A Trust Framework of Ubiquitous Healthcare with Advanced Petri Net Model

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Abstract. Ubiquitous healthcare, which enables patients to access medical services anywhere anytime, is still so immature that particularly trust issues in this area require more researches. In this sense, how to design a trustworthy ubiquitous healthcare system is an interesting problem to be resolved. In this paper, we propose a trust framework for ubiquitous healthcare systems by using advanced Petri net and verify how this trust framework evaluates trust properties when developing ubiquitous healthcare systems. The outcome of the research, the trust framework, can make it easy to understand how trust relationships can be built in ubiquitous healthcare systems via mathematical and graphical models.

Keywords: Trust framework, Petri net, Ubiquitous healthcare.

1 Introduction

As Information and Communication Technology (ICT) is growing rapidly, this technology has been applied to many areas. Healthcare industry has also got benefits from ICT [1]. However, common issues of healthcare industry such as limited budget and resources are still major problems that should be resolved. In this context, one of solutions that have been proposed for healthcare industry is ubiquitous healthcare. Ubiquitous healthcare is anywhere and anytime medical service adopting advantages of ubiquitous techniques such as mobile devices, sensors, etc. Ubiquitous technologies extend healthcare services from hospital-based to anywhere and anytime [2]. Patients, who use this service, send their health information with such equipments. However, as the information is private and contains valuable data, patients may not be willing to use the system even though it provides more convenient way to get healthcare services. Patients, for their trust decision, require the trustworthy information about medical professionals of this service. Therefore, trust has a critical role for using a ubiquitous service [3].

Trust plays an essential role in human life and society. Life without trust is unbearable and chaotic, because anything and everything would be possible [7]. The scenarios presented in [3] show the reason why trust in ubiquitous healthcare is important. In these scenarios, trust provides the decisive basis to make the proper decision among patients, healthcare service providers and resources. Therefore, while designing a ubiquitous healthcare system, we should mention a trust model [4].

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Trust has already been modeled with Petri net in different areas such as e-learning [5]. In ubiquitous healthcare, however, there is a lack of an appropriate model on trust. The contribution of this paper is to propose the basic trust framework for ubiquitous healthcare using Petri net model.

The result of this research is a basic research framework which can be used to study and understand the characteristics of ubiquitous healthcare as well as provide a way how to evaluate and analyze the trust issues when the developers implement ubiquitous healthcare systems. In addition, this framework helps overcome industry limitations such as limited budget and resources as we can see Petri net is currently used for an optimal modeling in various industry areas [6].

Firstly, we define healthcare behaviors according to the scenarios introduced in [3]. Then for mathematical and graphical modeling, we build trust development for ubiquitous healthcare and establish common activities in ubiquitous healthcare by using trust development with advanced Petri net model.

2 Background

Petri net model was created by Carl A. Petri in 1962. Primarily, Petri net was used to study communication with automata but nowadays it is used for modeling, formal analysis, and design of discrete event systems. In particular, as graphical and mathematical tools, Petri nets can be used for automated systems and real-time safety-critical systems because of verifying the model formally. They also have successful cases to model sequence controller [6, 8]. Petri net has not been used only as a process development tool for complex system but also as a mathematical model for reflecting the system behavior [8].

As industry areas are growing, various applications of Petri have been developed, e.g. high-level Petri nets, timed Petri net, fuzzy Petri net, advanced Petri net, Amended Colored Petri net [5, 8, 9]. Especially, advanced Petri net in [5] is introduced for the multi-user collaboration. This advanced Petri net model, in particular, adds the weight of trust rates and reliable factors on Petri net. Thus, this improved Petri net builds trust development in virtual university. Moreover, A Colored Petri net trust model was proposed for public-key infrastructure in [10]. This flexibility of Petri net on trust also makes it possible to apply to the trust development in ubiquitous healthcare.

3 Building Trust with Advanced Petri Net Model

In this section, we define healthcare behaviors based on Petri net approach. The following definition represents the well-formed net for healthcare behaviors concerning trust. For trust development, we use divided nets consisting of healthcare workflow and activities of resources. Each net has the weight of trust rate.

