Using Game Theory to Analyze Strategic Choices of Service Providers and Service Requesters

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***Abstract*—With the rapid development and popularization of Web services, online privacy has become a rising concern. In order to prevent service providers from abusing private information of service requesters, service providers are required to publish their privacy policies. If a service provider's privacy policy is not consistent with a service requester's privacy preference, the provider and the requester can negotiate. Whether the negotiation is successful or not depends on the strategic choices of the provider and the requester. This paper analyzes strategic choices of service providers and service requesters in negotiations by game theory. We propose a game theoretic model for negotiations between providers and requesters, discussing providers' and requesters' strategic choices in one-time negotiation and repeated negotiation. In addition, a case study is given to demonstrate how to use our game theoretic model to analyze the strategic choices of providers and requesters in negotiations.**

***Index Terms*—Negotiations, Game Theory, Privacy Policies, Privacy Preferences**

I. Introduction

Nowadays, increasing people are accustomed to using Web services. When they enjoy the convenient and efficient services on the Internet, their private information is inevitably collected by service providers. As service requesters, it is difficult for them to control the way their private information is used by service providers. To avoid the misuse of service requesters' private information, service providers are asked to publish their privacy policies. Privacy policies specify how service providers will deal with the private information, which they get from service requesters. Service requesters also design their privacy preferences which state the way in which the private information will be handled. P3P privacy policy is one of the privacy policies widely used in the world [1]. P3P (The Platform for Privacy Preferences) [2] was released by World Wide Web Consortium (W3C) in April 2002. It provides a standard and machine-readable privacy policy. W3C also designs APPEL (A P3P Preference Exchange Language) [3] which allows service requesters to specify their privacy preferences.

The consistency of privacy policies and privacy preferences means that service providers will handle private information according to service requesters' requirements. In this case, requesters will use the services offered by providers. Conversely, if privacy policies are not consistent with privacy preferences, requesters will refuse to use the services so as to protect their privacy. Otherwise, providers and requesters will negotiate. The success of the negotiations relies on providers' and requesters' strategic choices. Providers have the choice to alter their privacy policies to be stricter or not alter their privacy policies. Requesters have the choice to modify their privacy preferences to be more moderate or not to modify their privacy preferences. If providers don't alter policies and requesters don't modify preferences when they are negotiating, the negotiations fail. Researchers have studied the negotiations between service providers and service requesters. Kheira Bekara and Maryline Laurent [4] proposed a negotiation mechanism, which supported automated negotiations on the inconsistencies between P3P privacy policies and privacy preferences. During the negotiations, privacy policies were changed from moderate to strict by providers, and privacy preferences were changed from strict to moderate by requesters. Salah-Eddine Tbahriti et al. [5] put forward a negotiation model to reconcile requesters' requirements with providers' policies in case of incompatibility. In their model, providers did not change their policies but offered incentives to requesters. If requesters accepted the incentives, they would modify their requirements to be compatible with providers' policies. Ke Changbo et al. [6] proposed a cloud computing oriented negotiation mechanism, in which service requesters didn't alter their privacy preferences and service providers changed their privacy policies to satisfy service requesters.

In this paper, we formulate negotiations between service providers and service requesters as a game theoretic model to analyze their strategic choices during negotiations. Both providers and requesters have two strategic choices in our game model. Providers may or may not alter their privacy policies to be stricter. Requesters may or may not modify their privacy

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preferences to be more moderate. Based on payoffs of different strategic choices, we can infer which strategies providers and requesters will choose.

This paper is structured as follows: In Section II we introduce related works. In Section III we give an overview of game theory. In Section IV we propose a game theoretic model for negotiations between service providers and service requesters and calculate the mixed strategy Nash equilibrium of the game model. In Section V we discuss the results of one-time negotiation and repeated negotiation. In Section VI we illustrate how to analyze providers' and requesters' strategic choices by our game model with a case study. In the end, we conclude and point out the future works in Section VII.

