Study on relationship between user awareness and QoE in communication delay on smartphones

Study on Relationship between User Awareness and QoE in Communication Delay on Smartphones

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***Abstract*—Network delay may occur on the LTE (Long Term Evolution) network due to signaling spikes. This decreases quality of experience (QoE). In this paper, we propose a method for mitigating the effect of such a delay. Our method acts as "a concierge" to divert the attention of users away from delay. The biggest advantage of our method is that it can be implemented at lower cost (e.g. capital investment) compared to other methods. To evaluate our method, we conducted a comprehensive user experiment using crowdsourcing. The results show the effectiveness of our method.**

Keywords— smartphones, communication delay, QoE, cognitive psychology

I. INTRODUCTION

Smartphones (hereafter called "terminals") that can be connected to a high-speed mobile networks such as LTE (Long Term Evolution) wireless communication system, are becoming widespread. When a terminal communicates through the LTE network, the control signal is generated in the LTE network for the allocation of radio resources. The control signal, which is generated each time a terminal connects to the LTE network, has increased due to the rapid spread of smartphones. When the control signal exceeds the design capacity of the LTE network, even momentarily, the quality of the LTE network deteriorates [1]. In addition, there are cases in which communication timing is synchronized between a large number of terminals because some smartphone applications communicate to check for updates and messages at the determined time regardless of the user's operation. In such a case, a large number of terminals will connect to the LTE network at the same time, generating a large amount of control signals. Such occurrence of instantaneous congestion of control signals is called "signaling spikes" and is a serious problem that adversely affects the entire LTE network [2][3].

Carriers are investing capital in accordance with the maximum control signal flow so that a control signal spike will not occur. However, irregular situations, such as events at which a large amount of people gather, cannot be supported. In fact, such a situation often occurs [4]. There are methods for preventing communication degradation by further capital investment or financially compensating the user. However, both methods incur further cost. To solve these problems, we previously proposed a method [5] (called "UE-based Network Access Timing Control Scheme (UENAC)") for distributing the timing at which the control signal is generated by applying a short random delay in each terminal so no signal congestion will occur in an entire network. The delay applied with UENAC is up to 8 seconds. Through simulation, we showed that this method can suppress control signaling spikes.

UENAC is a method, which is effective for suppressing signaling spikes; however, it affects the user quality of experience (QoE) due to communication delay applied to each terminal. In this paper, in view of the fact that user QoE is highly dependent on communication quality, we propose and evaluate a method for mitigating the decrease in QoE due to communication delay at low cost. An interesting point of our method is that it is based on the psychological aspects of a user. Specifically, it diverts the attention of a user away from communication delay.

The proposed method is implemented as a concierge-style service. The concierge-style service has ever been used in the existing operating systems of PCs and smartphones to provide a better user support. The concierge is an animated character displayed on the terminal screen who helps a user by telling useful information to the user whenever the operating system assists the user. The idea of our method is that when a communication delay occurs, the concierge says something to the user. This can divert a user's attention away from the communication delay, and thus decrease in QoE is expected to be avoided. We evaluated the effectiveness of the proposed method through an experiment involving the crowdsourcing of 400 people.

The rest of this paper is organized as follows. We discuss related work in Sect. II and explain our proposed method in Sect. III. In Sect. IV, we explain the experimental method. In Sect. V, we describe in details the experimental results and discuss the efficiency. Finally, in Sect. VI, we present our conclusions.

II. Related Work

A. Delay Impact on Users

In this section, we introduce previous studies that investigated the impact of communication delay on users.

According to a survey conducted by SmartBear Corporation, 3 seconds is the allowable range of user waiting time on a Web site [6]. If the Web site does not display within 3 seconds, 57% of users will give up on viewing the site. In addition, a waiting time increase of 1 second will decrease the number of views by 11% and user satisfaction by 16%. For mobile sites, this trend has become even more pronounced: 60% of users expect something to be displayed within 3 seconds. If the Web site does not within 5 seconds, 74% of users will move to another site.

Kuo et al. [7] designed a model in order to evaluate service quality of mobile value-added services. By using this model, they discussed the relationships among service quality, perceived value, customer satisfaction, and post-purchase intention. The results showed that service quality had a positive impact on customer satisfaction, in particular, the three dimensions of service quality ("customer service and system reliability", "content quality" and "connection speed") had significantly positive effects on customer satisfaction. Judging from this, it is confirmed that communication delay is one of the major concerns for user satisfaction.