Definition 1. Advance Petri net for healthcare workflow is a well-formed $HBPN = (P, T, A, T_{i\to(i+1)w}, M_0)$; where

$P = \{p_1, p_2, p_3 ..., p_m\}$ is a finite set of places to represent a state in healthcare workflow,

$T = \{t_1, t_2, t_3 ..., t_n\}$ is a finite set of transitions to represent behaviors in healthcare,
$A \subseteq (P \times T) \cup (T \times P)$ is a finite set of arcs such that: $P \cap T = P \cap A = T \cap A = \phi$
$T_{i \to (i+1)w} = range[0,1]$ is the threshold of trust rate from transition i to $i+1$
$M_0 : P \mapsto N$ is the initial marking, where N is a set of nonnegative integers.

Definition 2. Advance Petri net for resources is a well-formed $ARPN^m = (P_r^m, T_r^m, A_r^m, P_{r(i)w}^m, M_{r0}^m)$; where

$P_r^m = \{p_{r1}^m, p_{r2}^m, p_{r3}^m ..., p_{rj}^m\}$ is a finite set of places to represent a state of resources,
$T_r^m = \{t_{r1}^m, t_{r2}^m, t_{r3}^m ..., t_{rk}^m\}$ is a finite set of transitions to represent activities of resources,
$A_r^m \subseteq (P_r^m \times T_r^m) \cup (T_r^m \times P_r^m)$ is a finite set of arcs such that: $P_r^m \cap T_r^m = P_r^m \cap A_r^m = T_r^m \cap A_r^m = \phi$
$P_{r(i)w}^m = range[0,1]$ is the weight of trust rate from p_{ri}^m, the local trust information or score such as the trust or reputation level of resources rated by the patient's cell phone conducting the trust decision mechanism or previous patients and firing is occurred when $P_{r(i)w}^j \geq T_{j \to (j+1)w}$,
$M_{r0}^m : P_r^m \mapsto N$ is the initial marking, where N is a set of nonnegative integers.

Scenarios presented in [3] shows trust considerations as follows: the trust decision mechanism to choose first aid providers between the trust level and time, to provide the medical data according to the trust level of the data requesters, and to choose a reliable service provide based on the reputation rated by previous patient. These factors can be represented by the following definition similar to the way used in trust development in virtual university[5].

Definition 3. The total threshold of trust rate from transition i to j is formulated as follows:

$$T_{(i \to j)w} = \sum_{n=i}^{j} T_{i \to (i+1)w} \quad . \tag{1}$$

The average threshold of trust rate is formulated as follows:

$$avg \ . T_{(i \to j)w} = \frac{\sum_{n=i}^{j} T_{i \to (i+1)w}}{N} \quad . \tag{2}$$

such that N is the value divided the number of arcs from transition i to j as 2.

The total threshold represents the size of trust rate which can be the basis to decide the importance of trust and the average threshold can be basis to decide the density of trust rate.

Definition 4. The total weight of trust rate from P_{ri}^{m} to P_{rj}^{m} is formulated as follows:

$$T_{rw}^{m} = \sum_{n=i}^{j} P_{r(i)w}^{m} \quad . \tag{3}$$

This trust factor has the value between 0 and 1.

The average weight of trust rate is formulated as follows:

$$avg.T_{rw}^{m} = \frac{\sum_{n=i}^{j} P_{r(i)w}^{m}}{N} \quad . \tag{4}$$

such that N is the number of P_{r}^{m}.

The total weight of trust rate shows the flexibility to decide alternatives and the average weight of trust rate is the basis of the possibility for the trust decision e.g. $avg.T_{rw}^{k} < T_{k\to(k+1)w}$ shows the low trustworthy decision.

Graphical trust representation in Petri net is shown as Fig. 1. T_1 and T_2 are transitions to describe behaviors of healthcare such as the aid provider selection and the emergency expedient. T_{r1}^{1} is a transition of activity regarding resources. In this case, T_{r1}^{1} means the decision mechanism based on $P_{r(1)w}^{1} = 1$ and $P_{r(2)w}^{1} = 0.8$. $T_{(1\to2)w} = 0.8$ represents the threshold which is the minimum value firing P_1 according to the result of T_{r1}^{1}.

