of user U_i on all users in the system. If user U_i does not interact with user U_j, than the corresponding value R (i,j) in the matrix is set to 0.

With our local trust metric, the elements of matrix R can be computed:

Input: $\{U_1,...U_n\}$, R matrix

Output: ratings (trust scores) for users

1. Insert the explicit ratings in *R*
2. Insert the rating R(i,j) = *MaxWorth* for $\forall i = j$, $1 \le i \le n$, $1 \le j \le n$
3. For each *i*, $1 \le i \le n$

   For each *j*, $1 \le j \le n$

   Find $\{U_i^1,...,U_i^k\}$ satisfying the following conditions:

   User U_i evaluates each of these users

   There exists an explicit evaluation from users $U_i^1,...,U_i^k$ to U_j

   We compute a temporary value for $R(i,j)$ using

$$WI\_UU(U_i,U_j)=\frac{\sum_{l=1}^{k} WU(U_i,U_i^l)*WE(U_i^l,U_j)}{k*MaxWorth}$$

4. Repeat step 2 until *R* does not change anymore.
5. In the end, we get the values of the ratings stored into the system at some point.

Reputation Computation Service

We consider a mechanism for calculating the value of reputation, with respect to the *reciprocity* relationship between trust and reputation [12].

In our system, five levels of evaluation are available (described above). Let us consider U_i a user from system. The set $N_l^i = \{Ev_l^1, Ev_l^2, ..., Ev_l^k\}$ indicates the evaluations that the user has received in the level $l, 1 \le l \le MaxWorth$, *MaxWorth*=5.

These assessments are derived from the R matrix of ratings.

We specify $|N_l^i|$ to denote the N_l^i cardinal, and represent the ratings number of which user U_i has received in that interval.

We consider the formula for calculating the overall reputation of a user as follows:

$$\text{Rep}(U_i) = \sum_{l=1}^{MaxWorth} \frac{|N_l^i|}{\sum_{j=1}^{MaxWorth} P_{LW}^j * |N_j^i|} * P_{RC}^l$$

where:

P_{RC}^l is *reputation control parameter*

P_{LW}^j is *level weight parameter*

This formula is a general one and allows calculation of the reputation adjustment (using the P_{RC}^l factor) depending on the community profile. In our case, we have a closed medical community and therefore its members may be able to benefit by a certain trust level. In this situation, we can consider $P_{RC}^l = \max N_l^i$.

The second parameter ensures reputation calculation taking into account the number of ratings that the user has received on each range. Thus values of this parameter allows us we can consider that a range of ratings is more relevant than another.

This model provides an attenuation of bias evaluations (for examples we can consider that the assessments of [0.1] are given by malicious users or evaluations of [4.5] are made by affable users, and we can decrease the importance of these intervals).

Resources Recommendation Service

In our concrete case, we consider that a user may have a vision of a resource (e.g. doctor, hospital, medical service) depending on how others have rated the resource.

We considered a set of constructions, with the following semantics:

WE_UR **(*user$_i$*, *resource$_j$*)** represents the explicit rating given by *user$_j$* to resource *resource$_j$* .

WI_UR **(*user$_i$*, *resource$_j$*)** represents the implicit rating given by *user$_j$* to resource *resource$_j$* .

We consider the function ***WR*** **(*user, resource*)** for each pair (*user*, *resource*).

Its value is calculated as follows:

$$WR(U_x, R_y) = \begin{cases} WE\_UR(U_x, R_y), \text{ if } U_x \text{ explicity evaluates } R_y \\ WI\_UR(U_x, R_y), \text{ otherwise} \end{cases}$$

We consider U_i a user and R_j a resource from the community. The user U_i did not explicitly evaluate the resource R_j hence the system must calculate the value $WI\_UR(U_i, R_j)$. We consider $\{U_i^1, ..., U_i^k\}$ the users that were evaluated by U_i (so that we know the value *WU* (U_i, U_i^l), $l \le k$).

