Auction Based Resource Trading Using Relation Between Telecommunication Network Failure Rate and Users' Utility

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***Abstract*— The telecommunication services market has been greatly changed because of the significantly changing of telecommunication network technologies and corresponding users' environment. The application services on the network have become more important. As the application service platform, the telecommunication network with suitable pricing and high utility are required from users. In this paper, we aim to provide telecommunication network service with quality of service that satisfies users and social welfare. The impact of reliability of telecommunication service on users' utility is studied. The failure rate of service is important, but few studies have focused on this point. The relation between the failure rate and willingness to pay (WTP) as well as willingness to accept (WTA) are clarified through questionnaire survey. The survey results show the differences regarding the failure rate between mass and business users. In addition, we propose the method to improve the sum and average of users' utility with the auction based trading among the users when the failure occurred, and show the effectiveness of the method by the simulation.**

Keywords*— *Network, failure, user behaviour, user utility, willingness to pay, willingness to accept, pricing, auction, trading

I. INTRODUCTION

With the significantly changing of telecommunication network technologies and corresponding usage scenario, the market environment for telecommunication services has been greatly changed. The telecommunications carriers were earning revenue based on improving the telecommunication network function and providing new network service menus. Currently, telecommunications carriers need to earn revenue by not only the value of network function but also customer satisfaction by on-demand service or user support.

It is pointed out that the telecommunication network in Japan is over quality compared to the other countries. The appropriate communication charges such as the separation of devices and charges are discussed. Therefore, The MVNO service makes charges cheaper by limiting the user's bandwidth. On the other hand, large scale and wide area network failures have caused large social impacts. Thus, a network service that can provide a comfortable environment for the application services with appropriate charges. Therefore, the network reliability is also important.

The telecommunications network service consists of multiple parameters. For example, there are bandwidth, latency, recovery time, service lead-time, layer type, and optional services. The user satisfaction largely depends on the quality of the network elements affect the application service. The important parameters of network services depend on not only the characteristics of the application services but also the purpose of use.

The user's satisfaction with a network service is subjective and cannot be measured directly. However, it is possible to evaluate it relatively. Therefore, there is a method to evaluate the satisfaction of the service with monetary valuation. The Contingent Valuation Method (CVM) is known as the method of asking the willingness to pay (WTP) by users. WTP is the amount of money that the user can pay if his/her can benefit from the service. Thus, WTP is used as a measure of users' utility [2]. The reports of the relation between network service and user's utility with focused on bandwidth were proposed [3,4]. Moreover, the maximisation of users' utility for corporate users who are more sensitive to service quality than ordinary people is proposed [5,6].

Bandwidth is an important factor. However as mentioned, because of the importance varies depending on the application service, the reliability is also important. The methods for evaluating the reliability of the network services, the failure frequency evaluation method for networks, were proposed [7]. In addition, the rating scale of reliability, the studies of social loss evaluation [8,9], were proposed. These previous studies on reliability showed important aspects in the network service provisioning and are useful.

In this paper, we focus on user utility for reliability. In particular, to analyse the effect of the failure frequency of the network service on the user utility, the user's WTP and WTA (Willingness To Accept) are evaluated. WTA is "How much do you want to receive if you lose benefits." It is the price want to receive to use lower quality services than currently used. It is adapted to evaluate the utility of telecommunication services. Section 3 shows the outlines of the questionnaire for leading the user's utility function and failure frequency. Section 4 describes the function of failure frequency and the user's utility (WTP and WTA), and shows the characteristics of differences in mass users with business users, and also describes the tendency of WTP of business users. Section 5 shows the resource trading method and using auction based on the survey results, Section 6 describes the simulation results of the proposed method, Section 7 shows conclusion.

II. Questionnaire Survey on Failure Frequency

In this paper, the relationship between the user's utility and the failure frequency in wired network users is shown by questionnaire survey. The questionnaire survey consists of two stages. We hypothesise that the tendency of the requirement for the communication quality differs depending on the purpose of use, and compared and evaluated personal use (mass user) and work use (business user).

First, the whole users of the wired network are set as the population of users and analysed the ratio of the tendency. The majority of the mass users in this questionnaire evaluated. In this questionnaire, among the number of valid responses 111, 93 of wired network users are analysed. 93 wired network users include 90 for personal use and 3 for work use. This questionnaire response is not biased because the percentage is close to the telework users' percentage of 3.4% according to the survey [10]. Next, in order to evaluate the differences in the characteristics of business users, the survey was conducted by limiting the wired network to the n = 104 business users who are using at work. The questionnaire has the following questions, the amount paid, satisfaction, failure frequency, failure time, importance of applications, tolerance to failure, needs for the high-quality or low-quality network services, additional or discount fee for using the high-quality or low quality network services

This questionnaire shows 23.7% of users want to use high-quality service, 6.5% want to use low-quality service, 64.5% want to determine the balance of quality and charge. Therefore, the result shows a certain needs of high-quality service with an additional fee and low-quality service with discount fee. The payment rate when using high-quality service and the acceptance rate when using low quality service are collected.