Nishioka et al. [8] reported on survey results about the structure of "sense of trust", or "*anshin*", of users without technical knowledge during online shopping. "Perceived benevolence", "Perceived competence and integrity", "User impression", and "Perceived reputation of the company provided by a third party" has been cited as factors of *anshin*. A link between "Perceived competence and integrity" and *anshin* shows that a user feels *anshin* toward the site when he/she has subjectively determined that the site is competent. The user may deduce that the capital investment of the site is insufficient (lack of competence) due to communication delay, so there is a possibility that communication delay decreases a user's *anshin*.

B. QoE evaluation

Recently, QoE has been viewed as an important evaluation index of network quality in addition to quality of service (QoS).

Yamazaki et al. [9] investigated the effect on QoE on the mental state of users. They reported the results of QoE evaluation regarding the delay that occurs during a Web game that involves users solving a simple math problem. They changed the mental state of participants by classifying them into the following three groups: one that plays the game with time constraints (Pressured situation), one that plays the game while watching a news program (Relaxed situation), and a Control group (Normal situation). The added delay times were from 0 to 8, 10, and 12 seconds. As a result, the QoE of the Relaxed situation decreased less than that of the Pressured and Normal situations. This result indicates that QoE evaluation changes depending on the psychological state of the user.

C. Interface for Mitigating Effects of Delay

A progress bar that visualizes communication progression is said to be effective to mitigate the decrease in QoE due to communication delay. A previous study [10] investigated three different types of progress bars, one with a single color, one with changing colors, and one that displays an animated wave pattern. They found that the animated bar puts the least amount of stress on users.

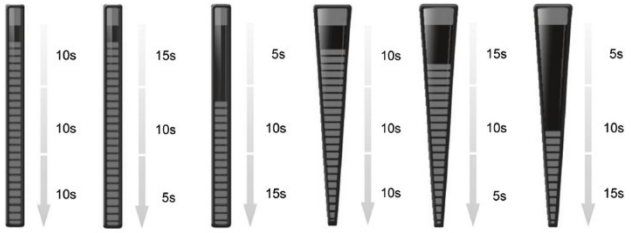

Fig. 1 Progress bar of design used in experiment [11]

Zhang et al. [11] reported on the results of investigating the change in a user's perception of time by using different shapes and display speeds of progress bars. Figure 1 shows the designs used in their experiment. The number written next to each design denotes speed. For example, in the second design from the left, display speed of the first one-third of a bar is 15 seconds, the next one-third is 10 seconds, and the last one-third is 5 seconds. As a result, the user changed his/her perception of time. The second design from the right was rated as the best design for giving the impression of shortened delay.

In the above studies, however, the user perceived that there was a delay. To maintain a high QoE, we argue that it would be more effective if a user does not notice any delay. Hence, we propose a method that involves diverting user attention away from delay.

III. Methods for Mitigating Decrease in QoE

Communication delay adversely affects QoE. Therefore, it is important to develop methods for mitigating the decrease in QoE due to communication delay. In this section, we introduce a conventional method that involves financially compensating users (called the "compensation method"). We also introduce our proposed method, which diverts user attention away from communication delay (called the "proposed method").

A. Compensation Method

When a communication disturbance occurred in the past in Japan, 700 Japanese yen was paid to the user as compensation [12]. We carried out an experiment to evaluate the adequacy of the compensation method and it has been confirmed through the experiment that a compensation can become an incentive for users to forgive communication delays [13]. Communication delay will decrease the user QoE, but the compensation method can make up for the degraded QoE due to communication delay. Needless to say, this method is costly due to it involving financially compensating users.

B. Proposed Method

For QoE degradation problems due to communication delay, we propose a method based on the psychological aspects of users. Specifically, the method involves diverting the attention of users away from communication delay by displaying "text the user would pay attention to" on the terminal screen while communication delay occurs. By diverting a user's attention

Fig. 2 Image of concierge

from communication delay, decrease in QoE is expected to be avoided and therefore no compensation is required. In addition, this method can be implemented at low cost since it involves only displaying text.

Since the proposed method involves diverting a user's attention from communication delay by displaying text, it is necessary to make a user want to read the text. We created an interface that displays an illustration of a concierge telling to the user. Since the use of illustrations is known to provide users with motivation to read a text [14], we expect that the user will read the text spontaneously.

We illustrate the image of the concierge used in this study in Figure 2. The text that simulates the speech of the concierge contains trivia ("Cats Day" in Japan is on February 22. It was enacted in 1987). It should be noted that the concierge will talk to the user not only when communication delay occurs but also in a variety of situations. Otherwise, if the concierge tells to the user only when communication delay occurs, the user would know by the appearance of the concierge that a delay has occurred.

