Service Control System Based on Behavioral Characteristics of User Multitasking

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***Abstract*—With the rapidly growing deployment of high performance mobile terminals, such as smart phones, multitasking becomes one of the popular uses of mobile services. As the user behaviors become more diverse, a service control based on user's behavior would be required. In general, users do not always pay attention to all services in terms of the progress of those services while multitasking. Thus, service control can be expected to maintain user satisfaction with the service at high levels by allocating computer and network resources to the specific service to which the user's attention is directed. This paper proposes a service control system based on the behavioral characteristics of users while multitasking. As an initial study for establishing a service control system, we first investigated the behavioral characteristics of users while multitasking through a subjective assessment of 400 participants. Furthermore, we verified the proposed system for the effect on traffic reduction by numerical simulations with the behavioral data and confirmed the effectiveness of the proposed system. The main contribution of this paper is that we clarified that the service control system based on behavioral characteristics would be useful in constructing a cost-effective network.**

Keywords-multitasking; user satisfaction; mobile service; service control

I. INTRODUCTION

Thanks to the rapid growth of mobile Internet services, we enjoy a variety of services everywhere whenever we want. Mobile services would be expected to expand continuously by diversifying according to user demand and behavior [1]. For telecommunication carriers and service providers, providing mobile services that ensure user satisfaction is one of the most crucial issues. User satisfaction with a service is called Quality of Experience (QoE). The term QoE is defined in ITU-T as follows [2]:

Quality of Experience (QoE): The overall acceptability of an application or service, as perceived subjectively by the end-user.

Notes

1) Quality of experience includes the complete end-to-end system effects (client, terminal, network, services infrastructure, etc.).

2) Overall acceptability may be influenced by user expectations and context.

The QoE assessment for the mobile communication service has been developed in the audiovisual research field, such as telephone speech and video. ITU-T P.800 [3] and ITU-R BT.500 [4] are representative. Recently, the QoE assessment for such interactive services as Web browsing and e-mail has been studied. Although many factors, such as reliability of the service and ease of use, can be expected to affect the QoE for interactive services, the most dominant factor was reportedly speed [5]. Traditionally, the so-called 8-second rule [6] was used as the index for Web site planning. ITU-T G.1030 [7] or other assessments [8] are currently recommended to determine the appropriate index. Based on the idea that subjective assessments with a method having high-ecological validity are important, the authors proposed an assessment method to assess the QoE under the actual context of use by using Web scripts [9].

Meanwhile, with the rapidly growing deployment of high performance mobile terminals, such as smartphones, multitasking becomes one of the popular uses of mobile services. Although the amount of traffic can be expected to continuously increase, in the mobile communication environment, the computational resources of mobile terminals and network resources are strictly restricted. Increasing network capacity to cope with huge volumes of traffic is not desirable because of the cost. Therefore, the available resources should be used effectively to maintain user satisfaction with services at high-level by implementing some sort of resource allocation and service control. In order to construct such a cost-effective network, we propose a service control system based on the behavioral characteristics of users while multitasking. In general, users do not always pay close attention to all services in terms of the progress of those services during multitasking. Thus, the behavioral data of users while multitasking would be useful information in the implementation of some sort of service control. We confirmed the effectiveness of the proposed system by numerical simulation using behavioral data obtained by subjective assessments with 400 participants.

This paper is organized as follows. In Section II, resource allocation methods to improve service quality are summarized. In Section III, we propose a service control system based on behavioral characteristics of users while multitasking. In Section IV, the field evaluation results regarding user satisfaction with services and the behavioral characteristics while multitasking are given. We also verify the effectiveness of the proposed system through a numerical simulation of bandwidth use based on the behavioral data obtained by the subjective assessment.

II. RELATED WORK

Here we briefly explain the conventional methods to improve service quality. As described previously, allocating limited resources is one of the most vital factors in the mobile environment. The basic approach is to allocate resources in order to maximize some sort of function.