Also these users have explicitly evaluated the resource R_j – additionally, we have the values *WE_UR* (U_i^l, R_j).

Following a similar reasoning process for the calculation of implicit user evaluations, the following formula is considered for the computation of the implicit user-resource evaluation:

$$WI\_UR(U_i, R_j) = \frac{\sum_{l=1}^{k} WU(U_i, U_i^l) * WE\_UR(U_i^l, R_j)}{k * MaxWorth}$$

where:

k is the number of users that have explicitly evaluate the R_j resource and were evaluated explicitly or implicitly by U_i with $1 \le l \le k$.

Using this formula, we obtain a ranking resource system depending on the user's point of view.

Simulations

To generate data used in the test experiments was used a data generator described in [5]. It can be set (depending on a number of parameters) to generate different types of assessments that reflect explicit situations that can be found in a community of e-Health. We will discuss two examples that will denote two types of modeling presented above.

Experiment 1. A particular community consisting of 10 patients and 5 family doctors is considered.

With our data generator, we obtain the following explicit evaluations:

Patient ID	1	10	10	9
Patient ID	4	5	7	4
Explicit Evaluation	4	5	3	2

Patient Id	1	2	4	4	6	7	8	5
Doctor ID	2	2	1	2	4	4	5	5
Explicit Evaluation	4	5	2	3	1	5	3	1

In this case, from the point of view of our model, doctors are resources for the patients.

Using explicit evaluations, the system will compute the following recommendations for users:

User ID	1	2	3	4	5	6	7	8	9	10
System Recomandations	2,1	2		2,1	5	4	4	5	2,1	4,5

For patient with ID = 10, we notice that a patient-doctor evaluation does not exists. However, this patient evaluates other two patients. Let us consider the situation when a patient with ID=10 leaves the area covered by a Local Sub-System1 and (s)he reaches in Local Sub-System2. If the patient having ID=10 knows some other patients from that area (in our example, ID=5, ID=7), our system can recommend a doctor. Also, if ID=10 does not know someone from that area, (s)he can access the Center for evaluation of e-Health services and obtain the doctors' reputations.

Experiment 2. Let us consider a particular community consisting of 4 doctors. Local trust metric will lead to achieving the following results:

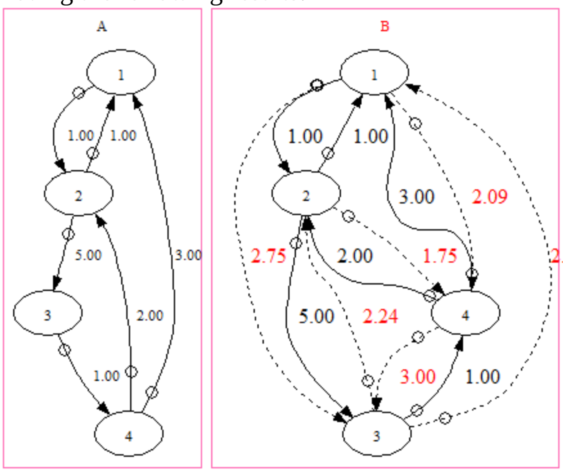

Fig. 5 The graph represents the community consisting of 4 users; A graph containing explicit ratings; B graph containing explicit and implicit ones; arcs are continuous if we have explicit evaluations and if we have implicit evaluations there are represented by dotted arcs

If we consider $P^{l}_{RC} = \max N^{i}_{l}$, then the reputation of the community members is:

User Id	1	2	3	4
Reputation values	4.40	4.0	4.5	4.0

IV. Conclusions

The paper presented the problem of trust and reputation applied in the e-Health systems. Our approach is based on a formal model introduced in [1] that allows the computation of trust and reputation values between different entities (e.g., patients and doctors, medical facilities etc.). As an instance of an e-Health system, we used Telemon – a SOA-based platform.

This computation could be performed by a specific module, presented in section III.

As a further direction of research, we intend to analyze the interoperability problems – at a level of semantic interoperability – in the context of trust and reputation, by following the directions presented in [13].

Acknowledgment

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