IV. Experimental Research

A. Purpose

The purpose of this experiment was to evaluate the effectiveness of the proposed method (whether the concierge can mitigate the decrease in QoE due to communication delay). We compared it with the compensation method.

B. Overview

We created a Web page for the experiment. By adding a delay to page switching within the Web page, it reproduced the occurrence of communication delay. We conducted the QoE evaluation with this Web page.

In this experiment, we created four participant groups as shown it below.

1. Without delay and without the method (called "No delay group")
2. Occurrence of a delay and without the method (called, "No method group")
3. Occurrence of a delay and with the compensation method (called, "Compensation group")
4. Occurrence of a delay and with the proposed method (called, "Proposed method group")

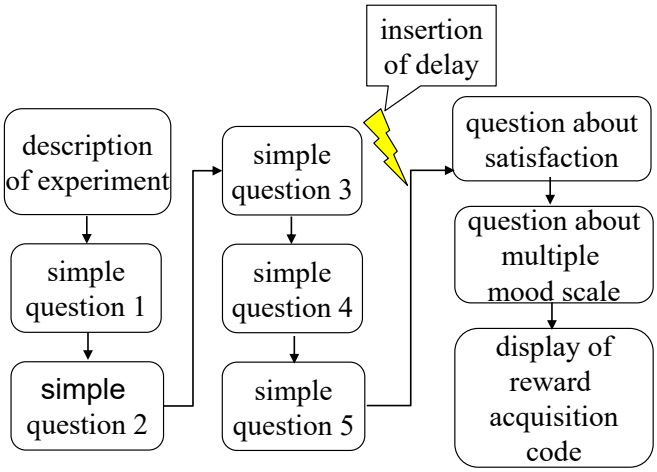

Fig. 3 Flow of experimental Web page

Table. 1 Number of participants involved in analysis

		No delay	No method	Compensation	Proposed method
All participants		83	96	95	96
Gender	Male	36	41	36	41
	Female	47	55	59	55
Usual communication satisfaction	Satisfaction	55	60	58	64
	No satisfaction	21	26	23	23
Interruption frequency on YouTube	No	26	28	32	32
	Yes	54	63	56	57
Internet knowledge	Low	22	39	28	33
	High	25	21	31	15

The behavior when the communication delay occurred in each group was different. In the Proposed method group, the concierge and the text were displayed (the concierge appeared and spoke to the participant) during the communication delay. In the compensation group, nothing was displayed during the communication delay. However, after the delay has elapsed, the compensation amount was displayed for the delay along with an apology. Because the No delay and No method groups are respective control groups, there was no special display.

We carried out a between-participant experiment so as not to have a bias of QoE evaluation from the experiences in each method. To prevent the bias of the QoE evaluation by experience of past communication delay, there was only one communication delay that occurred during the experiment for each participant.

C. Participatants

Four hundred participants were gathered through Lancers [15], which is a Japanese crowdsourcing service. We asked the participants to browse the Web page we have created. When the task is completed, the reward acquisition code is displayed at the page. The reward was payed to participants with the code. We set the reward of the task for the all groups to 80 yen and the compensation amount for the Compensation group to 20 yen. We explained to the participants that the task is an experiment for academic purposes.