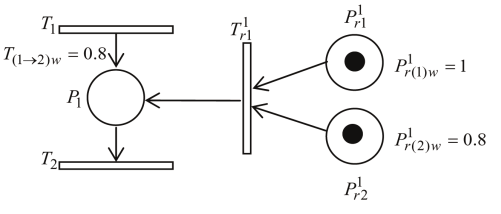

Fig. 1. Graphical representation of trust in advanced Petri net

4 Modeling Trust Framework of Ubiquitous Healthcare

4.1 Modeling Healthcare Behaviors with Petri Net

According to [3], we define healthcare behaviors. Usually, healthcare starts from monitoring a certain person and the monitoring system detects emergency situations. Ubiquitous technologies for healthcare make it possible to understand the emergency situation, make a decision, and communicate with other devices of stakeholders. In this process, various healthcare behaviors are generated. As we mentioned before, *HBPN* is a well formed net to show the mathematical representation of healthcare behaviors and Fig. 2 is a graphical description of healthcare behaviors for the emergency response.

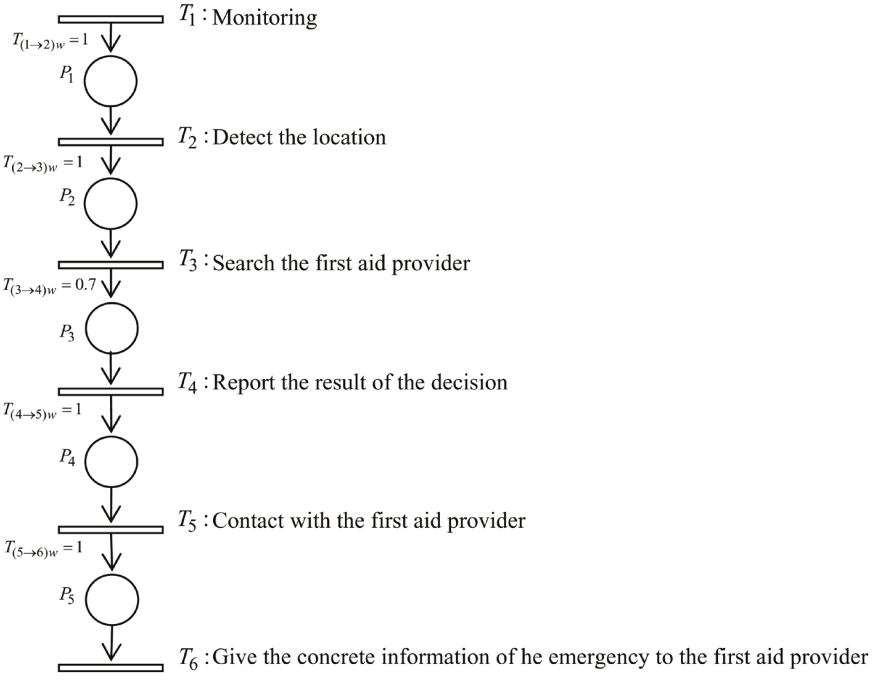

Fig. 2. Emergency response

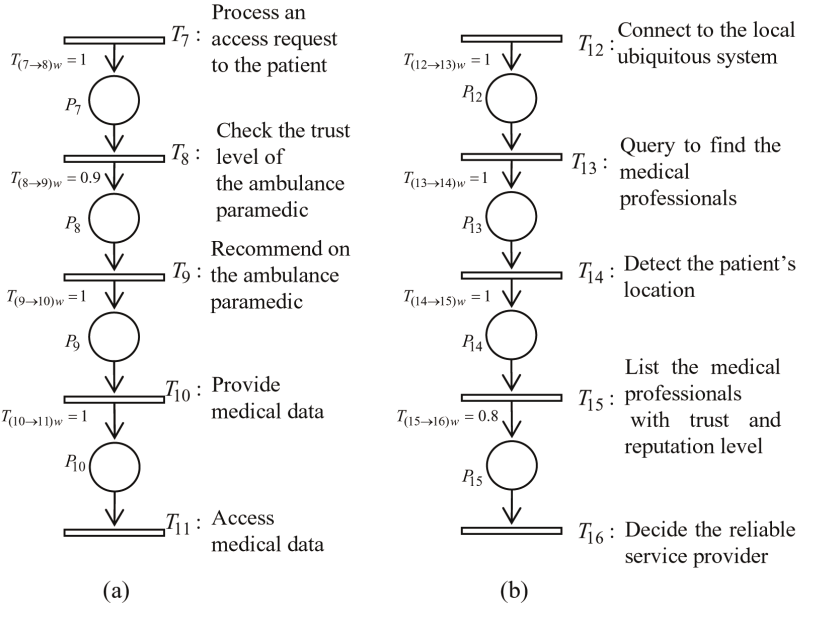

Fig. 3. (a) Access to medical data. (b) Choosing a reliable service provider

Next stage is accessing to medical data of the patient. In this case, after getting help from the first aid provider the ambulance paramedic arriving soon tries to request the permission to access the patient's medical data such as electronic patient record (EPR), and then give the emergency expedient. The aid provider's trust level is used for the decision of accessing data. Fig. 3 (a) shows the detail model of behaviors.

The last trust scenario in [3] shows how to choose a reliable service provider. The patients try to find the physicians with high reputation by their mobile device. They connect to the local ubiquitous healthcare system and query the reputation information from the system. The detail representation is shown as Fig. 3 (b).

4.2 Trust Framework of Ubiquitous Healthcare Based on Trust Activities with Advanced Petri Net

Healthcare trust activities are concatenated with Petri net healthcare behavior model. Fig. 4 shows various alternatives (a set of P_r^3) of the first aid provider. These alternatives have the weight of trust rate which is calculated with trust level and time of them. That is $P_{rw}^3 = \{1,0.6,0.4,0.8,0.5\}$. The trust threshold between T_4 and T_5 is $T_{(3\to4)w} = 0.7$. In this case, $P_{r(1)w}^3$ and $P_{r(4)w}^3$ is bigger than $T_{(3\to4)w} = 0.7$ and make P_3 be firing.

In trust activities for access to medical data, we can find two weights. One is for checking the trust level of ambulance paramedic who requests the patient's medical

