Experimental Analysis for the Design of Sustainable Service Computing Infrastructure

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***Abstract*—In a service computing environment, Web service is maintained by various stakeholders including content providers, users and integration vendors of the service computing environment. These stakeholders make decisions about software/product license structure and billing system of services they are involved in. Service computing environment can be regarded as being provided and maintained as a synthesis of all these individual services. However, to make this service computing environment a sustainable one, validity of billing structure and fairness of cost burden among users need to be satisfactory from the users' perspective. The purpose of this study is to clarify, from a gaming experiment on the Internet, how users using a service computing environment will react to cost burden rules of certain services. In the experiment, highly public service operation model such as Language Grid was assumed and user behavior was investigated by combining incentive effect, its nature as a social investment and its nature as a Donationware where the payment of compensation for use is left to the user's judgement. As a result, it was clarified that users' behavior had a certain pattern with regards to interest and passivity towards donation and investment.**

I. Introduction

In a service computing environment, configurable computing resources including network and server, storage and application software and contents are provided by many different stakeholders and shared by multiple users. In such a shared environment, there is a merit of service maintenance cost being reduced compared to a conventional computing environment. On the other hand, under a service computing environment, service is shared amongst unspecified number of users. Therefore, by exactly measuring resource use and building a service environment based on charge back model for billing, fairness will be secured. However, for example, with cloud computing environment such as Language Grid [1], there are many services aiming to achieve, as a social duty, provision of service of non-profit and highly public nature under a private/non-profit organization. Services possessing this type of nature is better provided free of charge if possible, but maintenance of service will inevitably require a certain cost. Therefore, how such costs to maintain service is borne amongst users who are the beneficiaries will be the issue. Our study assumed service operational model which is highly public and social in nature and user behavior will be investigated by combining incentive effect, its nature as a social investment and its nature as a Donationware where the payment of compensation for use is left to the user's judgement. If this knowledge is made clear, in the future, it will be possible to improve the sustainability of a service operational model which is highly public and social in nature.
The rest of this paper is structured as follows. Section 2 will introduce related works, Section 3 will outline the method of investigating user behavior by experiment and the experiment itself. In Section 4, experiment result and discussion will be provided and finally concludes the paper.

II. Related Work

Software can have various license forms. The GNU Project categorizes software as either free or proprietary [2]. Free software includes open source software, public domain software (with source), and copy left software. Proprietary software includes shareware and public domain software (without source). In addition, there are various payment models, for instance, perpetual license, pay-as-use, and donation. With the spread of SOA and cloud computing, the pay-as-use, subscription-based, and hybrid pricing models are becoming mainstream [3]. In service collaboration and cloud systems, each provider/user may constitute multiple entities. In the past, this has led to problems regarding resource pricing, cost burden, and profit sharing [4], [5]. However, there has been no research on the problem of the cost burden from the standpoint of providing services in public.
Raymond analyzed how the development of open source software (OSS) has affected the dynamic between the "gift economy" and the exchange economy [6], [7]. He said that OSS has near-zero replication costs and operates for the public good with noncompetitive consumption and non-exclusion of consumption, but the free rider problem does not occur. However, in the case of cloud services like the language grid, it is possible that the cost burden may arise. This is because the language grid is provided free of charge for non-commercial purposes only, and the cost burden is provided by the operation/provision side.
The fairness of services has been examined from the perspective of usage-sensitive charging [8], and the problems caused

by the transition of public services to competitive markets has been considered in terms of universal service obligations [9]. In both cases, the cost burden associated with services of a public nature has been a problem.

In addition, Eden and Tim developed the new ways of fund raising for a National Charity and modeled the cognitive processes involved in decision making. They showed the validity of building behavioral models using participatory games [10].

In this study, we apply a gaming simulation in a service computing infrastructure where the operation has a specified cost burden. In this way, we are able to analyze how service users participate in cost burden sharing.

III. Approach

A. Overview

Various licenses and payment systems exist for software and Web services, but well-known Web services that are provided through volunteer resources and services require some mechanism to manage the cost burden/sharing of users. Therefore, in this study, we propose donation and investment games for a machine translation service, where the service users are involved in a participatory simulation using MAGCruise [11]. Our experiment assumed service operational model which is highly public and social in nature and user behavior will be investigated by combining incentive effect, its nature as a social investment and its nature as a Donationware where the payment of compensation for use is left to the user's judgement.

