User-Centric Conflict Management for Media Services Using Personal Companions

Choonsung Shin, Hyoseok Yoon, and Woontack Woo

In this paper, we propose a user-centric conflict management method for media services which exploits personal companions for the harmonious detection and resolution of service conflicts. To detect conflicts based on the varying characteristics of individual users, the proposed method exploits the unified context describing all users attempting to access media services. It recommends and mediates users' preferred media contents through a shared screen and personal companions to resolve the detected conflicts. During the recommendation, a list of preferred media contents is displayed on the shared screen, and a personally preferred content list is shown on the user's personal companion comprising the selection of media contents. Mediation assists the selection of a consensual service by gathering the users' selections and highlighting the common media contents. In experiments carried out in a ubiHome, we observed that recommendations and mediation are useful in harmoniously resolving conflicts by encouraging user participation in conflict situations.

Keywords: Service conflict, context-aware media service, smart home, personal companion, service mediation.

I. Introduction

With an increasing number of studies on smart homes and offices, the interest in context-aware media services aimed at multiple users is also growing. Unlike media services intended for a single user, media services for multiple users have to deal with the preferences of a group of individual users. To meet this requirement, media services need to have a dedicated mechanism to provide service to multiple users which includes features for priority assignment and policy management [1], [2]. However, media services face even more challenges when they are applied to smart homes due to the different characteristics of individual residents in a smart home [3]-[6]. These challenges include the fact that it is difficult to define conflicts due to the dynamicity of users in a smart home. In addition, there can be no perfect resolution to reflect each resident's individual needs because residents all have different preferences, interests, and experiences. Moreover, residents are not simply users accessing media services; rather, they are the owners of the media services as well. These properties make it difficult to manage conflicts caused by multiple users.

Most research aimed at conflict resolution has focused on smart homes and intelligent offices. Examples of these systems include the reactive behavioral system (ReBa), which resolves conflicts among devices in an office environment by applying a layered architecture of activity bundles consisting of users' activities and reactions to the environment [7]. MusicFX, a music arbiter, selects music stations based on group preferences, reflecting multiple users' preferences in a fitness center [8]. The sensible agent system determines access privileges for agents accessing mutual resources [2]. In addition, the reconfigurable context-sensitive

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middleware (RCSM), an object-based framework for pervasive computing, resolves action conflicts by utilizing predefined rules [9]. Finally, Dynamo supports media content sharing and data exchanges between multiple users on the basis of social protocols [10].

However, the previous research has the following limitations when it is applied to a smart home. First, autonomous selection as a resolution can cause additional conflicts since the selection may take a service away from a user currently using the service, without that user's consent. Second, conflicts are only temporarily resolved because users cannot recognize and/or exchange contrary opinions. Although social protocols can manage the use of media content among individual users, problems based on the unexpected behavior of residents still exist.

In order to overcome the above-mentioned limitations, we will define a service conflict based on contexts, and propose a resolution method to exploit service recommendations and mediation. The proposed method detects service conflicts among users based on the context. This allows for the detection of service conflicts with rich user information, such as service profile, individual behavior, and user preferences. The proposed method then recommends and mediates the group's services to resolve the detected conflicts. In the case of recommendations, the method has the ability to generate a recommendation list based on the preferences of all users and then to display this list. As a result, the recommendations shown on the shared screen notify users of their different preferences. The recommendations delivered to the individual users then provide them with possible selections which reflect their combined preferences. Furthermore, the proposed method mediates the selections on the recommendation list by gathering all users' inputs and highlighting their choices. Hence, the users are able to exchange opinions regarding selected media contents and to ultimately decide upon an appropriate item which reflects their agreement and preferences. Therefore, the service conflicts among the users are resolved in such a harmonious way based on the mediation and their agreement.

The remainder of this paper is organized as follows. In section II, we describe service conflicts and potential resolution methods through the consideration of context-aware media services. A unified context is introduced in section III. We then explain how to manage service conflicts by exploiting personal companions in context-aware media services in section IV. In section V, we present the implementation of the proposed management method, with subsequent experiments and related analysis presented in section VI. Finally, we conclude our findings and discuss future works in section VII.