III. Result of Survey on Users' Utility

From the results of this questionnaire survey, we estimated the WTP function and WTA function of the network service for the failure frequency. The MOS (Mean Opinion Score) value is the average of user charges at failure frequency. In addition, the users whose current contract fees are significantly different from the Internet connection fee model case [11] are excluded. WTP function and WTA function of mass users and business users are estimated by using the least squares method to MOS values. The linear, logarithmic, exponential approximation and power approximation are used as regression equations. The contribution rates are shown in Table 1.

TABLE I. Contribution Rates of WTP/WTA Function

	WTP		WTA	
	Mass	Business	Mass	Business
Linear	0.81	0.87	0.84	0.85
Logarithmic	0.99	0.99	0.95	0.95
Exponential	0.83	0.88	0.89	0.92
Power	0.98	0.99	0.92	0.90

This table shows the logarithmic approximation is maximum for all functions. Thus, the WTP function and the WTA function should be estimated by the logarithmic approximation. Both WTP function and WTA function can be described by failure frequency *f*.

$$W(f) = -a \times ln(f) + b \quad (1)$$

IV. Comparison of User Characteristics

WTP and WTA function have been estimated in Section 3. In addition, we analyse the payment rate when using high-quality service and the acceptance rate when using low-quality service. The questionnaire asked the rate which the user wants to pay an additional fee (premium rate) when the failure frequency decreased by about one digit comparing with current contract fee, and also the rate which the user wants to accept discount fee (discount rate) when the failure frequency increased by about one digit. the comparison is shown in Figure 1.

This analysis shows different characteristics between mass users and business users at the premium rate and discount rate. In the viewpoint of WTP, Business users tend to pay an additional fee in decreasing failure frequency than mass users. This means the business users can admit the premium rate to improve poor quality situations. Furthermore, in the viewpoint of WTA, Business users tend to request more discount fee in increasing failure frequency than mass users. This means the business users cannot accept to deteriorate quality situations.

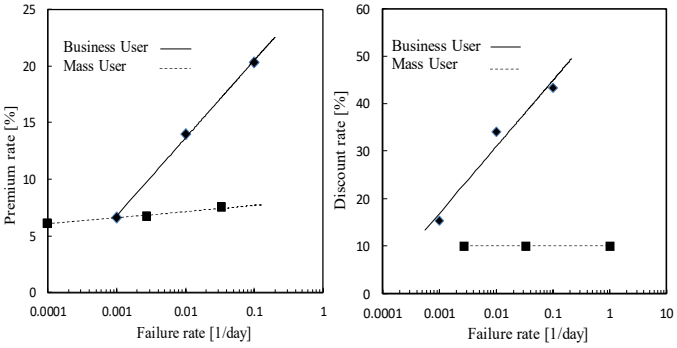

Fig. 1. Premium rate and Discount rate.

We also compare with low, middle and high quality in business users. Figure 2 describes the business user's WTP when adapting the premium rate and discount rate for the business users using high-quality, middle-quality and low-quality services. This figure shows that the user using high-quality services requests larger WTA when using low-quality services than the user using low-quality services. This tendency is considered to have a great influence on service selection.

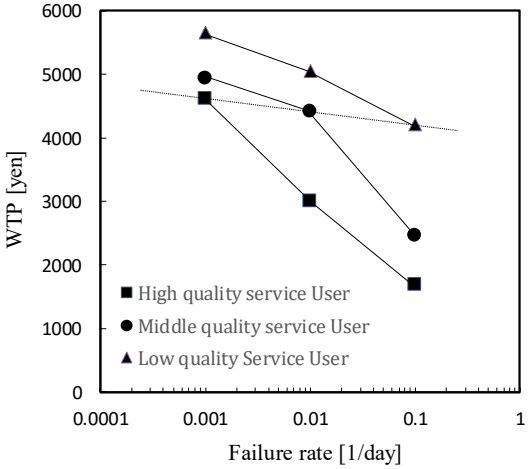

Fig. 2. WTP and service quality.