B. Experimental Setup

In this experiment, the following scenario was presented to the participants.

Machine translation services are provided publicly in the language grid. There is no license fee and it is designed to be used for free. However, we ask for contributions because support is required to maintain the service. In other words, payment is not obligatory, but donations are welcome (Donationware).

The following terms help to explain the experiment.

ROUND	Each time the player acts. We define 25 rounds as one game.
SET	Five rounds with identical rules. After five rounds, the rules change.

C. Game Design

In this study, we consider five rounds to constitute one set. Five sets of games with different rules for each set give a total of 25 rounds (Table I). Subjects were organized into groups of four people. At the beginning of every round, the original sentence was displayed. Subjects received 100 tokens of the in-game currency, and determined how much to donate or invest. At the end of a round, the usage rights (return) were determined and equally divided among the players in a group, and the sum of the usage rights and the amount of money left at hand gave each player's profit. A table was displayed listing the accounts, donations, usage rights, and the translation result. From the second round, we displayed the previous result for use in the decision-making. For example, if three out of four people paid 100 tokens and one paid 20 tokens, the total investment in the group is 320 tokens. By doubling the total investment in the group and dividing by 4 people, the usage right per person is 160 tokens. A player who pays 100 tokens gains 60 tokens, but a player who pays 20 tokens gains 140 tokens(Fig. 1). The flow of the game is shown in Fig. 2.

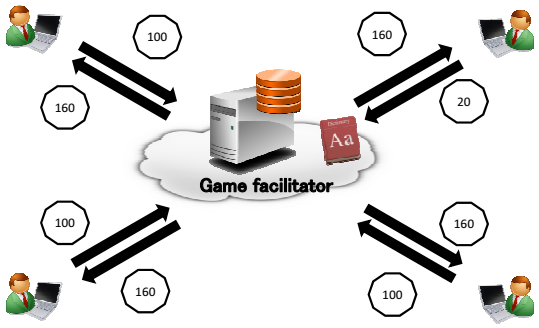

Fig. 1. Financial support game for web service management and maintenance

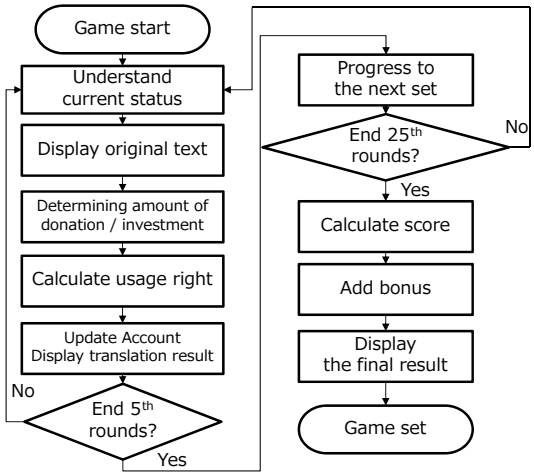

Fig. 2. Game flow

We now explain each set of the game. Sets 1 and 2 are donation games asking how much each player would like to donate to the machine translation service. Usage rights are always rewarded with 200 tokens, regardless of whether or not subjects donate and how much they give. When player i has an initial budget of 100 tokens and elects to donate g_i, the profit u_i is given by:

$$u_i = 100 - g_i + 200 \tag{1}$$

Sets 3–5 are investment games in which the usage rights change. Based on Fischbacher [12], the public goods game framework was used to design an investment game.

When player i has a budget of 100 tokens and elects to pay g_i, the profit u_i is given by:

TABLE I
SUMMARY OF ALL FIVE SETS OF EXPERIMENTS

Set	Payment(tokens)	Usage rights (token)	Use of services when there is no payment	Translation result
1	0 or 100	200	Possible	Korean
2	0-100	200	Possible	Korean
3	0-100	Total investment in group × 2 ÷ 4	Possible	Korean
4	0-100	Total investment in group × 2 ÷ 4	Possible with limited function	Chinese<English <Korean
5	0-100	Total investment in group × 2 ÷ 4	Impossible	Japanese<Chinese <English<Korean