II. Service Conflicts and Approaches for Resolution

1. Service Conflicts

Conflicts among multiple users who want to access the same media services occur when multiple users demand access to the same media services. In this situation, the media service recognize the users' customized services by exploiting this context. It then selects one possible response, based on either priority or policy, to manage multiple users. However, such a scenario will not satisfy the needs of multiple users due to the fact that a service is decided on without any agreement between the users involved. Furthermore, service conflicts often occur when multiple users attempt to access different media services sharing the same space. In this situation, the media can react to the user's context, but multiple users cannot enjoy individualized service due to the interference of different media services, such as sound and visual media in a limited space. Figure 1 shows an example scenario of service conflicts among multiple users.

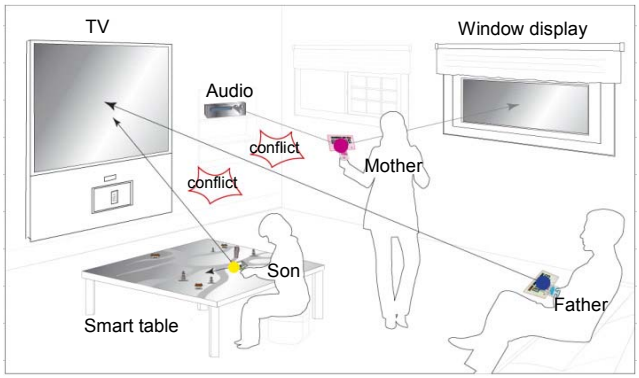

Fig. 1. Example of service conflict.

As shown in Fig. 1, the father and son are both attempting to access the TV service, while the mother wants to access the music player; the father and son usually watch news or animations, respectively, in the evening. Now, consider the situation that arises when the father is the first user of the TV service. The TV service recognizes the preferred programs of both the father and son, and if the TV service has a first-come-first-served (FCFS) policy, it would then select the father's program; otherwise, it would select a animation as the son's preferred program. Consequently, whichever TV service is selected, neither user is satisfied. The situation gets further complicated when the mother wants to listen to music, as she usually enjoys classical music in the evening. As the mother enters the room, the music player recognizes her preference and attempts to play a Mozart symphony. However, the music may not be successfully delivered to the mother due to the ongoing TV service. Similarly, the TV service may not be delivered to the father and son due to the music played by the music player. In

effect, all the users in the home are disturbed by each other.

Based on this example, it can be clearly seen that a conflict management method has to deal with service conflicts among users wanting access to the same media service as well as users who want to access different media services in a shared space.

2. The Proposed Conflict Management Approach

In order to reflect the individual characteristics of residents, we have proposed a conflict management method for handling service conflicts by making use of contexts and personal companions. The contexts include user-related information such as users' preferences and media service profiles, such as media service identity and required resources. The personal companion helps users control their preferred media services. It does this by first detecting a service conflict based on the contexts obtained from all users, information which includes the triggering information of specific media services. The method then displays (recommends) potential media contents on a shared screen and on the user's own personal companion. With the recommended media contents, the users can recognize other individuals' interests and select an item from the recommended contents. Thus, the method successfully arbitrates user inputs to provide a consensual service. Figure 2 illustrates the conflict resolution of the previous service based on the proposed conflict management method.

As Fig. 2 illustrates, a recommendation list of TV contents is displayed both on a shared screen and the users' personal companions when a service conflict is detected. According to each family member's preset preferences, a recommendation list, consisting of dramas, news, and animations, reflects the preferences of the father and the son. The recommendation is also given to other users and can be individually reordered by each user's preferences, based on their profile. This means that the father can see recommendations consisting of news, dramas, and animations, and the son can see recommendations consisting of animations, dramas, and news. Then, when they choose an item from the recommended list, the selection is highlighted on the TV screen, thereby recognizing the others preferences and opinions. They can also discuss appropriate content from among the recommendations. Furthermore, if the mother, the third user, wants to access the music player, her media service can similarly resolve the service conflict with the TV service. Here, a recommendation list, reflecting the mother's preferences is given to all conflicting users. Thus, the users in a conflict situation can harmoniously choose an item from the recommendation list so as to solve the conflict in the shared space.

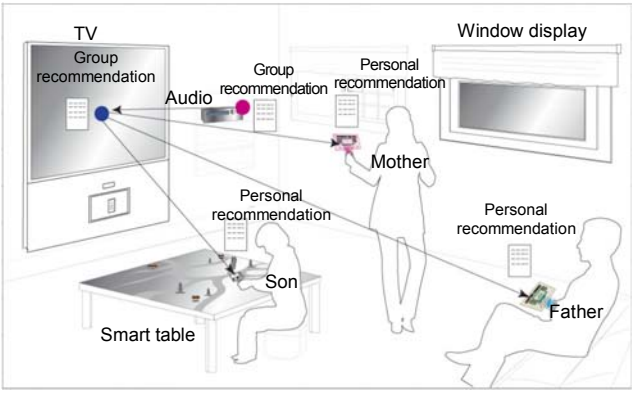

Fig. 2. Example of the proposed conflict resolution.