II. Related Work

If service providers' privacy policies aren't consistent with service requesters' privacy preferences, service providers and service requesters may negotiate on the inconsistencies. To address the limitation that P3P lacks a negotiation mechanism, Kheira Bekara and Maryline Laurent [4] proposed an automated negotiation mechanism which supported negotiations on the inconsistencies between P3P privacy policies and privacy preferences. During negotiations, privacy policies were changed from moderate to strict by providers, and privacy preferences were changed from strict to moderate by requesters. Salah-Eddine Tbahriti et al. [5] put forward a negotiation model to reconcile requesters' requirements with providers' policies in case of incompatibility. In their model, providers didn't change their policies but offered incentives to requesters. Once requesters accepted the incentives, they would modify their requirements so that it could be compatible with providers' policies. Ke Changbo et al. [6] proposed a cloud computing oriented negotiation mechanism. In the mechanism, users didn't modify their privacy preferences. Privacy policies satisfying both users and service composers were gained through exchanging privacy disclosure assertion.

Although game theory is initially developed in economics, it has been used to solve problems in many fields. Lisa Rajbhandari and Einar Arthur Snekkenes [7] used a game theory based approach to perform privacy-related risk analysis. In their game model, there were two decision makers which were an online bookstore and a user. The user had the choice to provide his genuine or fake personal information to the online bookstore. The online bookstore chose to exploit the personal information of the user by selling it to third parties or didn't exploit and used it for its own internal purpose. The probabilities and outcomes to determine the level of privacy risk could be computed by obtaining the benefits from the online bookstore's and the user's strategic choices. Spyros Kokolakis et al. [8] analyzed buyers' and sellers' privacy-related strategic choices in e-commerce transactions through game theory. They explained why buyers mistrusted privacy policies and discussed possible remedies to protect privacy. Shouke Wei et al. [9] applied game theory based model to analyze and solve water conflicts concerning water allocation and nitrogen reduction in the Middle Route of the South-to-North Water Transfer Project in China. They constructed a game model including a main game and four sub-games and used statistical and econometric regression methods to formulate payoff functions of players. Justin Zhan et al. [10] proposed an approach to generate gaming strategies for the attacker and defender in a recommender system. To analyze vulnerabilities and security measures incorporated in a recommender system, they defined attack graphs, use cases, and misuse cases in their gaming framework. Wu Jiang et al. [11] analyzed gaming behaviors of graduates in scholarship competition in China by using an evolutionary game theory approach. They found that graduate individual would adopt different strategies based on different number of graduate groups, symmetry information and asymmetry information. Zhang Cheng et al. [12] focused on cheating operations of nodes happened in Opportunistic Network. In order to improve the possibility of successful message transmission and reduce the probability of cheating, they converted the phase game of nodes into repeated-game and introduced the credit mechanism and punishment mechanism into the game. Mohamed Amine M'hamdi et al. [13] proposed a scheduling algorithm to help the controller agent improve the quality of the reputation mechanism. The algorithm was based on a class of games called Bayesian Stackelberg. Sun Weifeng et al. [14] proposed a game theoretic resource allocation model in grid computing. The model guaranteed higher tasks' victorious probabilities in grid resources scheduling situations. Wu Guowei et al. [15] put forward a game theoretic energy-aware scheduling algorithm for multi-core systems. The algorithm could reduce the temperature difference between different groups of cores, which effectively avoided the local hotspot of a processor.

III. Overview Of Game Theory

Game theory was theorized by John Von Neumann and Oskar Morgenstern in 1944 [16]. Nash proved the existence of Nash equilibrium in 1950, which laid the foundation for the generalization of game theory [17][18]. Today, game theory has been widely used in many fields, such as politics, economy and biology [19]. It analyzes the behaviors of decision makers in interactions. Compared with classical analytical methods, it doesn't have to rely on subjective probabilities or accurate data. Probabilities and outcomes can be computed according to the preferences or benefits of decision makers.