$$u_i = 100 - g_i + 0.5 \sum_{j=1}^{4} g_j. \quad (2)$$

In sets 4 and 5, the language of the translation destination changes according to the total investment within the group. The language is Chinese when the total investment in the group is from 0–199, English when the investment is 200–299, and Korean when the investment is 300–400. For the subjects, we explain the scenario that the value of information is high if the quality of translation is good. Scores are assigned according to the quality of the translation result, with one point for the lowest quality Chinese, two points for English, and three points for the best quality Korean. At the end of the game, the bonus is determined from the sum of the scores of the translation results of sets 4 and 5. Subjects receive 0 tokens when the total is 0–5 points, 1000 tokens for 6–10 points, 5000 tokens for 11–20 points, and 10000 tokens for 21–30 points. In set 5, no translation is performed when there is no investment by the group; thus, the translation result is in Japanese, and the score is 0 points.

D. Experimentation

We conducted experiments using 32 subjects (12 people for experiment 1, 12 people for experiment 2, and 8 people for experiment 3). The group members do not know who the other members are. We recorded data for 16 groups in each experiment, as the games were repeated with different group compositions. We distributed and explained the scenario, instructed the subjects on the games, and then conducted the games. After the games were finished, the subjects completed a questionnaire. Moreover, the games were anonymous and we explained that participants did not know who was in their group to simulate donation and investment over the Internet. The game interface is shown in Fig. 3.

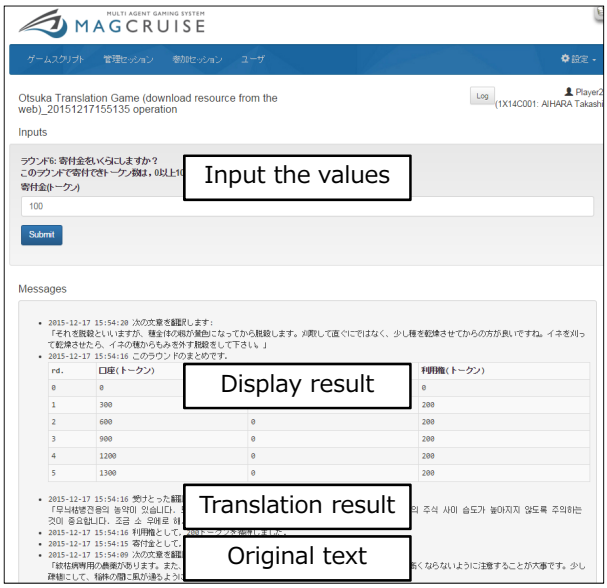

Fig. 3. Interface of experiment system

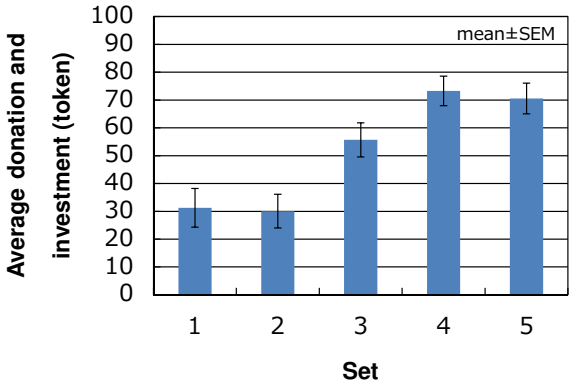

Fig. 4. Average donation and investment of all players per set (players: 32)

IV. RESULTS AND DISCUSSION

A. Average Donation and Investment of All Players Per Set

Figure 4 shows the average donation and investment behavior of all players in each set. From Fig. 4, we can see that there is no significant difference between sets 1 and 2 or between sets 4 and 5, but the other pairs differ from each other ($p<0.05$). The average value of sets 1 and 2 never exceeds 40.

B. Average Donation and Investment of Each Player Per Set

Figures 5–9 show the distribution of the average donation and investment for each set of players. Moreover, Table II show the statistics of each histogram.

In sets 1 and 2, the number of players with 0–10 tokens is the largest category (Figs. 5–9). Although there are some

players who make many donations, such as the players with 91–100 tokens in sets 1 and 2, other players invest a small amount, i.e., those with 0–10 tokens. Therefore, even under different rules, there are always players who donate and invest small amounts or who donate and invest large amounts.