III. Unified Context for Media Service

In order to manage service conflicts, we have adopted the unified context, which describes each users contextual information and their environment based on who, what, where, when, why, and how components (5W1H) [11]. Each component includes several context elements describing detailed information, and this representation is useful for describing the contextual information of the structured architecture. Here, we apply this representation to describe a user accessing a specific media service. The representation includes user profiles such as the user's preferences and identity, as well as the profile of the media service, such as the required resources, service status, action, and so on. Such context information can be easily obtained from previous context-aware media services already defined in previous context-related research [12], [13]. In terms of conflict management, Table 1 shows each part of a unified context which describes a user accessing a specific media service.

As can be seen from Table 1, the context elements used in conflict management are who, what, when, and how. The who component includes user profiles such as user identity, user preferences, and his/her neighbors. The what component describes properties of a specific media service such as the identity of the media service, a set of content items, resources, service status, an action, and the absolute time. The when component represents the time at which the unified context is created. The how component describes how a control object is used in the interaction and the extent to which the object can effect the scenario. Here, the where component describing the location of a user is not used because we assume that the conflict occurs in a relatively small space. The why component is used to describe the user's internal states such as intention, emotion, and attention. This component is also excluded due to the assumption that the what component includes an action corresponding to such states, plus other information regarding context-aware service, before conflict management occurs. All context components except for why and where components

Table 1. Unified context for describing a user accessing a specific media service.

Context components (elements)		Description
Who	User	A unique identifier indicating a user implicitly or explicitly giving a command to the media service.
	UserPreference (UP)	A function mapping the ContentItems to user preference values, represented as an M: 1 relation. The values range from 0.0 to 10.0, with 10.0 being the highest preference.
	NeighboringUsers (NU)	A set of users sharing the MediaService with the User.
What	MediaService	A unique identifier indicating a media service generating this unified context.
	DeviceName	A device where the MediaService is deployed. Each media service utilizes the resources of the device.
	ContentItems	A set of identifiers for contents that the MediaService provides.
	Resource	Resources that the MediaService needs for providing its media services, represented as a set of resources. According to the MediaService, more than one resource can be included.
	ServiceStatus	The current status of a media service. The state is one of values {on, off, pause, waiting}.
	Action	A command given to the MediaService. The value is one of states {play, stop, pauses, reverse, recommend, wait}.
When	AbsoluteTime	The time when the unified context is generated from the MediaService.
How	Manipulation	An object used in the interaction to control the MediaService.
	Target	An item of the User on a particular item selected from the recommended contents.

are used in conflict management.

In conflict management, this representation is used to describe several ways users interact with media services in specific situations. First of all, it represents a user approaching a specific media service. The description includes which media service he is interested in, what kind of actions he requires of the media service, and his preferences. Such information falls into the who, what, how, and when components. The current status of a media service is also described. This description includes the state of the media service, the occupying users, their preferences, necessary resources, and so on. Furthermore, the control and selection a user explicitly gives to a particular media service is described. The control is a triggering action given to the media service, and the selection is a choice based on a given recommendation. These descriptions include the user's preferred media services and a specific control or a selection. The who, what, and how components are used to describe such information.

IV. User-Centric Conflict Management for Media Services

To detect and resolve media service conflicts among users, the conflict management method introduced in section III is proposed. It collects and deals with unified contexts in three steps: conflict detection, service recommendation, and service mediation. In conflict detection, it collects unified contexts and determines whether service conflicts exist among the users. In the case of service recommendations, it generates a recommendation list of media contents based on the user preferences included in the unified contexts. This recommendation list is then used in service meditation to allow multiple users to consensually select an item, thereby overcoming the conflict situation. Figure 3 shows the overall procedure of the proposed conflict management method.