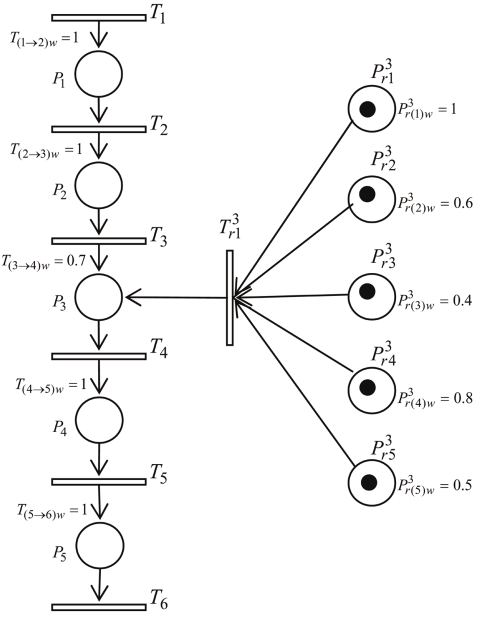

Fig. 4. Trust activity of emergency response

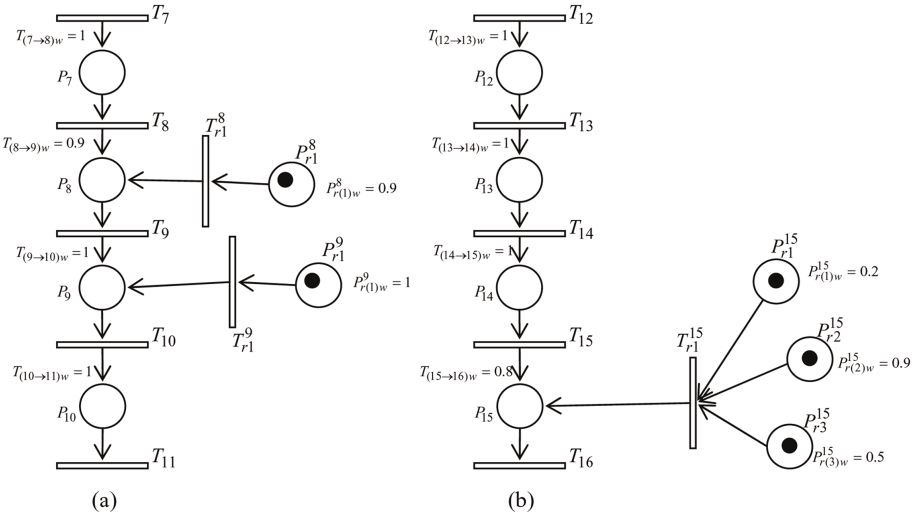

Fig. 5. (a) Trust activity of access to medical data. (b) Trust activity of the reliable service provider selection

data. The other is about the recommendation by the patient's general practitioner. Fig 5 (a) shows the example to permit access of medical data by ambulance paramedic because all weights are more than the corresponding thresholds.

In Fig 5 (b), we can find out the list of the trust weight regarding the reputation of the medical professionals. P_{r2}^{15} has the enough weight of trust and can be the only medical professional decided by the decision mechanism.

5 Conclusion

The problem addressed in this research is lack of an appropriate model on trust in ubiquitous healthcare. We proposed the basic trust framework for ubiquitous healthcare using advanced Petri net model. By determining healthcare behaviors according to the common scenarios, we built trust development for ubiquitous healthcare with advanced Petri net model.

For this purpose, we conducted a quantitative research to define the mathematical relationships between the trust factors and healthcare behaviors. We used advanced Petri net as a mathematical and graphical modeling tool. The trust development built with these mathematical relationships supports the design of the optimal activities among workflow and resources of ubiquitous healthcare.

As a result, the finding of this paper will contribute to implement the trustworthy ubiquitous healthcare system as a promising tool. In addition, this framework helps overcome industry limitations such as limited budget and resources. The future work can focus on enforcing the management method of trust factors as resources.

References

1. Wilson, P., Healy, J.C., Iakovidis, I.: E-health: current situation and examples of implemented and beneficial e-health applications. IOS Press, Amsterdam (2004)
2. Bottazzi, D., Corradi, A., Montanari, R.: Context-Aware Middleware Solutions for Anytime and Anywhere Emergency Assistance to Elderly People. IEEE Communications Magazine 44, 82–91 (2006)
3. Yuan, W., Guan, D., Lee, S., Lee, Y.-K.: The Role of Trust in Ubiquitous Healthcare. In: 9th International Conference on e-Health Networking, Application and Services, pp. 312–315. IEEE Press, Taipei (2007)
4. Stinson, J., Pellissier, S., Andrews, A.: Defining and Applying Generic Trust Relationships in a Network Computing Environment. ATI IPT Special Report (2000)
5. Wang, C.-C., Deng, L.Y., Chen, Y.-H.: A Petri Net-based Approach to Trust Development and Activity Understanding in Virtual University. In: 7th IEEE International Conference on Advanced Learning Technologies, pp. 98–102. IEEE Press, Niigata (2007)
6. Murata, T.: Petri nets: Properties, analysis and applications. Proceedings of the IEEE 77, 541–580 (1989)
7. Luhmann, N.: Trust and Power: two works. Wiley, Chichester (1979)
8. Zurawski, R., MengChu, Z.: Petri nets and industrial applications: A tutorial. IEEE Transactions on Industrial Electronics 41, 567–583 (1994)
9. Kwon, O.B.: Modeling and generating context-aware agent-based applications with amended colored Petri nets. Expert Systems with Applications 27, 609–621 (2004)
10. Lory, P.: A coloured Petri net trust model. In: 14th International Workshop on Database and Expert Systems Applications, pp. 415–419. IEEE Press, Prague (2003)