

# The Role of Trust in Ubiquitous Healthcare

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**Abstract**—As the cornerstone of effective patient-physician relationships in traditional healthcare infrastructure, trust faces new opportunities as well as challenges in ubiquitous healthcare system. Ubiquitous computing technologies enable participants in healthcare system share their experience more effectively, which leads to better trust decisions for trust decision mechanisms. At the same time, the environments for trust decision making in healthcare system becomes more dynamic because of the highly dynamic nature of ubiquitous computing. In this paper, we contribute to analyze the importance of trust in ubiquitous healthcare and give three typical scenarios of using trust in ubiquitous healthcare: Emergency Response, Ubiquitous Access to Medical Data and Choose a Reliable Service Provider. Trust is used as the basis for automatic decision making in these scenarios: whether to use a healthcare service, whether to permit the access to resources in dynamic collaborations between patients and healthcare service providers.

## I. INTRODUCTION

Health is the best wealth. It therefore lies in human's great interest to build and maintain an infrastructure of health. Healthcare is the support of individual and collective health. However, the healthcare industry is confronting a predicament nowadays, i.e. it is suffering from rocketing costs, the growing incidence of medical errors, inadequate staffing as well as the lack of coverage in rural and underserved urban areas [1]. Healthcare professionals are under increasing pressure to provide better services to more people with limited financial and human resources [2]. One proposed solution to the current crisis is ubiquitous healthcare. Ubiquitous healthcare makes healthcare available anytime, anywhere—ubiquitously. It supports various healthcare services such as patient monitoring, location-based medical services, emergency response, and ubiquitous access to medical data.

In traditional healthcare infrastructure, trust has been considered as the cornerstone of effective patient-physician relationships. The need of trust relates to the information asymmetries arising from the specialist nature of medical knowledge as well as the uncertainty and risk regarding the competence and intentions of the medical professionals on whom the patient is dependent [3]. Trust encourages the usage of services and facilitates. It also inspires the reveal of important medical information and has an indirect influence on health outcomes through patient satisfaction, adherence and continuity of health service providers [4].

Ubiquitous computing technologies bring trust new opportunities as well as challenges in healthcare system. On one hand, the patient is able to make more reliable trust decisions since ubiquitous computing enables more efficient collections and exchanges for the information required by the patient's trust decision mechanism. This empowers the patient to have more reliable and suitable healthcare services. In traditional healthcare collaborations, trust is based on the patient's own past experience as well as the word-of-mouth experience provided by limited number of acquaintances. This information may be far from enough to judge the real quality of certain healthcare service providers, let alone the situations under which no information is available. By using advanced technologies (particularly wireless technologies and the Internet) to connect computing devices in certain environments, ubiquitous computing enables the patient to make more trustworthy decisions since information can be collected from all those who had past interaction history with certain healthcare service providers. On the other hand, ubiquitous computing technologies lay the patient's trust decision mechanism in a more dynamic and uncertainty environment. Ubiquitous technologies enable large number of different service providers dynamically be involved in healthcare system, such as hospitals, GPs, dentists, pharmacies, drug companies and insurance companies [5]. Mobile devices interact with each other and with the healthcare infrastructure to offer people more feasible real-time healthcare services. At the same time, these devices enable dynamic collaborations between different service providers. In these very dynamic ubiquitous environments, to make trust decisions becomes more difficult.

Up to now, the research on trust is very rare in ubiquitous healthcare since to involve ubiquitous technologies in the healthcare system is still in the beginning stage. And to the best of our knowledge, no literature has systematically clarified the role of trust in ubiquitous healthcare. Our paper contributes to analyze the importance of trust in ubiquitous healthcare system. In addition, we make an effort to give several basic scenarios for the usage of trust in ubiquitous healthcare system. The analysis on the role of trust in these scenarios is also given in details. Finally we make a discussion on the future works.

## II. SCENARIOS OF TRUST IN UBIQUITOUS HEALTHCARE

Trust is a complex subject relating to the truster's belief in honest, truthfulness, competence, reliability etc of the trustee. Though trust has been considered extraordinary important in

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many researches, there is no consensus on what trust is. We use one of the common definitions of trust mentioned in [6] in our paper:

**Definition 1:** Trust is the subjective probability by which an individual, A, expects that another individual, B, performs a given action on which its welfare depends.

When evaluating trustworthiness, truster's personal observations on the trustee's behaviors are essential. In case personal experience is absent, trust often has to base on recommendations from others. Reputation is a collective measure of trustworthiness based on the recommendations given by other members in a certain community.

**Definition 2:** Reputation is what is generally said or believed about a person's or thing's character or standing.

The reputations of certain healthcare service providers are based on the ratings given by those who had past interaction history with these healthcare service providers.