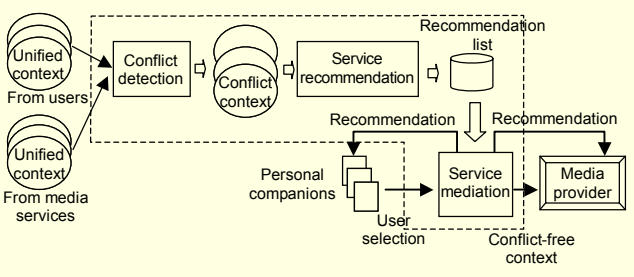

Fig. 3. Overall procedure for conflict management.

As shown in Fig. 3, the method gathers unified contexts from two kinds of sources to detect possible service conflicts: unified contexts describing users accessing the same media service, and unified contexts describing users who want to access different media services. If service conflicts are detected from these contexts, a list of items is generated for the conflicting users by summing and normalizing their preferences. The method starts to mediate the users' selections by highlighting user inputs on a shared screen so that the users' choices can be visualized until the users consent to an item from the recommended contents. During mediation among the users, the recommendation list can be continually updated with the preferences of new users who are trying to use the same

service. Finally, a conflict-free context is obtained as a result of the service mediation, and delivered to the media service provider.

1. Conflict Management

A. Conflict Detection

The unified context includes the user's contextual information and the media service profile. Most context-based media services utilize context information to provide users with relevant information or services [14]-[16]. The proposed method is designed to intercept the contextual information delivered to the media service providers and exploit the contexts generated from other context-based media services to detect service conflicts among users who want to access different media services.

As an example, let a set of unified contexts describing users and their preferred media services be the active contexts in a specific media service (ACS). The ACS can be further divided into two parts according to the users attempting to access the media services: the unified contexts of users accessing a specific media service (MCS) and the unified contexts of users occupying other media services (OCS). Service conflicts are detected by (1) with ACS, a set of collected unified contexts of the users in the specific media service.

$$\begin{aligned}&\mathrm{ServiceConflict}(C_A, C_S)\\ &\Leftrightarrow \{\mathrm{User}(C_A) \neq \mathrm{User}(C_S)\\ &\quad \wedge \neg\exists x{:}(\mathrm{PreferredItem}(C_A, x) \wedge \mathrm{PreferredItem}(C_S, x))\}\\ &\quad \vee \{\mathrm{MediaService}(C_A) \neq \mathrm{MediaService}(C_S)\\ &\quad\quad \wedge (\mathrm{Resources}(C_A) \cap \mathrm{Resources}(C_S) \neq \varphi)\},\end{aligned} \tag{1}$$

where C_A is the unified context of a user belonging to ACS, describing the users accessing the media service or accessing other media services; C_S is the unified context of the currently active service state as the result of another action initiated from a user; User(C_A), MediaService(C_A) and Resource(C_A) return an identifier of the user and the media service and the set of resources described in C_A and C_S, respectively. The PreferredItem(C_A, x) and PreferredItem(C_S, y), obtained from (2), respectively return items x and y, having the highest preference from among the set of media contents in each C_A and C_S.

$$\begin{aligned}&\mathrm{PreferredItem}(C, x)\\ &\quad \Leftrightarrow \exists x \,\forall y : \mathrm{UP}(C, x) \geq \mathrm{UP}(C, y),\end{aligned} \tag{2}$$

where x and y are elements of the ContentItems of a particular media service. UP(C, x) and UP(C, y) respectively return preference values which correspond to particular items x and y of the unified context C.

Thus, service conflicts are detected if a user's preferred media items are different from those of others using the service, in a situation in which more than one user attempts to access the same media service. Service conflict is also detected if different media services access the same resources. In other words, we can obtain a conflict list consisting of unified contexts belonging to ACS if ServiceConflict(C_A, C_S) returns true; otherwise, no service conflict is detected.

B. Service Recommendation

Service recommendations generate a list of media items to be given to the conflicting users. The order of the items on the list is determined based on user preferences and the deviations of user preferences. Recommendations proceed in three steps: rating media content regarding one media service, selecting one media service for recommendation, and rating items of different media services. In the first step, the proposed method obtains a list from the unified context which describes all users accessing the same media service by maximizing group preferences and minimizing deviation of the preferences. Hence, we can rearrange the items of media content by applying the group preference (GP) and deviations of the group preference (DGP) to individual preferences. Note that the GP is a function mapping each item of ContentItems to a degree of preference in a range from 0.0 to 10.0. It is obtained by summing and normalizing the user preferences, as follows:

$$\mathrm{GP}(\mathrm{Item}) = \frac{1}{|\mathrm{MCS}|}\sum_{C \in \mathrm{MCS}}^{N} \mathrm{UP}(C, \mathrm{Item}). \tag{3}$$