A game generally comprises four parts: the players, their strategies, payoffs and the information they have [20]. According to different criteria, the game can be categorized into a static/dynamic game and a complete/incomplete game. A static game is one in which players choose simultaneously or not choose simultaneously but players who choose secondly not knowing the actions of players who choose firstly (vice versa for the dynamic game). A complete information game is one in which players know about the strategies and payoffs of others (vice versa for the incomplete information game).

If a player's chosen strategy is the best response to the strategies of others, it is the optimal strategy for the player. A Nash equilibrium is a strategy profile consisting of each player's optimal strategy. Players in the game don't have enough reasons to break the equilibrium [21]. A mixed strategy is a probability distribution of the players' pure strategies. The expected payoffs of players in a game can be calculated based on the mixed strategy Nash equilibrium.

IV. Game Theoretic Model For Negotiations

In this section, we will formulate negotiations between service providers and service requesters as a game theoretic model and calculate the mixed strategy Nash equilibrium of the model.

A. Game Formulation

We construct a game theoretic model for negotiations to analyze service providers' and service requesters' strategic choices. To formulate the game, we assume that it is a static and complete information game. The game is static as we stipulate that the provider and the requester choose their strategies simultaneously. It is of complete information as we assume that both the provider and the requester know about the strategies and outcomes of each other. In the following, we will explain the strategies of the players and how the data are collected to estimate the payoffs.

Players: It is a two-player game between the service provider and the service requester. We assume that both the provider and the requester are rational. They have the incentive to optimize their payoffs.

Strategies: Both the service provider and the service requester have two strategic choices. The service provider has the choice to alter his privacy policy to be stricter or keep his privacy policy unchanged. The strategies of the service provider are given by {Alter, NotAlter}. The service requester has the choice to modify his privacy preference to be more moderate or keep his privacy preference unchanged. The strategies of the service requester are given by {Modify, NotModify}.

Payoff:

1.Data Collection:

We need to collect data to estimate the payoffs of the provider and the requester. Table I lists the data related to the service provider.

TABLE I
DATA RELATED TO THE SERVICE PROVIDER

	For Service Provider	
Strategic Choices	Alter	NotAlter
Modify	a, b	a
NotModify	a, c	d

For the service provider: In the case where the service requester modifies his preference to be more moderate, if the service provider alters his policy to be stricter, the negotiation is successful. The service provider benefits from providing services to the requester (a) and pays additional cost to implement the stricter policy (b). If the service provider keeps his policy unchanged, the negotiation is successful. The service provider benefits from providing services (a) and doesn't have to pay a cost for altering his policy. In the case where the service requester keeps his preference unchanged, if the service provider alters his policy to be stricter, the negotiation is successful. The service provider benefits from providing services to the requester (a) and pays additional cost to implement the stricter policy (c). The value of c is greater than b because the degree to which the policy is altered is bigger. If the service provider keeps his policy unchanged, the negotiation fails. The service provider suffers a loss resulting from not providing services for the requester (d).

Table II lists the data related to the service requester.

TABLE II.
DATA RELATED TO THE SERVICE REQUESTER

	For Service Requester	
Strategic Choices	Modify	NotModify
Alter	e, f	e
NotAlter	e, g	h

For the service requester: In the case where the service provider alters his policy to be stricter, if the service requester modifies his preference to be more moderate, the negotiation succeeds. The service requester benefits from using services offered by the service provider (e) and suffers a loss resulting from reducing demands for privacy protection (f). If the service requester keeps his preference unchanged, the negotiation succeeds. The service requester benefits from using services offered by the provider (e) and doesn't have to suffer a loss resulting from modifying his preference. In the case where the service provider keeps his policy unchanged, if the service requester modifies his preference to be more moderate, the negotiation succeeds. The service requester benefits from using services offered by the provider (e) and suffers a loss resulting from reducing demands for privacy protection (g). The value of g is greater than f because the degree to which the preference is modified is bigger. If the service requester keeps his preference unchanged, the negotiation fails. The service requester suffers a loss resulting from refusing to use services provided by the provider (h).