With the basic concepts of trust and reputation, we are ready to give some typical scenarios in ubiquitous healthcare. Trust is assessed and used as the basis in these scenarios for automatic decision making: whether to use a healthcare service, whether to permit the access to resources in dynamic collaborations between patients and healthcare service providers.

### A. Emergency Response



Figure 1. Emergency response scenario.

An emergency response scenario is shown in Fig. 1. Bob is on his way back from tour and his car has a collision with other cars because of the heavy foggy weather. Bob falls in faint. His cell phone detects the unusual impact force and automatically sends a request to the ubiquitous healthcare system. The system detects the location of the accident according to Bob's cell phone. The locale information is then collected by traffic cameras located near the accident scene. The system therefore dispatches an appropriate number of police, fire and ambulance vehicles based on the locale information.

On its way to the accident scene, the ambulance reports to the ubiquitous healthcare system that it will take approximately 20 more minutes than average to arrive due to the low visibility weather. The system then requests back to Bob's cell phone to check Bob's setting on emergency. If the ambulance paramedics can not arrive immediately in very emergency situations, the setting given by Bob allows the first aid given by other reliable providers.

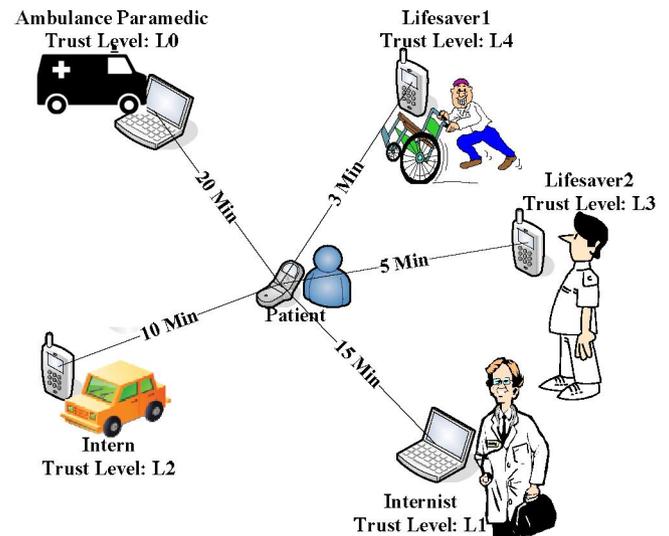


Figure 2. Finding first aid provider.

The ubiquitous healthcare system searches possible first aid providers around the accident scene based on their registered mobile devices. It is reported that four people are able to give first aid nearby: two lifesavers, an intern and an internist as shown in Fig. 2. Both of the lifesavers are able to give Artificial Respiration (AR) and External Chest Compression (ECC). Their trust level is  $L_3$  and  $L_4$  respectively. And it takes them 5 minutes and 3 minutes respectively to arrive the accident scene. The intern and internist are able to give basic medical treatments as well as AR and ECC. Their trust level is  $L_2$  and  $L_1$  respectively. And the time for them to arrive is 10 minutes and 15 minutes respectively. The information is sent to Bob's cell phone. The trust decision mechanism on Bob's cell phone then makes a tradeoff between the trust level and time. The cell phone sends the decision made by the trust decision mechanism back to the system, e.g. the trust decision mechanism chooses the lifesaver whose trust level is  $L_3$  and is 5 minutes away from Bob. The system contacts with the selected first aid provider and gives the concrete information of the accident, e.g. local information.

### B. Ubiquitous Access to Medical Data

Bob successfully gets the first aid given by a lifesaver as shown in Fig. 2. And the ambulance arrives at the accident scene 20 minutes later. The ambulance paramedic, Dr. Black, is ready to give the basic emergency treatment. Dr. Black first needs to access Bob's electronic patient record (EPR) to make sure if Bob has any contraindication. As shown in Fig. 3, Dr. Black first uses his PDA to send a request to Bob's cell phone. By the identity of Dr. Black's PDA, Bob's cell phone checks the trust level of Dr. Black. Based on Dr. Black's request, the ubiquitous healthcare system sends a recommendation on Dr. Black to Bob's cell phone. Using the recommendation given by the system and the trust level of Dr. Black, the trust decision mechanism on Bob's cell phone makes a decision to provide part of his EPR. Bob's trust decision mechanism then gives

permission on Dr. Black back to Dr. White, Bob's GP who is in charge of Bob's EPR. Dr. Black can then contacts with Dr. White and successfully access Bob's EPR.