Utility-based resource allocation methods have been widely studied [10]-[12]. The purpose of the utility-based approach is to maximize total utility defined by the utility function. Thus if the utility function is used that consists of metrics that reflect the user's perception for a certain service, then the function can be expected to maximize the QoE for the service. However, since the user's perception of a certain service can be affected by his/her circumstances and the context of use [13], it is difficult to allocate the resources, so as to maximize the QoE.

Context-aware resource allocation has received much attention recently [14]-[16]. Proebster et al. proposed a context-aware resource allocation method to improve the QoS of heterogeneous traffic [16]. By using context information collected from user terminals, the base station scheduler can allocate the available resources to each user more efficiently than previous methods. For example, this method focuses on the foreground/background state of the service/application generating the traffic and allocates more resources to the service in the foreground. The foreground/background state for a certain service was previously determined using this method, e.g., web browsing is the foreground and file downloading is the background. However, in a multitasking environment, a certain service/application can be used as the foreground sometimes and as the background at other times. The foreground/background state and the context of use for a service/application can vary from time to time and the timing of the change is different for each user. Therefore, we need resource allocation or a service control method that can handle the variations of the context of use for a certain service immediately.

III. SERVICE CONTROL SYSTEM BASED ON BEHAVIORAL CHARACTERISTICS OF USERS MULTITASKING

We propose a service control system based on behavioral characteristics of users while multitasking. In a multitasking environment, although users can run a variety of services and applications simultaneously, they do not always focus their attention on every service and application. User satisfaction with a service fluctuates depending on the style and context of use. In a multitasking environment, the service can be enjoyed as either the foreground (FG) task or the background (BG) task. When a certain service is enjoyed as a BG task, the focus of the user's attention would be relatively low compared with when the service is enjoyed as a FG task. Therefore, the user can be expected to accept the given service quality for the BG task even when the quality is not very high. If we can control the network and server resources appropriately based on the behavioral characteristics as long as the information about the application type and the context of use collected from each user, the service control method can be expected to retain user satisfaction as a high level. For example, suppose a large number of users enjoy a certain service. Their styles of use would be different; some users use the service as a FG task and others use the service as BG tasks. In this case, if the service quality for the user of the service as a BG task was degraded by implementing some sort of service control, the user satisfaction for the service may not deteriorate.

In order to establish such a service control method based on the behavioral characteristics of users, one possible system configuration is shown in Figure 1. Each user terminal monitors the context of use regarding the application running on the terminal and behavioral data of the user and sends the monitoring results to the service control server (SCS) at the appropriate time. The SCS determines the service control policy based on the collected information regarding each user terminal and sends the determined service control policy to the user terminals, the intermediate nodes, and the Web servers depending on the policy. The user terminal can control the computational resource allocation with each task. The intermediate node and the Web server can implement priority control and traffic shaping, e.g., changing the bandwidth allocation.

In addition to the above service control method that implements traffic control on the user terminals and intermediate nodes, it is possible to implement the QoE improvement method that provides an appropriate time filler for the user [17]. The typical time fillers are a loading bar, a progress bar, and other short movies. These prearranged fillers can be stored on the terminals by default, and the terminal then displays them during the waiting process. Additionally, more flexible news, trivia, and advertisements can also be utilized as time fillers. In [17], we confirmed that the time filler has a significant effect on the decrease in dissatisfaction while waiting, though it is strongly influenced by context.

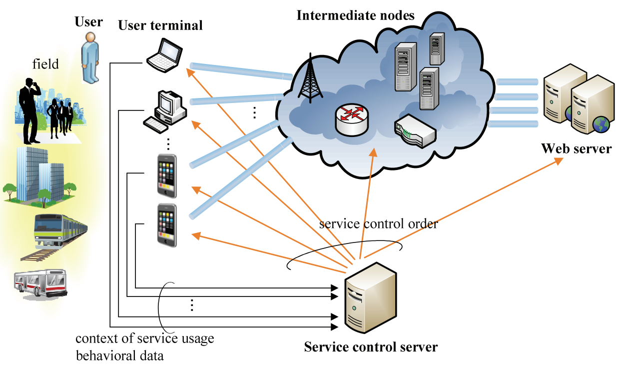


Figure 1. System configuration of the proposed method.