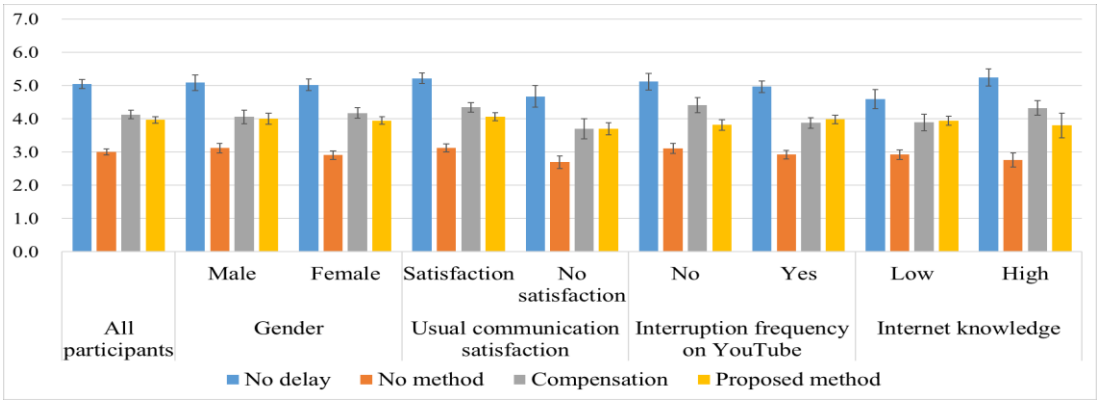

Fig. 4 Means and standard errors of satisfaction level

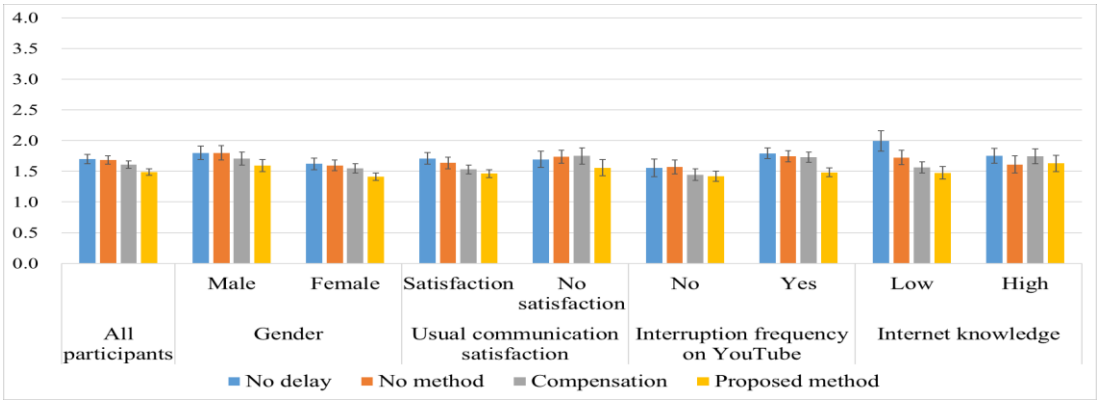

Fig. 5 Means and standard errors of "Hostility"

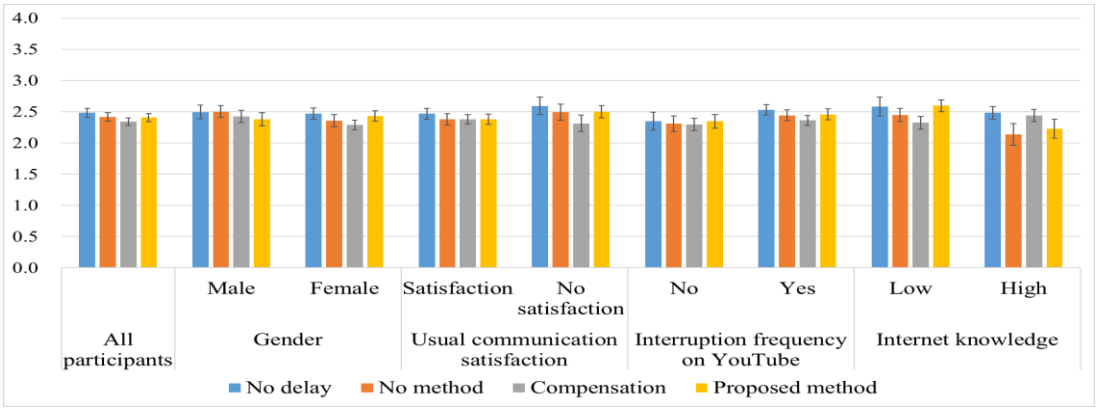

Fig. 6 Means and standard errors of "Boredom"

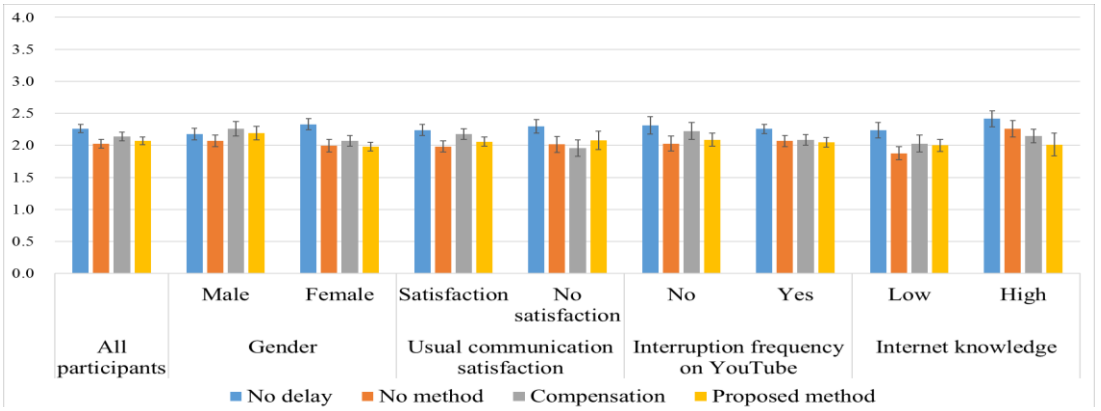

Fig. 7 Means and standard errors of "Liveliness"