2.Estimation:

The negotiation between the service provider and the service requester is shown in Figure 1. The provider may or may not alter his privacy policies to be stricter. The strategies of him are given by {Alter, NotAlter}. The requester may or may not modify his privacy preferences to be more moderate. The strategies of him are given by {Modify, NotModify}. Therefore, there are four strategy profiles which we will present in the following paragraphs. SP and SR denote respectively the provider's payoff and the requester's payoff.

{Alter, Modify} means the provider alters his policy to be stricter, while the requester modifies his preference to be more moderate. The provider benefits from providing services to the requester (a) and pays additional cost to implement the stricter policy (b). Thus, the provider's payoff is a-b. The requester benefits from using services offered by the provider (e) and suffers a loss resulting

from reducing demands for privacy protection (f). His payoff is e-f.

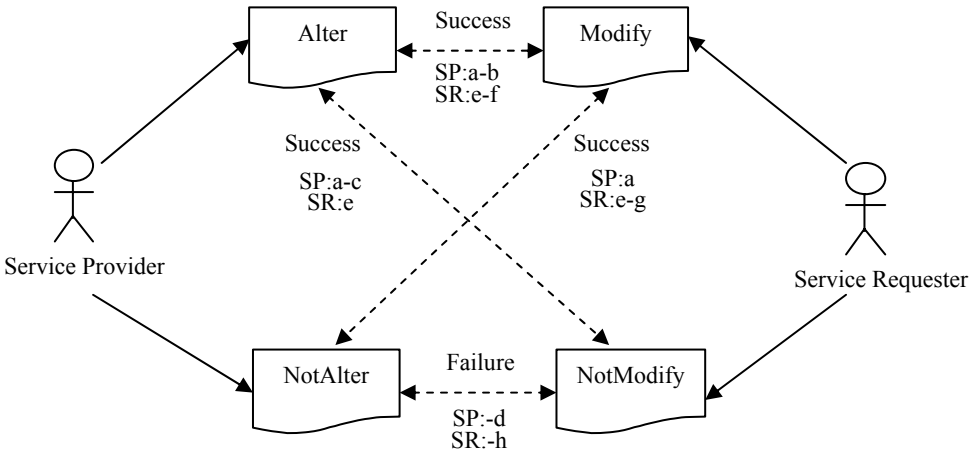

Figure 1. The negotiation between the provider and the requester

{Alter, NotModify} means the provider alters his policy while the requester keeps his preference unchanged. The provider benefits from providing services (a) and pays additional cost to implement the stricter policy (c). Thus, the provider's payoff is a-c. The requester benefits from using services (e) and doesn't have to suffer a loss resulting from modifying his preference. Thus, the requester's payoff is e.

{NotAlter, Modify} means the provider keeps his policy unchanged while the requester modifies his preference. The provider benefits from providing services (a) and doesn't have to pay a cost for altering his policy. Thus, his payoff is a. The requester benefits from using services (e) and suffers a loss resulting from reducing demands for privacy protection (g). His payoff is e-g.

{NotAlter, NotModify} means the provider doesn't alter his policy while the requester doesn't modify his preference. The provider suffers a loss resulting from not providing services (d). His payoff is -d. The requester suffers a loss resulting from refusing to use services (h). The requester's payoff is -h.

B. Game Solution

TABLE III.
PAYOFFS OF THE PROVIDER AND THE REQUESTER

		Service Provider	
		Alter	NotAlter
Service Requester	Modify	e-f, a-b	e-g, a
	NotModify	e, a-c	-h, -d

The payoffs of the provider and the requester are shown in Table III. The first value of each cell is the payoff of the service requester while the second value is the payoff of the service provider. Using the payoffs in Table III, we can find the mixed strategy Nash equilibrium in the negotiation. We assume that the provider plays the strategies Alter and NotAlter with probabilities p and 1-p respectively, and the requester plays the strategies Modify and NotModify with probabilities q and 1-q respectively. Mixed strategy Nash equilibrium makes players indifferent between their pure strategies. So, we set the expected payoffs of players' pure strategies equal to solve the mixed strategy Nash equilibrium.