IV. EXPERIMENTS

In order to establish the proposed service control system, we first have to clarify the behavioral characteristics during multitasking and user satisfaction with the service in both cases where the service is running as a FG task and a BG task. Here we conducted the subjective assessment of mobile services by using the high ecological field evaluation method proposed in [9].

A. Field evaluation system

The overview of the proposed Web script-based method is depicted in Figure 2. As shown in Figure 2, our proposed method is extremely simple, since only a subjective assessment server (SAS) is required to construct the system. The SAS plays two roles: distributing a program for artificial context (PAC) written in a Web script such as FlashLite and receiving the answers from participants. In our proposed method, the participant's own mobile terminal can be used without any modification, since most commercial mobile terminals support Web scripts by default. Thus, a large-scale subjective assessment can be conducted easily in the field with little effort, since the test organizer needs to prepare neither customized terminals, nor elaborate network systems.

A general sequence flow for conducting the subjective assessment using this method is as follows. The participant first sends a request to the SAS via the Internet. Then, as a response, the SAS distributes the PAC to the mobile terminal. Second, the participant conducts the field evaluation using the PAC. As described later, since the PAC can be run without an actual communication environment, the participant can conduct the field evaluation anywhere. Finally, the participant sends the results to the SAS via the Internet. Once the participants have obtained the PAC, all necessary procedures can be accomplished according to the instructions for the PAC.

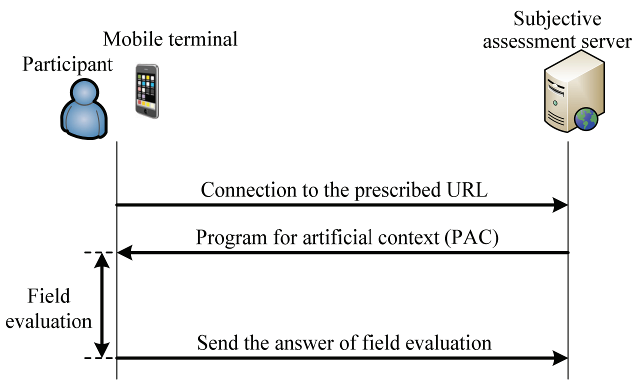


Figure 2. Sequence flow for conducting the subjective assessment.

B. Behavioral characteristics on multitasking

We conducted a subjective assessment to evaluate user satisfaction with the waiting time while content is downloading using smartphones. In this test, participants used their own smartphones and assessed the waiting time during downloading with a five-grade rating score. The PAC utilized in this test is an application for an Android terminal and shown in Figure 3. The PAC emulates the tabbed browser. Here we assume the situation where the user is Web browsing in tab A while downloading a video file in tab B. Although tab A is the foreground task and tab B is the background task at first, the participants can switch the FG/BG task freely by touching the tab. Note that the download speed is not changed regardless of whether the tab B is a foreground or background task. The time when the participant switched the FG/BG task is logged with the PAC as data representing user behavior.

By touching the start button of Picture #1 in Figure 3, the displayed picture immediately changes into Picture #2, which shows the Web browsing in tab A and the downloading in tab B. After a predetermined waiting time, Picture #2 changes into Picture #3 and reporting that downloading has finished; note that even when the downloading has finished, tab B does not automatically become the foreground. Thus, the participant makes tab B the foreground task by touching tab B and goes ahead with the assessment by touching the Next button in Picture #4. In Picture #5 of Figure 3, the participant evaluates the waiting time with a five-grade rating score.

The experimental conditions are shown in Table I. As shown in Table I, in tab A, trivia consisting of about 150 words or a *senryu* consisting of 17 words are shown; note that the *senryu* is a traditional form of Japanese poetry with a 5-7-5 syllable structure. Although there are individual differences, it needs about 12 seconds and 2 seconds to read through the trivia and the *senryu*, respectively. In conditions 1 and 3, the progress bar that represents the progress of the download is shown in tab B. The user interface design for each condition is shown Figure 4. In each condition, the participant assesses 5 patterns of waiting time. We recruited a total of 400 participants consisting of 224 males and 176 females; note that all participants conducted the subjective assessment using their own smartphones.