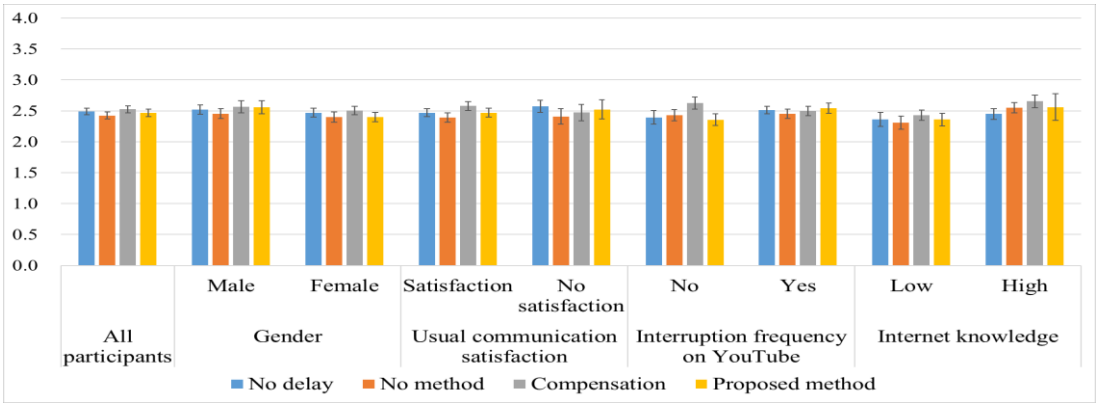

Fig. 8 Means and standard errors of "Concentration"

D. Experimental Web Page

The web page used in the experiment was created using HTML, JavaScript and PHP. The page was composed of nine pages. Figure 3 shows the transition flow of the experimental Web page. First, there was a description of the experimental page, followed by five questionnaire pages containing simple questions. If a participant is in the Compensation and the Proposed method group, when the participant answered the fifth question, a 10-second delay was applied during the transition to the next page. Then the participant answered the question regarding his/her satisfaction and the multiple mood scale. In the final page, the reward acquisition code was displayed and the experiment ended.

Five questions in the questionnaire pages in this experiment are as follows.

1. Age (Teens or less, 20s, 30s, 40s, 50s, 60s or above)
2. Gender (Male, Female)
3. Are you satisfied with the communication speed in your daily smartphone use? (Dissatisfied, Moderately dissatisfied, Neutral, Slightly satisfied, Satisfied)
4. When you view YouTube (or the other video hosting service) with a smartphone in your daily use, how often are the videos interrupted? (Never, Not very often, a little time, Sometimes, Most of the time, Don't use)
5. What is your Internet knowledge level? (1: novice, 2, 3, 4, 5, 6, 7: expert)

Questions 1 and 2 ask for basic information of the participant. The purpose of questions 3–5 is to ask for information about his/her smartphone use. The QoE will be relative to daily experience, so Question 3 and 4 ask for the usual transmission quality of each participant's smartphone. The QoE may be affected by technical knowledge level [16], so Question 5 asks for the level of each participant.

For the No method, the Compensation and the Proposed method group in this experiment, 10-second delay was applied during the transition from the fifth question page to the next page. According to a previous study [6], this delay length is "enough to hate" for people and hence all the participants will be frustrated with the 10-second delay. It is noted that the participant's smartphone downloaded the data of all the experimental Web pages at the start of the experiment, and then the Web pages give the participants the impression of actually browsing the Internet by adding a short delay to page switching. This experimental setting is to eliminate the difference in the transmission speed of the Internet communication between participants, and we set the short delay during page switching to 0.4 second expect for when the 10-second delay was inserted.