The DGP is the mean square error (MSE) of the individual user's preferences against GP. Equation (4) shows the DGP of the media contents:

$$\mathrm{DGP}(\mathrm{Item}) = \frac{1}{|\mathrm{MCS}|}\sum_{C \in \mathrm{MCS}}^{N} (\mathrm{UP}(C, \mathrm{Item}) - \mathrm{GP}(\mathrm{Item}))^2. \tag{4}$$

Consequently, the media item having the smallest MSE has a lower deviation than other media contents. This means that an item having a lower preference distribution has a lower deviation than other items, even though they may have the same group preferences. With (3) and (4), we can obtain a new item list consisting of {(Item, Preference)$_{(0)}$, (Item, Preference)$_{(1)}$,…, (Item, Preference)$_{(K)}$} ordered by GP and DGP. Thus, a unified context which includes the items and its neighbors can be obtained and added to OCS for further recommendation.

Next, service recommendations prevent more than one media service recommending the same media contents. To achieve this, the service recommendation decides on one appropriate media service to recommend items with an

absolute time, the time at which the media service was activated. Therefore, the media service that was activated earliest has the highest priority in service recommendation. The remaining media services then deliver their item lists, as obtained from (4), to the selected media service from among the other potential media services.

In a recommendation involving different media contents, the conflict management method determines the recommendation order of the media contents of the media services. This step is only required when a list of media contents consists of different types of media services. For this purpose, we introduce a utility function for determining item precedence with respect to the number of users and their preferences. The utility is normalized based on the total number of users involved in the service conflict. Therefore, the utility of each item is defined by the number of users multiplied by their user preferences, and then divided by the total number of users involved in the service conflict, defined as

$$\text{Utility(Item)} = \frac{(|\text{NU(C)}|+1) * \text{UP(Item, x)}}{\sum_{\text{C}\in\text{OCS}} (|\text{NU(C)}|+1)}, \qquad (5)$$

where NU(C) returns a set of neighbors accessing the same media service, and the integer 1 is the default user described in the unified context C belonging to OCS.

As such, items in the media service and in other media services can be reordered based on the utility of (5). The item with the highest utility is located first in the recommendation list. By applying the utility of the items, we can obtain a recommendation list consisting of {(Item, Preference)$_{(0)}$, (Item, Preference)$_{(1)}$,⋯, (Item, Preference)$_{(L)}$} ordered by the utility, where L is the total number of media contents of the media services in which the users might be interested. Finally, a unified context including the items and the neighbors are obtained as a recommendation.

C. Technically Augmented Social Mediation

Finally, the proposed method mediates user inputs to permit the media service to only react to items that all conflicting users agree on and to retain consistency when dealing with multiple individual input devices. Mediation is an arbitration technique widely used in making a correct decision when the application cannot make such a decision by itself [17]. The technically augmented social mediation handles potentially conflicting user inputs from multiple input devices to obtain the consent of users to one of the recommended items. During the final decision, the mediation collects the users' selections and decides whether the users agree on a specific item of the recommended items. For this purpose, it utilizes three parameters to make a final decision from among multiple inputs because the media service cannot guarantee that all users have provided inputs corresponding to the recommendation. Mediation parameters include IndividualWeight, DecisionThreshold, and DecisionTimeout.

IndividualWeight refers to the weight of an individual user input. The IndividualWeight is assigned when mediation starts with a recommendation. The weight is also assigned differently according to users and policies because a user's selection is not always the same. The weight is divided by the number of users who are in conflict if they have an equal right to make a decision; if a particular user has a higher precedence in decision-making, that user has a higher weight than other users.

ThresholdWeight refers to the time when a final decision is made. We assume that all users have agreed on one selection if the sum of the IndividualWeights is greater than this value. The threshold value is determined according to users and policy. In the case of majority rule, the threshold is half the maximum weight. Therefore, if the sum of the IndividualWeights is greater than half of the threshold, the final decision is made according to the majority rule. When there is a policy which requires the consent of all users, the threshold is set to the maximum weight. Consequently, the final decision is made if all users consent to an item. In addition, all inputs from the same user are considered to be one input.

DecisionTimeout is a waiting period until a final decision is made automatically. The timeout is used to end a mediation process ahead of schedule as no more user input is entered. Users need a time buffer for coordinating their choices with others, even if they can easily select their preferred contents from among the recommended media contents. This is because there are other residents sharing media services in the room. Consequently, with a time buffer, the mediation automatically assumes that the users agree on the current media content as a conflict resolution.