The subjective assessment results are shown in Figure 5. As seen in Figure 5, user satisfaction with the waiting time is different depending on the conditions. We tested the differences between the conditions by applying two-way ANOVA with two independent variables: waiting time and conditions. Accordingly, it was found that the main effect of condition was significant at the 1% level. By comparing conditions 1 and 2 and conditions 3 and 4, we can see that by representing the progress bar, user satisfaction with the waiting time improved. For both conditions 1 and 2, user satisfaction with waiting time improved compared with condition 5, while in conditions 3 and 4, user satisfaction deteriorated. In conditions 1 and 2, user attention was focused on reading the trivia, and they were not aware they were waiting for the download to finish. Consequently, user satisfaction did not deteriorate.

Next, the number of times the FG/BG task switched during one given condition is shown in Figure 6; the number of switches was calculated as the average of all participants. As it can be seen from Figure 6, the participants tended to switch FG/BG task more frequently when the progress bar was not shown in tab B. We performed the two-way ANOVA with two independent variables, waiting time and condition, then it was found that both the main effects of waiting time and condition were significant at the 1% level.

Next, we classified the participants into two groups per each condition. The participants who switched FG/BG task at least one time during each condition were classified into the first group. The other participants were classified into the second group. Figure 7 shows the user satisfaction of each group. Note that in conditions 1 and 3, since the number of participants who switched FG/BG task at least one time during the given condition was few, we did not analyze per each group any more. As can be seen from Figure 7, the participants who frequently switched FG/BG task tended to be dissatisfied with the waiting time.

Consequently, the users who used the service as a BG task were not dissatisfied with the service even though the service quality was degraded. Therefore, it can be expected that the service control system would work well if we used the behavioral data of the user appropriately.

TABLE I. Experimental conditions

Condition	Tab A	Tab B	Waiting time [sec]
1	Trivia	Progress bar	4, 10, 15, 20, 25
2	Trivia	--	4, 10, 15, 20, 25
3	Senryu	Progress bar	4, 10, 15, 20, 25
4	Senryu	--	4, 10, 15, 20, 25
5	--	--	4, 10, 15, 20, 25

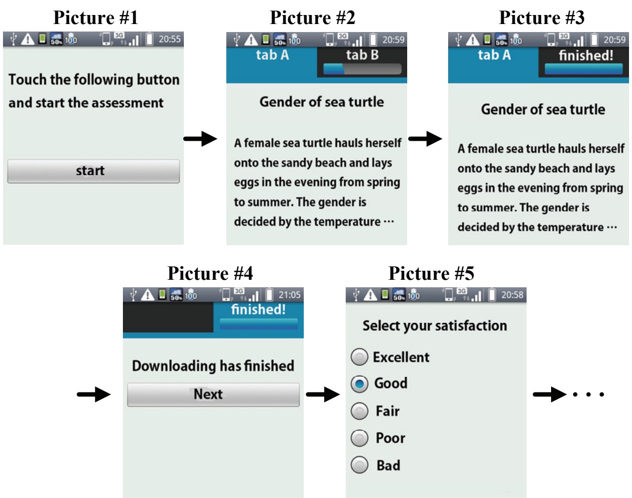


Figure 3. Example of screen transition in the PAC.

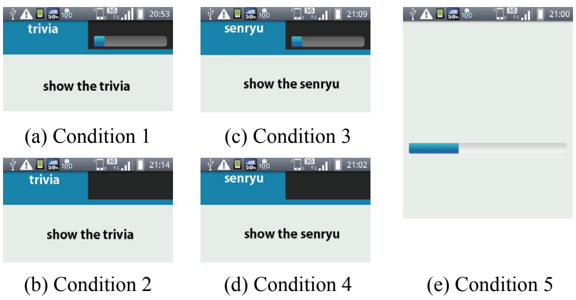


Figure 4. User interface design of each condition.