When a participant answered Question 5, the next page was for a question regarding his/her satisfaction. The participant was asked to evaluate how much he/she was satisfied with the communication speed in the browsing of the experimental Web pages. The participants evaluated their satisfaction on a 7-point scale (very bad, bad, slightly bad, fair, slightly good, good, very good). In addition, to carry out a more detailed analysis of satisfaction, another page for answering the multiple mood scale [17] was displayed to the participants. The multiple mood scale is originally designed to evaluate eight emotion moods, but this experiment used four moods to reduce participants' burden. We used the four emotion moods of "Hostility", "Boredom", "Liveliness", and "Concentration" since they are likely to be related to communication delay emotions. The participants were asked to evaluate how much they feel each emotion mood on a four-point scale (don't feel at all, don't feel too much, feel a little, definitely feel).

V. Experimental Results and Discussion

A. Classification of Participants by Attribute

To analyze the satisfaction level by attribute of participants, we classified participants according to their answers of Questions 1-5. The classified attributes are shown below. Each number shown below corresponds to the question number given in Section IV.D. We did not classify participants by age since most who participated were in their 30's.

2. Gender: "Male" and "Female"
3. Communication satisfaction: "Satisfaction (Slightly satisfied, Satisfied)" and "No satisfaction (Dissatisfied, Moderately dissatisfied)"
4. Interruption frequency on YouTube: "No (Never, Not very often)" and "Yes (a little, Sometimes, Most of the time)"
5. Internet Knowledge: "Low (1 to 3)" and "High (5 to 7)"

Since "Neutral" in Question 3 and "4" in Question 5 are neutral answer, we excluded them in the classification. Since

"Don't watch" in Question 4 is N/A (not-applicable), we also excluded it in the classification.

B. Exclusion of Improper Answers

For accurate analysis, we excluded participants who gave an improper answer based on the following three criteria. Table 1 shows the number of participants after exclusion.

- Participants answered the degree of satisfaction with the communication speed with respect to the browsing of the experimental Web pages but to their daily Web page browsing.
- Participants gave reasons that involved factors not related to the experiment
- Participants contradicted their satisfaction and reasons (e.g., answered "Satisfied" but gave a negative reason).

C. Means and Standard Errors

In this experiment, satisfaction level was quantified for analysis as follows: {very bad, bad, slightly bad, fair, slightly good, good, very good} = {1,2,3,4,5,6,7}. In the same way, degree of each emotion factor on the multiple mood scale was quantified for analysis as follows: {don't feel at all, don't feel too much, feel a little, definitely feel} = {1,2,3,4}. Figure 4 shows the means and standard errors of satisfaction level for each attribute, and Figs. 5-8 show the means and standard errors of each emotion factor for each attribute.

D. Effectiveness

We conducted an analysis of variance (ANOVA) to analyze the difference between the average satisfaction level of each group. To determine the effectiveness of the proposed method, we conducted a one-way ANOVA for each group and a sub effect test (multiple comparison of Ryan) using the data of all participants. The ANOVA and sub effect test used ANOVA4 on the Web [18]. The significance level was set to 5%.

Table 2 lists the results of the analysis. The results show the satisfaction levels for the Proposed method group and Compensation group are significantly higher than that for the No delay group and No method group. Hence, the proposed and compensation methods were verified to mitigate the QoE degradation caused by communication delay. Furthermore, since the Proposed method group differed non-significantly from the Compensation group, we suggest that the effect of the proposed method is equivalent to pay the compensation.

E. Comparison with Compensation Method

To compare the proposed method with the compensation method, we conducted a two-way ANOVA on "the satisfaction and emotion factor levels of participants" and "each attribute classified in Section V.A".

We carried out a two-way ANOVA using the data of all the groups. However, we could not confirm the significance between them. So, we attempted to analyze using only the data from the Proposed method group and Compensation group. The results suggest the following two interactions: between the satisfaction and interruption frequency on YouTube and between "Boredom" and Internet knowledge. Table 3 shows the results. After conducting a simple main effect test, we found the following.

I. With the compensation method, the participants who experienced less interruption on YouTube had a high degree of satisfaction. [F (1,173)＝(4.849), p=.029]

II. For participants who experienced less interruption on YouTube, the compensation method provided a higher level of satisfaction than the concierge method. [F (1 ,173) ＝(6.057), p=.015]

III. In the concierge interface, the participants whose knowledge of the Internet was low felt "Boredom" more. [F (1 ,103)＝ (5.110), p=.026]

From I and II, we can assume that participants who experienced less interruption frequency on YouTube (i.e., participants with higher communication speed in their daily life) likely to feel higher satisfaction by receiving compensation. In other words, it is assumed that if users are accustomed to higher communication speed, such persons would tend to seek bigger compensation from experiencing communication delay. This means that capital investment of the carrier can make users more sensitive to communication failure. However, if the carrier does not invest capital, it is apparent that it will lose its competitiveness with other carriers. To address the inconsistency between capital investment and maintaining user QoE, we argue that making the user not feel a delay, such as with the proposed method, is effective.