When calculating p, we assume the expected payoff the requester gains by modifying his preference is E_{R1}, and the expected payoff the requester gains by keeping his preference unchanged is E_{R2}.

$$E_{R1} = (e-f)p + (e-g)(1-p)$$
$$E_{R2} = ep + (-h)(1-p)$$

In the mixed strategy Nash equilibrium, the provider's strategic choices make E_{R1} equal to E_{R2}.

$$E_{R1} = E_{R2}$$
$$(e-f)p + (e-g)(1-p) = ep + (-h)(1-p)$$
$$p = \frac{g-h-e}{g-h-e-f} \quad (1)$$

When calculating q, we assume the expected payoff the provider gains by altering his policy is E_{P1}, and the expected payoff the provider gains by keeping his policy unchanged is E_{P2}.

$$E_{P1} = (a-b)q + (a-c)(1-q)$$
$$E_{P2} = aq + (-d)(1-q)$$

In the mixed strategy Nash equilibrium, the strategic choices of the requester make E_{P1} equal to E_{P2}.

$$E_{P1} = E_{P2}$$
$$(a-b)q + (a-c)(1-q) = aq + (-d)(1-q)$$
$$q = \frac{c-a-d}{c-a-d-b} \quad (2)$$

After calculation, we get p and q. Hence, we can know the probabilities with which the provider and the requester will choose a particular strategy.

V. Results Of Negotiations

If the service provider and the service requester only negotiate once, the negotiation is a one-time game. Therefore, the provider and the requester will choose their optimal strategies based on the mixed strategy Nash equilibrium. However, if the requester asks for services offered by the provider more than once, the provider and the requester negotiate many times. We assume that changes in policies and preferences in the negotiation are not saved by the provider and the requester. These changes are only temporary compromises for the sake that the negotiation succeeds.

In the finite case, the requester asks for services several times and then stops. The provider and the requester negotiate finite times. Thus, the negotiation is a finitely repeated game. Using backward induction, we obtain the result of this game. We should first examine the last round. In the last round, the service provider and the service requester will choose their optimal strategies based on the mixed strategy Nash equilibrium. So in the penultimate round, the service provider and the service requester will also choose their optimal strategies. And so on, the service provider and the service requester will also choose their optimal strategies from the beginning. Therefore, the result of the finitely repeated game is the same as the one-time game. The provider and the requester will choose their optimal strategies based on the mixed strategy Nash equilibrium.

In the infinite case, the requester asks for services endlessly. The provider and the requester negotiate infinite times. Thus, the negotiation is an infinitely repeated game. At this point, the provider and the requester may not choose their optimal strategies. Considering their long-term interests, the provider and the requester will cooperate.

VI. Case Study

Consider the scenario between a user and an online bookstore. The user asks for services provided by the online bookstore. Because of inconsistencies between the online bookstore's privacy policy and the user's privacy preference, the online bookstore and the user negotiate with each other. The data related to the online bookstore are shown in Table IV and the data related to the user are shown in Table V.

TABLE IV.
DATA RELATED TO THE ONLINE BOOKSTORE

	For online bookstore	
Strategic Choices	Alter	NotAlter
Modify	1, 1.2	1
NotModify	1, 1.7	1

TABLE V.
DATA RELATED TO THE USER

	For user	
Strategic Choices	Modify	NotModify
Alter	2, 1.5	2
NotAlter	2, 2.5	1

If the online bookstore chooses the strategy Alter and the user chooses the strategy Modify, then the online bookstore benefits from providing services to the user (1) and pays additional cost to implement the stricter policy (1.2), and the user benefits from enjoying services offered by the online bookstore (2) and suffers a loss resulting from reducing his demands for privacy protection (1.5). Thus, the online bookstore's payoff is 1-1.2=-0.2. And the user's payoff is 2-1.5=0.5.