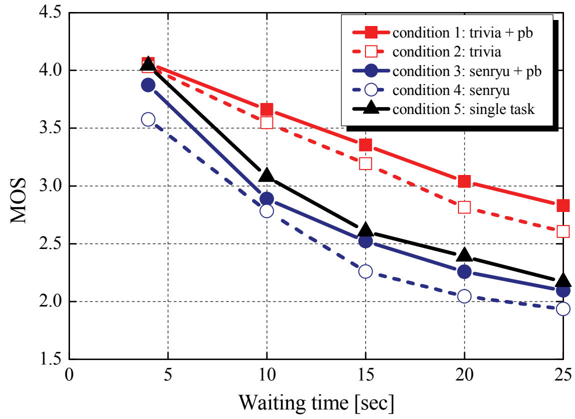


Figure 5. The subjective assessment results.

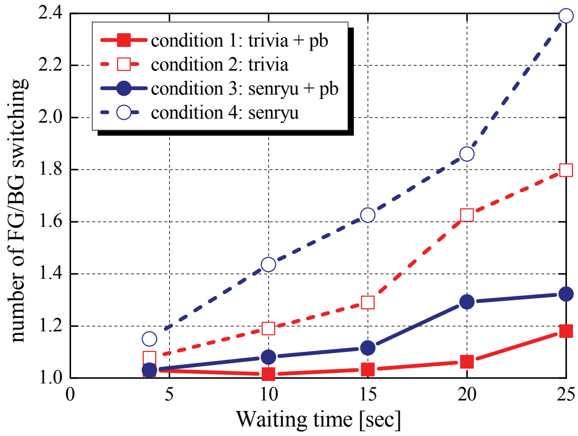


Figure 6. The average number of FG/BG switches per condition.

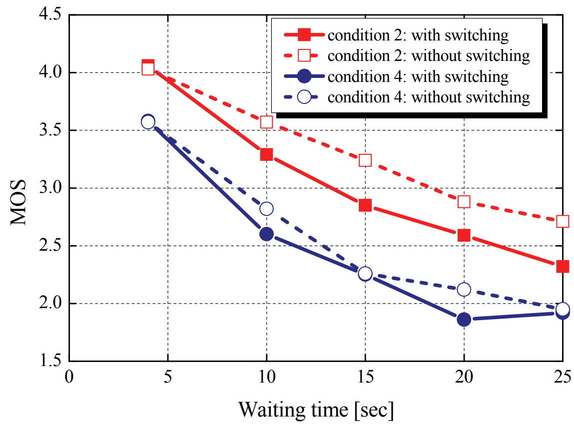


Figure 7. The relationship between user satisfaction and number of switches.

C. Numerical simulation

Here we verify the effectiveness of the proposed service control system by a numerical simulation based on the behavioral data obtained from the subjective assessment in the previous subsection. We simulated how much traffic could be reduced by using the proposed system. In this simulation, we assumed that about a thousand users browsed the Web while downloading a certain content file. The experimental conditions are shown in Table II. As shown in Table II, we set the content file size to 1.0 MB. As seen in Figure 5, if we adopt the waiting time when the reference value of MOS is set to 3.0, the acceptable waiting time for condition 1 is about 20 seconds and that for condition 5 is about 10 seconds. Therefore, we assumed that the acceptable waiting time when the user uses the service as a FG task was 10 seconds and that for the BG task was 20 seconds. This meant that the required throughput was 800 kbps when the content file download was performed as a FG task, while the required throughput was 400 kbps when the download is a BG task.

As described in the previous subsection, we obtained the behavioral data regarding the FG/BG switching timing of 400 participants. By using the behavioral data of condition 1 in the subjective assessment, we generated a traffic generation pattern for each user as shown in Figure 8. For example, since user #1 downloaded the file as a BG task to the last, it followed that user #1 required throughput of 400 kbps to the last. Since some users, such as the users #2 and #3, downloaded the content as a FG task occasionally, it followed that they required throughput of 800 kbps occasionally. Note that we did not care that there were identical traffic generation pattern among the 400 patterns.