For III, we assumed that the participants with little Internet knowledge expected that the concierge (artificial intelligence) can perform something more advanced. Hence, we speculate that they felt stronger "Boredom" with the concierge telling about only trivia.

It should be noted that we could not confirm the significance by analysis using the data of all the groups. Since the discussion of this section is based on the data analysis of only the Proposed method group and Compensation group, there is not enough evidence for the above conclusion. In the future, we plan to carry out an additional experiment to confirm that the above analysis results are reasonable.

F. Consideration of optimal investment

Currently, LTE carriers are investing capital in accordance with the maximum usual control signal flow to prevent a decrease in user QoE due to signaling spikes. We believe that it is possible to carry out capital investment more efficiently by combining it with the proposed method.

It is clear that a suppression in capital investment decreases communication quality and the user QoE. We argue that the proposed method, which diverts user attention away deterioration of communication quality, can be an effective alternative to mitigate the QoE degradation. That is, if the reduction in communication quality within a range that can distract the user's frustration with the proposed method, we can expect to maintain user QoE even if the communication quality is reducing by suppressing capital investment.

Table 2 Analysis results of satisfaction for all participants

Group	Means	Standard errors	ANOVA		Multiple comparison		
			F-value	p-value	vs B	vs C	vs D
A.No delay	5.048	0.140388	F(3,366)= 51.278	0.000****	significant	significant	significant
B.No method	3.000	0.095428			-	significant	significant
C.Compensation	4.126	0.125682			-	-	not significant
D.Proposed method	3.969	0.097061			-	-	-

****p<0.001

Table3 Analysis results using only proposed and compensation methods. (Upper: between user satisfaction and interruption frequency on YouTube, Lower: between "Boredom" and Internet knowledge)

1. Group	2. Interruption frequency on YouTube	Means	Standard errors	ANOVA					
				1		2		1×2	
				F-value	p-value	F-value	p-value	F-value	p-value
Compensation	No	4.406	0.22468318	F(1,173) =2.032	0.1559	F(1,173) =1.121	0.2911	F(1,173) =4.224	0.0414*
	Yes	3.875	0.20612163						
Proposed method	No	3.812	0.11786221						
	Yes	3.982	0.12768492						

1. Group	3. Internet knowledge	Means	Standard errors	ANOVA					
				1		3		1×3	
				F-value	p-value	F-value	p-value	F-value	p-value
Compensation	Low	2.321	0.43862777	F(1,103) =0.069	0.793	F(1,103) =1.184	0.2911	F(1,103) =4.447	0.0374*
	High	2.439	0.43805733						
Proposed method	Low	2.594	0.45155744						
	High	2.227	0.57500893						

*p<0.05

G. Frequency of concierge occurrences

Frequency of the concierge occurrences is a very important parameter of our method. In general trivia is not important information at all for user and therefore, if a trivia-telling-concierge often appears, users will feel that it is annoying. On the other hand, however, if the concierge tells trivia only when communication delay occurs, it would become the sign of the delay.

In Japan, the 2014 fiscal year report says that the communication failure has occurred 6 times during 2014 [4]. Judging from this data, let us suppose that the concierge tells a trivia 52 times a year at random intervals (once a week in average). It is expected that users would not be able to directly know which trivia-telling-concierge in 52 appearances are due to communication delay, and we assume that the concierge that tells a trivia have appeared once a week might not be too much bother to users.

However, we should remind the fact that a concierge tells not only trivia but also any kind of information. A concierge displays a message on the terminal screen whenever the operating system of the smartphone has something to inform the user. It is supposed that the appropriate frequency of appearances of the trivia-telling-concierge would vary based on how often the message-telling-concierge is expected to appear [19]. We are going to investigate the proper frequency through experiments.

VI. CONCLUSION

We proposed and evaluated a method for mitigating the decrease in user QoE due to communication delay that is based on the psychological aspects of the user. The proposed method does not give the user the impression that there is communication delay by displaying text and illustrations. Through an experiment, we verified that the proposed method can mitigate the QoE degradation due to communication delay.

Future work will involve an evaluation experiment by changing the communication delay length and frequency. We will also attempt to develop a more effective behavior of concierge for mitigating the decrease in QoE than the proposed method.