If the online bookstore chooses the strategy Alter, while the user chooses the strategy NotModify, then the online bookstore benefits from providing services (1) and pays additional cost to implement the stricter policy (1.7), and the user benefits from using services (2) and doesn't have to suffer a loss resulting from modifying his preference. Thus, the online bookstore's payoff is 1-1.7 =-0.7. And the user's payoff is 2.

If the online bookstore chooses the strategy NotAlter, whilst the user chooses the strategy Modify, then the online bookstore benefits from providing services (1) and doesn't have to pay a cost for altering his policy, and the user benefits from using services (2) and suffers a loss resulting from reducing his demands for privacy protection (2.5). Thus, the online bookstore's payoff is 1. And the user's payoff is 2-2.5=-0.5.

If the online bookstore chooses the strategy NotAlter and the user chooses the strategy NotModify, then the online bookstore suffers a loss resulting from not providing services (1), and the user suffers a loss resulting from refusing to use services (1). Thus, the online bookstore's payoff is -1. And the user's payoff is -1.

The payoffs of the online bookstore and the user are shown in Table VI.

TABLE VI.
THE PAYOFFS OF THE ONLINE BOOKSTORE AND THE USER

Online Bookstore / User	Alter	NotAlter
Modify	0.5, -0.2	-0.5, 1
NotModify	2, -0.7	-1, -1

By substituting the data in Table VI into the expression (1) and expression (2), we get p = 25% and q = 20%, which means the online bookstore alters his policy to be stricter with a 0.25 probability and the user modifies his preference to be more moderate with a 0.2 probability. Table VII lists the probabilities with which the online bookstore and the user will choose a particular strategy.

TABLE VII.
THE PROBABILITIES DISTRIBUTIONS OF STRATEGIES

		p=25%	1-p=75%
	Online Bookstore / User	Alter	NotAlter
q=20%	Modify	0.5, -0.2	-0.5, 1
1-q=80%	NotModify	2, -0.7	-1, -1

According to the data in Table VII, NotAlter is a dominant strategy for the online bookstore, since regardless of the user's choice the online bookstore gets a

better payoff. For the user, NotModify is a dominant strategy which makes the user get a better payoff. Therefore, the online bookstore tends to keep his policy unchanged and the user tends to keep his preference unchanged. Probabilities 1-p and 1-q shows that the online bookstore refuses to alter his policy with a 0.75 probability and the user refuses to modify his preference with a 0.8 probability.

If the user asks for services provided by the online bookstore once, the user and the online bookstore will negotiate once. Based on the mixed strategy Nash equilibrium, the online bookstore and the user will choose the strategy profile {NotAlter, NotModify}.

If the user asks for services finite times, the user and the online bookstore will negotiate finite times. The result is the same as only negotiate once. The online bookstore and the user will choose the strategy profile {NotAlter, NotModify}. However, if the user asks for services infinite times, the user and the online bookstore will negotiate infinite times. The online bookstore and the user will not choose the strategy profile {NotAlter, NotModify} because it will make them bear the greatest losses in the long term. Considering their long-term interests, the online bookstore and the user will cooperate and choose the strategy profile {Alter, Modify}.

VII. Conclusions And Future Work

This paper analyzes service providers' and service requesters' strategic choices in negotiations through game theory. We propose a game theoretic model for negotiations between providers and requesters, discuss providers' and requesters' strategic choices in one-time negotiation and repeated negotiation, and demonstrate how to use our game theoretic model to analyze providers' and requesters' strategic choices through a case study.

However, the negotiation between the provider and the requester in this paper is for the whole privacy policy. Such negotiation is coarse grained. In fact, a privacy policy generally consists of many privacy statements. Each statement specifies the handling of a private data. So the negotiation for a privacy statement is fine grained. In future research, we plan to study the negotiation which is for a privacy statement of a particular private data. The study will help the provider and the requester to reach an agreement on the handling of a particular private data.

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