Here we use the 3 different access patterns shown in Figure 9; access patterns (a), (b), and (c) follow a normal distribution in which the mean and standard deviation are 20 and 7 seconds, 20 and 5 seconds, and 20 and 2 seconds, respectively. The number of total users in each access pattern is 974, 979, and 991, respectively. In each access pattern, we randomly selected one participant among 400 participants and generated the traffic pattern for the selected participant shown in Figure 8.

Figure 10 shows the simulation results regarding the required bandwidth. As can be seen from Figure 10, the required bandwidth can be reduced by using the proposed system. The reduction rate for access pattern (c) is larger than that for access pattern (a). Thus, the proposed service control system worked well because access timing was more concentrated in short period of time. User satisfaction with the service would improve if we allocated redundant bandwidth to the user who needed more bandwidth.

TABLE II Experimental conditions

Parameter	Value
Content file size	1.0 MB
Required throughput	400 kbps (for BG task) 800 kbps (for FG task)

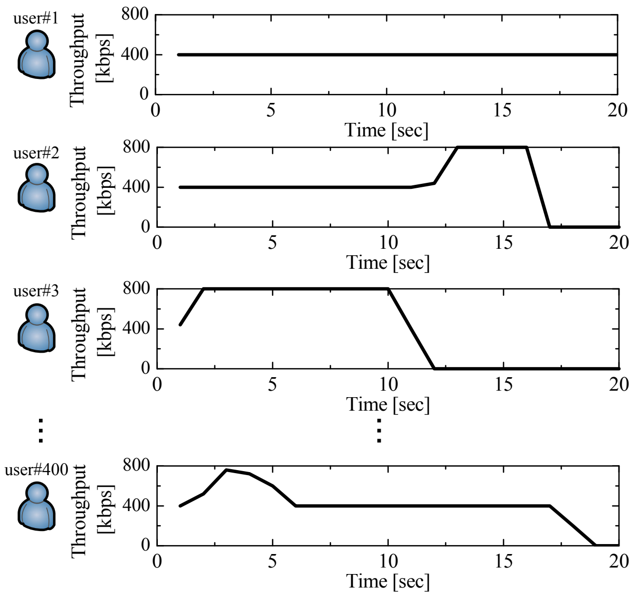
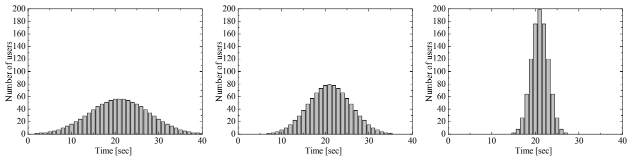


Figure 8. Example of traffic generation pattern.



(a) (b) (c)

Figure 9. Access pattern utilized in the experiment.

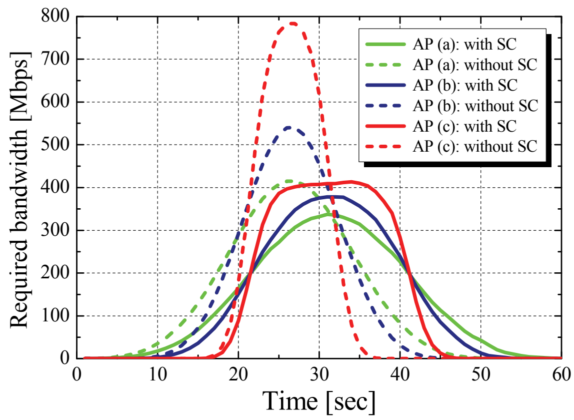


Figure 10. Simulation results of required bandwidth.

V. CONCLUSION

This paper presented a service control system based on behavioral characteristics of users while multitasking. As an initial study toward establishing the service control system, we first assessed user satisfaction with waiting time when downloading and the behavioral characteristics while multitasking by conducting a subjective assessment with 400 participants. As a result, users tended to accept relatively long waiting times when they used a certain service as a background task.

Next, we verified the effectiveness of the proposed service control system using a numerical simulation based on behavioral data obtained from the subjective assessment. Consequently, the more the access timing was concentrated within a short period of time, the greater the effect on traffic reduction.

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