ACKNOWLEDGMENTS

The cat image using the proposed method is a free image published in GATAG (http://free-illustrations.gatag.net/). In the analysis of the experimental results, we received quite a lot of advice from Prof. Takeo Isarida of Shizuoka Sangyo University, Japan and Prof. Yuko Araki of Shizuoka University, Japan.

REFERENCES

[1] Y. Choi, C. Yoon, Y. Kim, S.W. Heo and J.A. Silvestor, "The Impact of Application Signaling Traffic on Public Land Mobile Networks" , IEEE Communications Magazine, vol. 52, pp.166-172, January 2014.

[2] M. Gupta, S.C. Jha, A.T. Koc and R. Vannithamby, "Energy Impact of Emerging Mobile Internet Applications on LTE Networks: Issues and Solutions" , IEEE Communications Magazine, vol. 51, pp.90-97, February 2013.

[3] Rethink Wireless, "DoCoMo demands Google's help with signalling storm-Rethink Wireless", http://www.rethink-wireless.com/2012/01/30/docomo-demands-googles-signalling-storm.htm, (9 August. 2016.)

[4] "Accident situation of telecommunications services (2014)", http://www.soumu.go.jp/main_content/000371631.pdf (9 August. 2016) (in Japanese)

[5] D. Arai., T. Ogishi, M. Watari, S. Ano, M. Nishigaki and H. Mineno, "UE-based Network Access Timing Control Scheme for Avoiding Signaling Spikes", ICC (IEEE International Conference on Communications) 2015, pp.3604-3609, June 2015.

[6] SmartBear Software, "The Cost of Poor Web Performance [INFOGRAPHIC]", http://blog.smartbear.com/web-performance/the-cost-of-poor-web-performance-infographic/ (9 August. 2016)

[7] Y.F. Kuo, C.M. Wu and W.J. Deng, "The relationships among service quality, perceived value, customer satisfaction, and post-purchase intention in mobile value-added services", Computers in Human Behavior Volume 25, pp.887-896, July 2009.

[8] D. Nishioka, Y. Saito and Y. Murayama, "The influence of knowledge level in information security onto the factors of Anshin for online shopping users", 2014 47th Hawaii International Conference on System Sciences, pp.310-319, January 2014.

[9] T. Yamazaki, M. Eguchi, T. Miyoshi and K. Yamori, "Quality of Experience Modeling with Psychological Effect for Interactive Web Services", 2014 IEEE Network Operations and Management Symposium (NOMS), pp.1-4, May 2014.

[10] C. Harrison , Z. Yeo and S.E. Hudson, "Faster Progress Bars: Manipulating Perceived Duration with Visual Augmentations", CHI(ACM Conference on Human Factors in Computing Systems) 2010, pp.1545-1548, April 2010.

[11] H. Zhang, G. Liu and H. Fang , "Cross-Over Study of Time Perception and Interface Design", HCI International 2015, pp.105-116, August 2015.

[12] KDDI Corporation, "The measures and cause about a series of LTE communication failure", http://www.kddi.com/corporate/news_release/2013/0610a/pdf/sanko.pdf (9 August. 2016) (in Japanese)

[13] T. Shirai, S. Kobayashi, T. Suzuki, M. Fujita, D. Arai, T. Ogishi, H. Mineno and M. Nishigaki, "A Study on the Relationship between Incentive and QoE in User-Equipment-Based Network Access Timing Control Scheme", 2015-CSEC-68-34, pp.1-8, May 2015 (in Japanese)

[14] H. Shimada and M. Kitajima, "Motivation Effect of Illustrations in Text Comprehension: An Eye-tracking Study", CogSci 2007: Annual Meeting of the Cognitive Science Society, p.1853, August 2007.

[15] Lancers, "Lancers", http://www.lancers.jp/ (9 August. 2016) (in Japanese)

[16] P. A. Kara, L. Bokor and S. Imre, "Analysis of assessment alteration phenomena of subjective Quality of Experience measurements in 2D and 3D mobile video services", Infocommunications Journal6(2), pp1-11, June 2014

[17] M. Terasaki, Y. Kishimoto and A. Koga, "Construction of a multiple mood scale", Shinrigaku Kenkyu : The Japanese Journal of Psychology 62.6(1992), pp.350–356. (in Japanese).

[18] Kiriki Kenshi, "ANOVA4 on the Web", http://www.hju.ac.jp/kiriki/anova4/ (9 August. 2016) (in Japanese)

[19] J. A, Gallud and R. Tesoriero, "Smartphone Notifications: A Study on the Sound to Soundless Tendency", MobileHCI 2015, pp. 819-824.