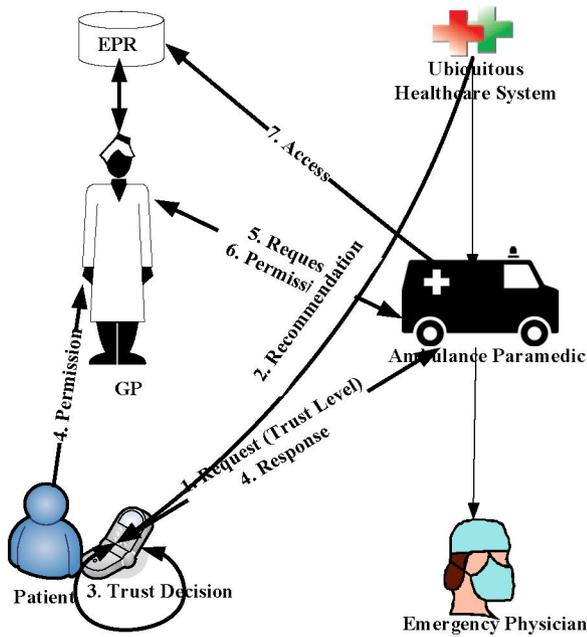


Figure 3. Ubiquitous access to medical data scenario.

In case other healthcare providers want to access Bob's EPR, the trust decision is made based on the requesters' trust levels and the recommendations given by those who had past interactions with the requesters. For example, as shown in Fig. 3, when arrives the hospital, Bob is transferred to the emergency department and the emergency physician, Dr. Smith, is in charge of Bob's case. Dr. Smith needs Bob's EPR to give the treatment. Besides Dr. Smith's trust level, the recommendations given by others who had past interactions with Dr. Smith, e.g. Dr. Black, are also involved in the trust decision making mechanism.

### C. Choose a Reliable Service Provider

Alice is abroad attending a conference. Because of the chilly weather, she catches a bad cold as well as a fever. Since Alice has no idea about the local physicians as shown in Fig. 4, she uses her PDA to get in touch with the local ubiquitous healthcare system. In her requests, Alice gives the keywords "cold" and "fever". The system detects her location according to the PDA and lists the physicians who are related to the given keywords around the area. Along the list, the system also gives the trust level and reputation of each physician. Alice checks the listed physicians and chooses several candidates with high reputation. To make decision, she makes further query for the rating given by previous patients. She finally decides to choose Dr. Johnson since he has a high reputation and the previous patients thought he is quiet affable. Alice makes an appointment by her PDA and the ubiquitous healthcare system gives the detail information on how to arrive there.

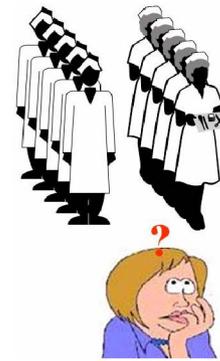


Figure 4. Choose a Reliable Physician/Nurse Scenario.

After careful medical diagnosis, Dr. Johnson suggests Alice to have an intramuscular injection since she asks for quicker recovery. By contacting the ubiquitous healthcare system, Alice's PDA lists all the relative nurses in this hospital. Alice checks the nurses' reputation given by precious patients as well as the rating details. She finally chooses a nurse with high reputation and a twist of the wrist since she is much afraid of pain.

## III. CONCLUSION AND FUTURE WORK

Ubiquitous computing technologies have begun to be used in healthcare infrastructure because of the following unique advantages[2]: (1) the wide range deployment of wireless networks improve the communications among patients, physicians, and other healthcare service providers, (2) the wireless networks enable the delivery of accurate medical information anytime anywhere, thereby reducing errors and improving access, (3) advances in wireless technologies—such as intelligent mobile devices and wearable networks—have made possible a wide range of efficient and powerful medical applications, (4) ubiquitous healthcare has the potential to reduce long-term costs and improve quality of service.

Ubiquitous computing technologies enable patients and healthcare providers share their experience more effectively, which leads to better trust decision. At the same time, the environments for trust decision making in healthcare system become more dynamic because of the highly dynamic nature of ubiquitous computing.

In this paper, we introduce the importance of trust in ubiquitous healthcare and give three typical scenarios of trust in ubiquitous healthcare: Emergency Response, Ubiquitous Access to Medical Data and Choose a Reliable Service Provider. Trust and reputation are used as the basis in these scenarios on choosing reliable healthcare providers and making decision on whether to permit the access to resources in dynamic collaborations between patients and healthcare service providers.

The research on trust in ubiquitous healthcare is still in the beginning level. However, we do believe that the usage of trust in ubiquitous healthcare applications presents a promising path for the future research. We plan to focus on more details on ubiquitous healthcare trust models in the future, such as the trust decision mechanism, the reputation mechanism, and the

risk analysis of the trust values. In the trust decision mechanism, we will first make clear the possible factors which affect the trust decision in ubiquitous healthcare and the relationship between those factors.

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