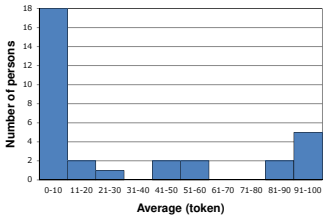

Fig. 5. Average donation and investment of each player in set 1 (players: 32)

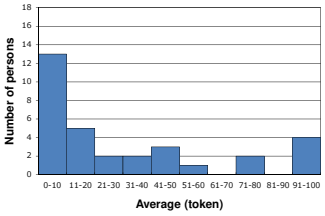

Fig. 6. Average donation and investment of each player in set 2 (players: 32)

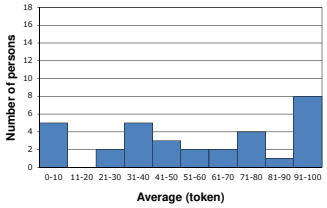

Fig. 7. Average donation and investment of each player in set 3 (players: 32)

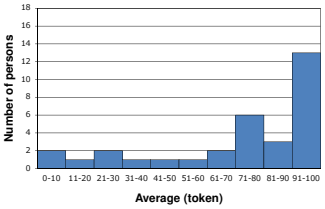

Fig. 8. Average donation and investment of each player in set 4 (players: 32)

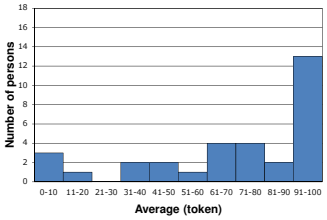

Fig. 9. Average donation and investment of each player in set 5 (players: 32)

TABLE II
THE STATISTICS OF EACH HISTOGRAM

Set	Minimum	Maximum	Average	Standard deviation
1	0	100	31.2	39.82
2	0	100	30.07	34.794
3	0	100	55.68	35.19
4	0	100	73.26	30.57
5	0	100	70.56	31.688

Table III is a frequency table of payment that the players actually paid. The class of 0–9 tokens and 90–100 tokens occupy for 77.6% from cumulative ratio as there are many players which paid 0 token or 100 tokens. The same tendency is seen also except for set 1.

C. Result of Questionnaire on Motivation for Donation and Investment

Figure 10 shows the results of a questionnaire on the subjects ' motivation for donation and investment for each set. The questionnaire was conducted after the game had finished. Set 1 was the least motivated, and set 5 was the most motivated. The number of subjects who selected 5, indicating high motivation, was smallest in set 2, and the number who chose 1, indicating low motivation, was smallest in set 4.

TABLE III
FREQUENCY TABLE OF PAYMENT

Boundary value	Frequency	Cumulative frequency	Cumulative ratio
0–9	605	605	37.8
10–19	26	631	39.4
20–29	25	656	41
30–39	17	673	42.1
40–49	24	697	43.6
50–59	88	785	49.1
60–69	24	809	50.6
70–79	92	901	56.3
80–89	62	963	60.2
90–100	637	1600	100

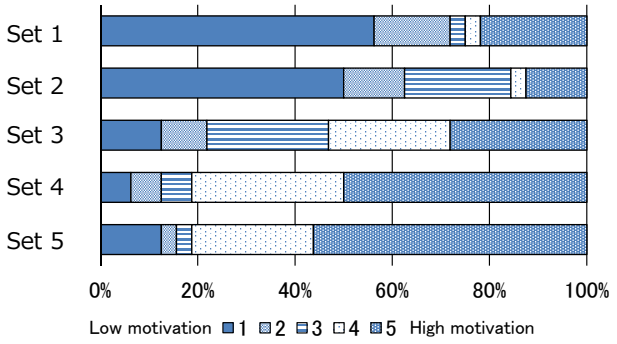

Fig. 10. Result of questionnaire on motivation for donation and investment

D. Standard deviation of each player's payment

Figure 11 is a histogram which shows the standard deviation of 28 players' payment without 4 players who always repeated the same action. Moreover, Figure 12 is a scatter plot graph. In this figure the horizontal axis corresponds to the standard deviation and the vertical axis corresponds to the average value. A player with a small standard deviation pays a similar amount stably. Conversely, the player with large standard deviation has large variation in payment amount. A player with high average value and large variance invests according to the situation. A player with a low average value and small variation is a player who does not pay stably. We list some characteristic players IV. We analyze those players in detail in the next section.

