Synchronized Context Sharing over Multiple Devices: Personalized Rendering of Multimodal Contents

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***Abstract*— In this paper, we introduce a method for synchronization of multiple devices based on context sharing and system design for multimodal contents service. A main advantage we can expect from our system environment is eliciting abundant function features of each device and exploiting them for rendering multimodal information in more efficient ways. To make it feasible, context sharing takes a significant role in integrating whole environment. Based on shared context, system gets a guideline for assigning a role for each device in current configuration and makes them have synchronized behaviors. In a multimodal contents service, the contents are processed and converted into service data sets which are separated into each modal information. Each modal information is mapped to function features of devices. We design user profile, for generating proper user context in a service, and device profile, for acquiring synchronized behavior over different capability of devices. The service system monitors changes of user's context and evaluates state of synchronization between devices in run-time. And it adaptively controls the service data flow to have stable and continuous performance.**

Keywords—Multiple Device, Context Sharing, Multimodal Contents

I. INTRODUCTION

Nowadays, it becomes common to possess more than one smart device for single user. So, people are surrounded with multiple devices which are connected and integrated closely over networks. Behind soaring popularity of various types of cloud services, devising a convenient way for sharing information over multiple devices has become important research topic. Most cloud services make it a goal to provide with convenient way of sharing data between multiple devices centering main server system. Data transferring can be usually accomplished by one of three forms. The first form is synchronization between certain locations of file systems of devices. If certain modification is happened in the locations, for example deleting, editing or generating a file, server system automatically detects it and adjusts same modification to every linked device though online. The second form, which is specific type of the first, is synchronization based on data filtering. Every data in the whole storage is sorted by their data type. Only the data whose type matches priori defined data type are transferred to every linked device and then synchronization is accomplished. The filtering the data, which is about selecting data type, could be differently set in each device and each service context. Typical usage of the service is automatic uploading of pictures in smart phone. User can set it to upload picture files only with WIFI connection. The last form is data streaming on user's demand. Before user requests to transfer the data, all user can see is list of accessible data in the cloud storage. If user requests certain file, then server starts to transfer the file to client device.

Common restriction we can find from current cloud services is that they would be inconsiderate to simultaneous use of client devices and data sharing between devices in run-time. If user tries to access a certain data with more than one device, several problems would arise. The first restriction can be found in inaccessibility to each modal information with simultaneous way using multiple devices. To elicit befit of multi-device environment, it should be able to access to each modal information selectively to have most preferable form of playing it in current combination of devices. And the second issue is synchronization of its rendering on each device. The most challenging issue in real-time synchronization would arise because of different system performance on each device. Even though we manage to acquire a mean to exchange context information between multiple devices with minimal time-delay, system performances for transferring and rendering a proper data on different devices are hard to be fully synchronized. Especially for the multimedia contents, when we consider keen visual motion sensor of human cognition, even a slight synchronization failing of rendering an image over the screens of multiple devices will bring a drastic cut down of usability.

In this paper, we propose cloud-based multimedia service system architecture devised for multiple device environment. In this system, users get provided with way to access multimodal contents using multiple devices in concurrent manner to acquire each modal information selectively. And user can have synchronized behavior of multiple devices when it plays the contents. With this system, user can have preferable distribution of multi modal information over user's current configuration of multiple devices. As a mean to achieve this goal, we introduce a method of context modeling and sharing mechanism for multiple-device environment. And also we describe in detail about real-time synchronization method. We make it a goal to have a stable synchronization performance with multiple devices which have different hardware configuration under unpredictable system environment.

II. Related work

It becomes a trend to have a multiple devices and conveniently access various contents with less restriction than before. There are a lot of smart devices you can find in daily lives. Each device is devised to have optimal usage context. For example, smart phone is suitable device to access network with less circumstantial restriction and acquiring essential information instantly. Otherwise, smart tablet, which has relatively bigger screen than smart phone, is quiet useful for simple office work, like word processing and e-mailing, when user is outside of office. So, using a multiple devise based on wireless network becomes quiet common[2]. In multiple device environment, it is realized as an important issue to have a continuous and efficient information sharing between devices when user changes working device[3,4,6]. For the continuous working on multiple devices, defining a current user's context and exchanging it between devices are also important[7]. Due to various functionality and capacity of modern smart devices, suitable contents transformation is also required for achieving efficient system performance. Not only with efficiency aspect, adaptation of service content is essential process for providing users with better user experience[1,10]. Considering those requirements, service system targeting multiple device environment should be designed to fully exploiting the every function features so as to provide rich functionality to users. In our research, considering above requirement, we devise a multimodal contents service system using multiple device environment