V. AUCTION BASED RESOURCE TRADING

In this section, to suppress the decrease in users' utility, the method of trading the network service vacancy between users when a failure occurs in the network service is discussed. the user's utility change depends on their conditions. For instance, in the difference between the characteristics of mass users and business users, the business users place importance on the quality of working hours, but mass users place importance on the quality from evening to night. Thus, the users do not desire high quality throughout the day, their needs also depend on the time and applications. Therefore, it is possible to optimise the service quality and the users' utility by providing the architecture of trading services at appropriate timing for various users with the different quality requirement. In this paper, we propose applying an auction mechanism for fair and efficient trading among users when a failure occurs.

The auction requirements to apply in the failure situation are real-time and instantaneous transactions so that simultaneous and sealed auctions are needed. Additionally, due to competition among users for the tradable capacity, single unit and multi good auctions are a requirement. There are various auction mechanisms. In this paper, we apply First Rejected bid Auction (FRA) and Double Auction (DoA) which satisfy the above requirements [12, 13].

The simulation targets two types of services, high-quality service and middle-quality service, and simulates the users' utility when the network service failure occurs. The network model is a single carrier in order to evaluate the users' utility by trading between users. Let us consider the network capacity of high-quality service and the middle-quality service. n_{ch} is the total number of the capacity of high-quality service and n_{cm} is also total number of capacity of middle-quality service. Let n_h and n_m denote the number of users using the high and middle-quality service. WTP/WTA and premium/discount rates apply to the above questionnaire results. In addition, let p_{my} denote a probability value that the middle users can release their resource for reasons such as not using the service when a failure occurs. The simulation is under the situation that high-quality service cannot be used due to a failure, and the utility of the user is evaluated. As evaluation targets, Let U_{total} and U_{ave} denote the sum of users' utility and the average of users' utility:

$$U_{total} = \sum_i^H U_{hi} + \sum_j^M U_{mj} \tag{2}$$

and

$$U_{ave} = \frac{\sum_i^H U_{hi} + \sum_j^M U_{mj}}{n_h + n_m} \tag{3}$$

For evaluation, the situation A is NOT using the auction WITH switching between services, B is using FRA and C is using DoA.

A: NOT using the auction

As switching between services when high-quality service failure occurs, this situation assume to switch the high-quality service users to middle-quality service unconditionally. If the availability of the middle-quality service is sufficient, middle-quality users will not be affected. However, if the availability of the middle-quality service is insufficient, the shortage of middle-quality users will not be able to use service. Let n_s denote the shortage of middle-quality users. In addition, p_{my} is a probability value that the middle-quality users can release. Therefore, $(1 - p_{my})n_s$ middle-quality users will not be able to use the service against their will. In this situation, U_{hi} and U_{mj} as follows:

$$U_{hi} = WTP_m + \Delta WTP_{m \to h} \tag{4}$$

and

$$U_{mj} = \begin{cases} WTP_m & \text{if user m not release} \\ -(WTP_m - WTP_l) & \text{if user m can release} \\ -\Delta WTA_{m \to l} & \text{if user m not want to release} \end{cases} \tag{5}$$

B: Using FRA

As switching between services when high-quality service failure occurs, this situation assume to trade the high-quality service users to middle-quality service with FRA. All user participates in FRA, and goods are the shortage of middle-quality services. FRA is a sealed-bid auction, and the price is the second highest bid. If a number of goods is N, it is allocated to N bidders, and the price b_p is the $N+1$ highest bid. In addition, in the case of $N = 1$, it becomes second-price sealed-bid auction. In this situation, U_{hi} and U_{mj} as follows:

$$U_{hi} = \begin{cases} WTP_m + \Delta WTP_{m \to h} & \text{if user h not bet} \\ WTP_m + \Delta WTP_{m \to h} - b_p & \text{if user h won} \\ 0 & \text{if user h lost} \end{cases} \tag{6}$$

and

$$U_{mj} = \begin{cases} WTP_m & \text{if user m not release} \\ WTP_m - b_p & \text{if user m won} \\ -(WTP_m - WTP_l) + b_p & \text{if user m lost and can release} \\ -\Delta WTA_{m \to l} + b_p & \text{if user m lost and not want to release} \end{cases} \tag{7}$$

C: Using DoA

Same as FRA, this situation assume to trade the high-quality service users to middle-quality service with DoA. DoA is an auction of buying and selling goods. When the buyer bid is higher than the seller bid, the auction is concluded. The high-quality users bid as buyers b_{hi}, the middle-quality users bid as sellers in s_{mj}.