TABLE IV
CHARACTERISTIC PLAYERS

Player	Minimum	Maximum	Average	Standard deviation
3	100	100	100	-
27	0	0	0	-
6	0	75	35.16	35.134
14	0	62.5	30.2	22.348
28	72.5	100	85	10.383

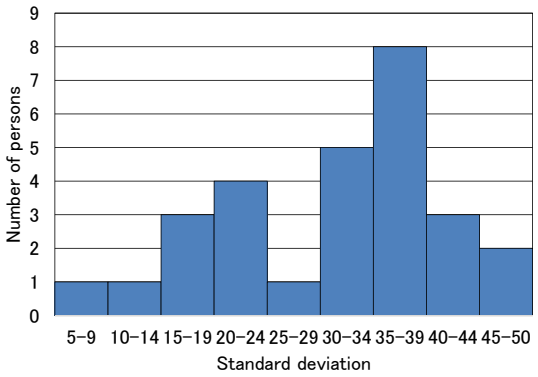

Fig. 11. Standard deviation of each player's payment (players: 32)

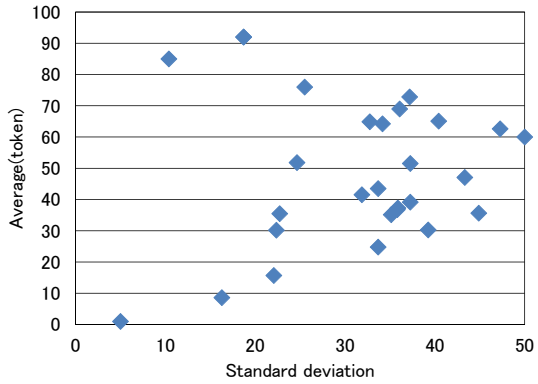

Fig. 12. Scatter plot graph with average and standard deviation (players: 32)

E. Player Behavior and Questionnaire Results

Next, Figs. 13–17 show the correlation between the players' actual donation and investment behavior and the questionnaire survey results for each set. To indicate the characteristics of different players, we named the 32 subjects P1–P32.

First, we examine the behavior of P3 and P27, whose motivation and donation/investment amount remained the same throughout the experiments. P3 always donates or invests 100 tokens. In the questionnaire, P3 stated that "I thought I'd pay for the translation service" regarding sets 1 and 2 and "I tried to maximize the profit of everyone" regarding sets 3–5. Therefore, P3 is always a cooperative player. P27 did not donate and invest any tokens throughout the experiments. P27 answered that "I tried to maximize my profit" for all sets. P27 is always an uncooperative player.

Next, we look at P6, whose motivation and donation amount are low in sets 1 and 2 but increase in sets 3–5. P6 stated that "I do not have enough money to donate" in sets 1 and 2. Regarding set 3, P6 answered "As people in the group are investing, I invested", and then, in sets 4 and 5, "I made a minimum investment to earn a bonus." This player made donations and investments according to the incentive of a bonus.

P14 is similar to P6, because the motivation for sets 3–5 is higher than in sets 1 and 2. However, the investment amount remains small. The reason for this was "Because I thought that members would not invest unless I invested." This player only pays a small amount, even though he feels motivated to donate and invest.

Finally, we mention P28, who was more motivated in sets 1 and 2 than in sets 3–5. In set 1, "I felt that investment would be doubled," he answered. In set 2, P28 donated less than in set 1, and stated that "I earn at least 100 tokens" regarding motivation. In sets 3–5, "I thought my amount doubled at least, so I kept it as high as possible. But I did not know how much other players will invest, so I tried various amounts." This player had more motivation for sets 1 and 2 because he expected reliable usage rights. This player is highly motivated to donate and invest when usage rights are always given.

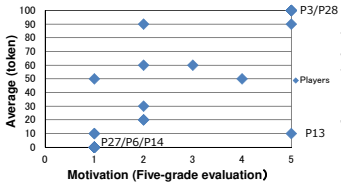

Fig. 13. Correlation between actual donation/investment behavior and questionnaire results in set 1

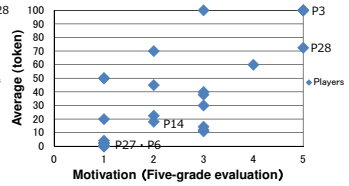

Fig. 14. Correlation between actual donation/investment behavior and questionnaire results in set 2