III. Process of Multimodal contents service using multiple device

As we explained in previous section, main characteristic of our service can be found in simultaneous use of multiple devices for getting provided with multimedia contents. In our system, we have designed two cases of integration of multiple devices. The first case is integration between multiple mobile devices. This case is about integration between mobile devices, like smart phones with smart tablets. In this case, every device accesses service through wireless network, which has relatively unstable network bandwidth. Therefore due to their mobility of devices, physical configuration based on their location can be dynamically changed during a service. The other case is integration between mobile device and stationary device, like smart phone with smart TV. In this case, usually stationary devices are connected with the service server through wired network so that relatively stable network performance can be expected.

In our research, using multiple devices, single user or multiple users are provided with multimodal multimedia contents. Users can have control of contents by mapping the rendering feature of devices to each modal information. The mapping can be established automatically by service system and manually by user in either way. The initial step is registering user and user's devices to the system. This step includes authentication of the devices for the service and benchmarking test for determining actual capability of the device in service environment. After finishing initial steps for the service, main service system prepares for starting the main service. To start the service, system determines configuration of devices. This step is for gathering the knowledge of every function features of currently connected devices and listing possible options for rendering the multimodal contents by exploiting the function features selectively. Multimodal contents we have targeted in this research are 2-D contents which usually contains images, videos, audios and text information.

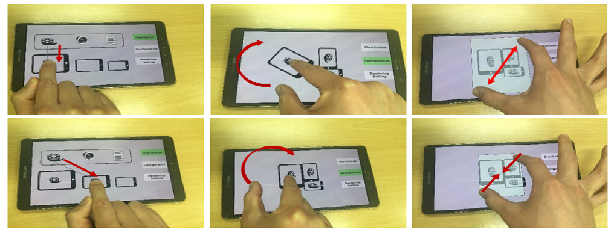

Fig. 1. Interface for distributing service contents to multiple devices. In the first column, it shows assigning each modal information to devices with drag and drop gesture. The second column shows a configuring device layout in physical space with rotating gesture. And the last column shows a defining an image area for the rendering using multiple mobile devices.

User can start the service with one of his or her device. Once the user select a device as starting device, system sets the device as a main device, which takes a central role for sharing context with the other multiple devices. Then, server generates initial information and transfers it to main device so as to get ready to start service. Initial information contains list of contents which user is allowed to access, and interface object which provides a mean to distribute multimodal contents to multiple device. Initial information also contains user's histories which are a list of contents which have been chosen by the user in previous times and their bookmarks. If user starts the service, with user interface, user can select each modal information from the contents and assign it to connected devices. In this step, user is able to set the resolution of information, such as resolution of frame images, the number of channels of sound, and also the rule for dividing single channel information. Figure1 shows user interface design which user can use for handling each modal data for distribution.

A. *Visual Information Rendering*

In most of cases, main research topic for visual information rendering is usually focused on optimized presentation on display device. Optimization means, in this context, to adjust image resolution, size and frame per second considering specification of display device. In multiple device environment, it also needs to consider adjustment of images as device configuration changes according to user's demands. In multiple device environment, there are several possible scenarios where displaying environment changes.

The first case is a situation of single user with multiple mobile smart devices. As we think about mobility of the devices, user can change its alignment as user wants. With the multiple devices, user can define every display area as a single rendering space for visual information. In this case, the image should be properly cropped and processed for each device considering its configuration in physical environment.