Let $b(1) \geq b(2) \geq \cdots \geq b(n_h)$ be ascending order of b_{hi} and $s(1) \leq s(2) \leq \cdots \leq s(n_m)$ be descending order of s_{mj}. when $k = \text{argmax}\, b(k) \geq s(k)$ is the conclusion of the auction,

$$b_p = (b(k-1) + s(k-1))/2 \tag{8}$$

In addition, the users' utility is the same as FRA.

VI. Simulation Results

The number of high-quality service users is variable for this simulation. This simulation also adopts WTP and WTA function that are led in this paper. Figure 3 shows the comparison of the average of all users' utility among NOT using auction (normal) and FRA/DoA. Figure 4 shows also the comparison of the sum of all users' utility. These figures are led by using parameter at p_{my} as 0.1, 0.2, and 0.3.

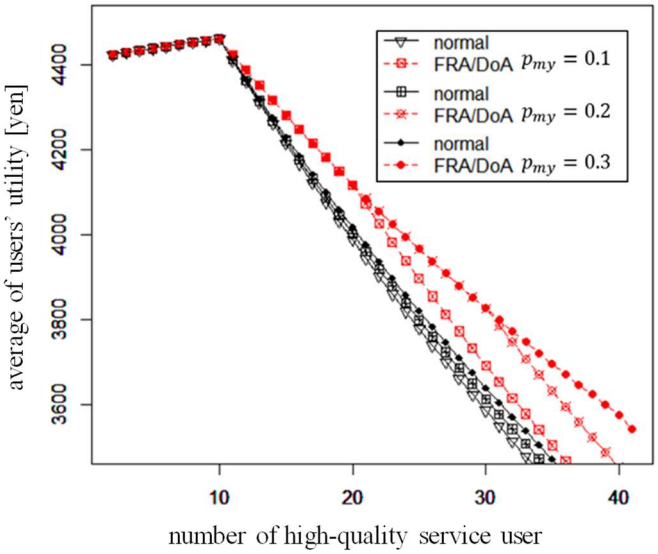

Fig. 3. Average of users' utility.

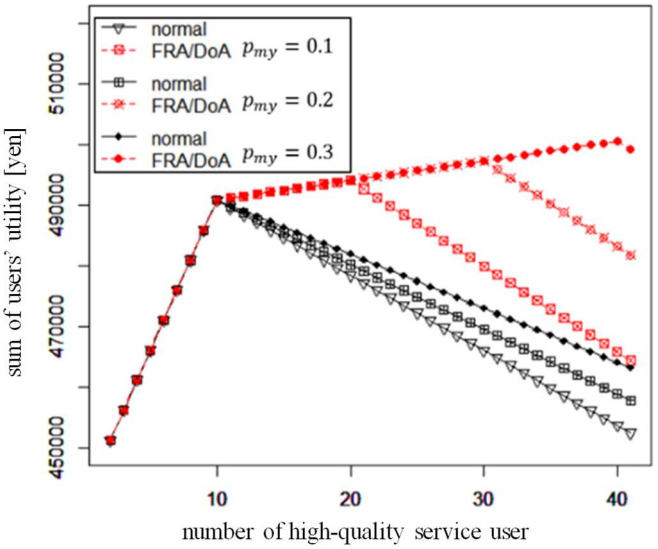

Fig. 4. Sum of users' utility.

According to this simulation, the auction method between users has a higher average of users' utility than the method without the auction. In addition, the auction has a higher sum of users' utility than without the auction. the result is due to the two points. The first point is high-quality users are relieved. The second point is the difference of the middle-quality users' utility. When the vacancy of middle-quality services is not enough, a part of middle-quality users have to release their resource, some users who do not want to release is greatly reduced their utility in the NOT using auction. Because there is no means to judge whether the user can release or not. Therefore, this leads to a decrease users' utility with probability $(1 - p_{my})$.

On the other hand, with the auction mechanism, the user's situation whether the user can release or not can be judged by the bid price in the auction. Therefore, the loss of users' utility can be minimised by using the auction. In addition, there is no difference in the users' utility between FRA and DoA because the utility offsets the auction bided price.

VII. Conclusion

In this paper, we proposed the relation between failure frequency and user's utility (WTP and WTA) in reliability, which is an important aspect of quality in network service by the questionnaire survey. Moreover, the important view of the difference between the characteristics of mass users and business users for failure frequency is shown. We proposed the method to improve the sum and the average of users' utility with the auction trading among the users when the failure occurred and the simulation showed the effectiveness.

This result shows the useful architecture that the trading between users improves the users' utility from the viewpoint of reliability. This architecture can be adapted in an environment where multiple carriers provide various network services. As future work, we will evaluate multiple carriers, service types and quality variations. We will also consider the automatic trading architecture for maximising users' utility with estimating the required quality when the failure occurs.

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