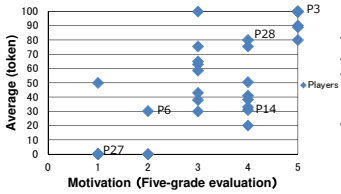

Fig. 15. Correlation between actual donation/investment behavior and questionnaire results in set 3

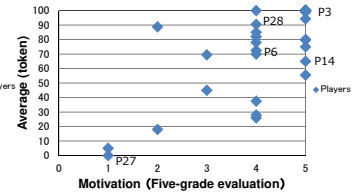

Fig. 16. Correlation between actual donation/investment behavior and questionnaire results in set 4

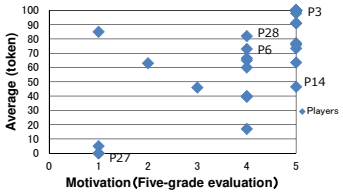

Fig. 17. Correlation between actual donation/investment behavior and questionnaire results in set 5

From the above, we classified the players into five categories.

1) Always cooperative players
2) Always uncooperative players
3) Players who donate and invest according to incentives
4) Players who only pay a small amount, even if they feel motivated to donate and invest
5) Players with high motivation for donation and investment when usage rights are always given

F. Average Donation and Investment of All Players Per Round

The table V shows the average value, standard deviation and range for each round. There is no noticeable trend in Sets

1 and 2. The significant set about the range is the set 3. It is a phenomenon that it becomes uncooperative state in iterated prisoner's dilemma game. It turns out that it is decreasing to round 4 and round 5 with peak 3 in sets 4 and 5. The difference between the set 3 and the sets 4 and 5 is considered to be due to the existence of not only teams falling into non-cooperative state but also teams in cooperative state from the middle round because of incentive. However, the last round has the lowest value even in set 5 as in set 3.

TABLE V
AVERAGE DONATION AND INVESTMENT OF ALL PLAYERS PER ROUND

	Round	Average	Standard deviation	Range
Set1	1	31.3	41.64	3.1
	2	31.3	45.35	
	3	31.3	39.66	
	4	29.7	41.85	
	5	32.8	43.27	
Set2	1	34.77	36.271	9.71
	2	30.97	35.706	
	3	29.58	37.215	
	4	25.06	35.555	
	5	29.95	39.763	
Set3	1	63.14	38.636	13.17
	2	57.08	38.317	
	3	56.94	38.209	
	4	51.3	37.918	
	5	49.97	39.457	
Set4	1	70.16	34.343	4.84
	2	73.39	32.856	
	3	75	30.953	
	4	74.91	31.91	
	5	72.86	34.077	
Set5	1	72.25	33.527	9.3
	2	73.19	31.788	
	3	74.08	32.767	
	4	68.52	35.559	
	5	64.78	38.793	

G. Three-level Player Behavioral Model

From the results, we propose the following three-level player behavioral model (Fig. 18). The motivation for the game rules is a unique value with which each player evaluates the rules of the game. It indicates payment amount for the first round. The motivation for each round changes according to the outcomes from the previous round. The motivation increases and decreases with respect to the amount determined by the motivation for the game rules. The change in motivation differs for each player. Eventually, the payable threshold is inherently linked to each player. For instance, even for a player who is motivated to pay 5 tokens, the actual payment amount may not be 100 tokens. It corresponds to the standard deviation mentioned above.

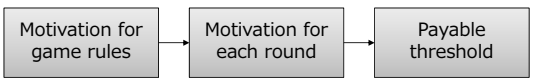

Fig. 18. Player's decision-making flowchart

V. CONCLUSION AND FUTURE WORK

This study assumed the service operational model which is highly public and social in nature, and user behavior was investigated by experimental gaming simulation combining incentive effect, its nature as a social investment and its nature as Donationware where payment of compensation for use is left to the judgement of the user. As a result, existence of users actively trying to make donations and social investment and existence of users constantly passive to this kind of act as well as existence of users oriented to free ride to other users were confirmed. Furthermore, incentive effect as a bonus was confirmed which clarified that it functions in the form of a charge back. These were summarized and five behavioral models were extracted. In the future, a system to independently restrain the behavior of free riders and a rule to bring out donation and investment behavior that will further heighten the satisfaction level of the user will be examined. To make service computing environment which is highly public and social in nature such as, for example, the Language Grid, sustainable, revision of rules will be examined so that validity of service billing structure and fairness of cost burden amongst users are appropriate as seen by the users.

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