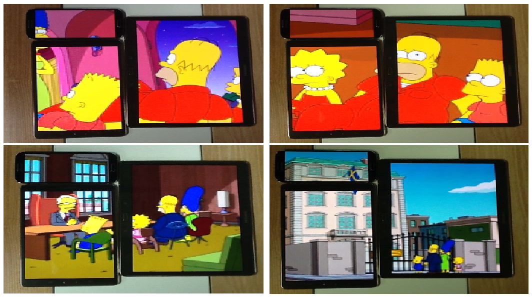

Fig. 2. Using multiple display devices for visual information rendernig

The next is single user with mobile device and stationary device. In this case, it might be conceivable to integrate the devices as we do in the first case. However it cannot be wise to do that because of immobility of the stationary device which makes us have less application. Furthermore, usually stationary devices have relatively bigger display area, so we can think about new line of application domain in this situation. Bigger size means users focus cannot reside on both of devices, mobile device and stationary device, at the same time. That means in users perception, there is a main device where user's focus resides relatively longer than the other one. We can exploit that fact in content distribution step. It is possible to make main device used for displaying main information and let second device used for displaying addition information on user's demand. For example, let's assume that user tries to watch the movie using multiple device environment consisting of smart tablet and smart TV. User is able to set the smart TV as a main device for displaying the movie image. And with smart tablet, which automatically becomes a second device, user can see the introduction of movie or subtitle information. This kind of contents distribution can be set through user interface of the service. The third case is about multiple users with multiple mobile smart devices. In this case, as we do in the first case, users can integrate the each one's device and use them as if they are single display device. Only one difference of this case comparing the first, it needs to generate new context by coinciding the different contexts which comes from different users. Once we have a coincided context, it is possible to use environment just like we do in the first case. The last case is about multiple users with mobile smart devices and stationary devices. In this case, as it has multiple contexts per users, same circumstance can be differently defined on each user's stand. For an example, let's assume that two users are watching a 2-D video contents using smart TV. In this case their points of views are coincided on the screen of smart TV. If one of the users wants to rewind or fast forward the contents to see the other point of time, the user would be able to do that using his or her smart device. In this situation, smart device is used for generating personalized viewing of the information. The most useful feature we can use in this case, 2-D contents also can be distributed based on time dimension.

B. Sound information rendering

In modern multimedia contents, sound information gets more important than before as it is conceived as important factor to provide a great user experience. Considering this circumstance, even mobile smart devices, which have densely integrated hardware modules inside, are designed to have innate high performance speaker modules. In multiple device environment we have designed, user can select device for rendering the sound information as user's preference. Let's assume that multiple device environment which consists of mobile smart devices. In this case, user would be able to select the device which has better equipment for rendering the sound than the others. And as another concept, sound information can be synchronized with video information on different device. As user watches movie with distant display device, the user is able to get sound information with user's smart device.

IV. System Architecture

Entire system consist of main server and client application as described in figure 3. The main server takes a role for managing multimedia contents and profile information of users and devices. Server monitors current context of users. The server modules can be mainly divided into three parts. The first part is for generating datasets from original multimedia contents. And the second part is context manager, which is responsible for awareness of user's context based on user's current service environment including information of user's service request. The last one is network manager which manages actual communication and data transportation between server and clients. Explanation of each part is detailed in following sections

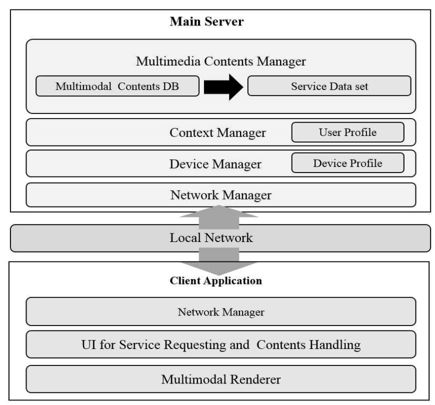

Fig. 3. Using multiple display devices for visual information rendernig

V. Context Awareness and Sharing

To be aware of user's context in service, it is necessary to have proper user model which can be used for presenting a user as a profiled information. And we also need to have model for representing a device as a profiled information as well. User's profile and those of devices in use are based on determining current context of user. The attributes of device model are device ID, display specification, rendering performance, networking performance and device type. Display specification is about resolution, size and density of pixels. Nowadays, density of pixels is getting higher rapidly in smart devices. So, it is necessary to have that information to properly anticipate how the certain size of image is going to appear in the actual display device and to determine optimal size of image to be rendered.

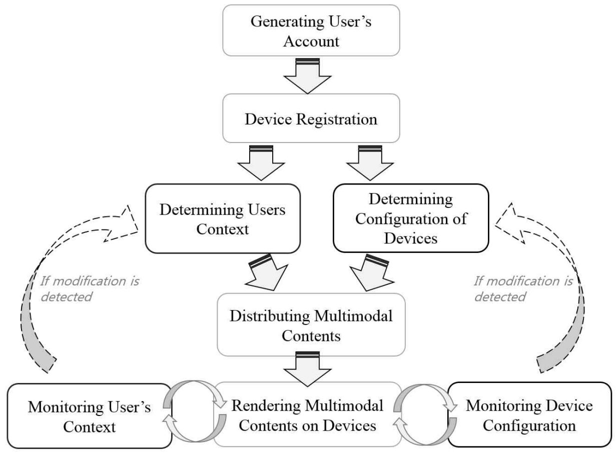

Fig. 4. System Process of Multimodal Contents Rendering Service

And it is also even more important when user combines multiple devices which have different display specification and then, makes them act like single display. Rendering performance is about capacity of processing graphical information. This value is related with renewal of frame image per second in service. And networking performance is set by measuring time for transferring certain size of data under reference network environment. The attributes of user model are user ID, IDs of devices belonging to the user, service history, preference service type, user's current activated devices and current state of service requirement. By containing information of user's every devices, system can model concrete service environment of user. User's context can be defined by referring type of required service contents and current device configuration. Context sharing makes it a goal to have continuous and optimized performance of service when device configuration is changing. A role of system service is automatic detection of user's context in real-time and generating proper package of data. figure 4 shows overall process of system service process. Devices are synchronized by sharing current user's contexts. Figure 5 shows example of multiple device environment with two users who has different user context. In the first user's profile, his preference in language is set to Chinese and in the second user's profile, it is set to English. When they watches movie together sharing the space, each user would be provided with different information according to user's preference. In this situation, a role of smart TV is space for rendering shared information of users. And mobile device personalized space which is generated by referring user's context. In each user's point of view, the entire content is serviced with a consistent form.

Fig. 5. Using multiple display devices for visual information rendernig

VI. Adaptive Data Streaming Control

To have synchronized performance of multiple devices, there are several restrictions which we need to consider to make it feasible. The first thing we need to think about is dynamically changing bandwidth of wireless network environment. Unlike wired network, wireless network environment can have unpredictable condition. The second thing is irregularity of data processing performance of mobile device caused by priori scheduled background task. Unlike desktop environment, mobile devices have quiet limited system resources. Because of that, every process gives and takes certain level of effect with each other no matter how they are well scheduled in process queues of mobile operating system. If there is running pre-scheduled background services in mobile devices, it is hard to have expected performance. It is not possible to interfere with other process during run-time so that it cannot be a possible prevent unpredictable factor to disrupt on performance in a service. Because of those two hard-to-predict circumstantial issues, service system monitors state of synchronization for every data packet transfer. Once service starts, for managing multiple devices, server generates same number of system objects and let them run on each thread. The system object takes a role to select service dataset which has proper level of quality for being rendered on target device and evaluate system performance in current system environment. For optimization of rendering video information, initial resolution sets to be equal to device screen resolution. If the FPS (Frame per second) is lower than certain degree, which we set it as 20 in our study, it gradually degrades level of information quality. Likewise, in each thread, system objects adaptively adjust data streaming independently. For getting synchronization between devices, each system object leaves log about index number of last frame transferred. A Server system checks frame indices which come from each devices. If corruption of synchronization is detected, system sends a signal to the thread which shows unsynchronized behavior.

VII. Conclusion

In this paper, we introduce a synchronization of multiple device environment for rendering multimodal contents. For the synchronization of multiple devieces, we devise a method of sharing context with multiple devices. Context is defined by user's profile, devise's profile and service type user requires. By sharing context with multiple devices, we can have a sychronzied performance from multiple devices, making them act like single device. And by modeling an multimodal contents to have more suitable form to be rendered in multiple device, user can easily configure the service environemt as they want. As the most distict charateritic of multiple device environment, each function feautre of multiple devices is fully expoited using our system design.

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