Based on these parameters and the recommendation list, the proposed method starts to mediate user inputs. It distributes the recommendation list to both the users and the media service provider. As a result, the recommendation list is displayed on a shared screen and each user's preferred content list is shown on each user's personal companion as well. Therefore, users see not only their own preferred content, but also the other users' preferences. Each user can then select an item from the recommended contents. If an item is selected from the recommended contents, the unified context including user identity and selection is delivered to the media service.

By collecting the unified context, the mediator highlights a selected item to visualize the user's choice to the other users. It continues to visualize the user's choice to other users, if the

sum of the weight is less than the DecisionThreshold and the DecisionTimeout has not yet expired. Otherwise, it makes a final decision if the sum of the weight is greater than the DecisionThreshold or the DecisionTimeout has expired. As a result, the method generates a context containing the user's choice and delivers it to the media service provider. Consequently, by allowing the users to express and share their preferences, they can enjoy a consensual service.

2. Personal Companion

When a conflict occurs, users involved in the conflict need to be notified. As an interface between the media service and the users, we have introduced the personal companion. Each user has a personal companion to interact with services, which receives recommendation information whenever its user causes or encounters a service conflict with other users. It also generates a personalized recommendation list onto a user interface by exploiting the user profile from the obtained recommendation information. Figure 4 shows the overall architecture of the personal companion.

The personal companion receives recommendation information as a unified context from a conflicting media service. It refines and tailors the obtained recommendation list into a personalized recommendation list by utilizing the user profiles on the conflicting media service. It constructs the personalized recommendation list by including items of the user's interests and excluding any irrelevant items. The items on the personalized recommendation list are then sorted based on the user's preferences, such that a highly preferred item is placed at the top for easy access. After constructing the personalized recommendation, user interface (UI) generation graphically represents the recommendation list and each item is mapped with its corresponding commands and content. Whenever a selection is made in a conflict situation, the unified context is transferred to the conflicting media service to notify it of the selection.

Based on the recommendation, the personal companion presents a subset of possible control parameters to guide the user to a conflict resolution. The recommendation list essentially serves as a constraint on a user's actions to maintain a controlled and tractable manner.

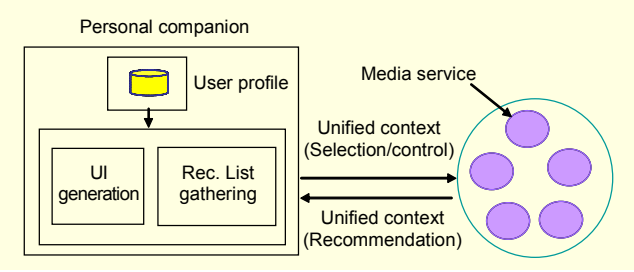

Fig. 4. Architecture of the personal companion.

V. Implementation

In order to take advantage of the rapid prototyping of context-aware applications, we utilized ubi-UCAM 2.0, a unified context-aware application model for ubiquitous computing environments, which supports independence between sensors and services [16]. Specifically, the proposed method was implemented as a part of the context manager, a component for managing unified contexts and connecting them with the service provider of ubiService, a context-aware service in the application model. Figure 5 shows the implementation of the proposed conflict management framework embedded in ubi-UCAM 2.0.

As shown in Fig. 5, the conflict manager gathers unified contexts from the context integrator [18], a component which collects and integrates contexts from users, sensors, and other media services to generate the unified contexts of individual users. The conflict manager detects potential service conflicts from the collected unified contexts after context matching. If service conflicts are detected, it then tries to resolve conflicts

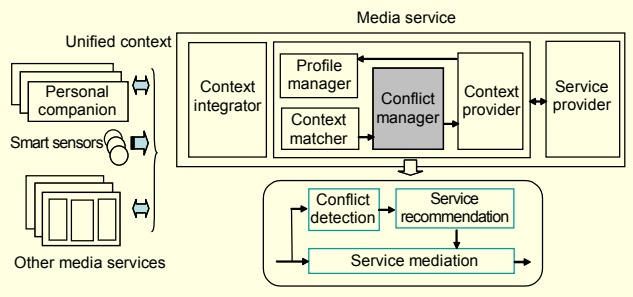

Fig. 5. Implementation of the proposed conflict management framework.

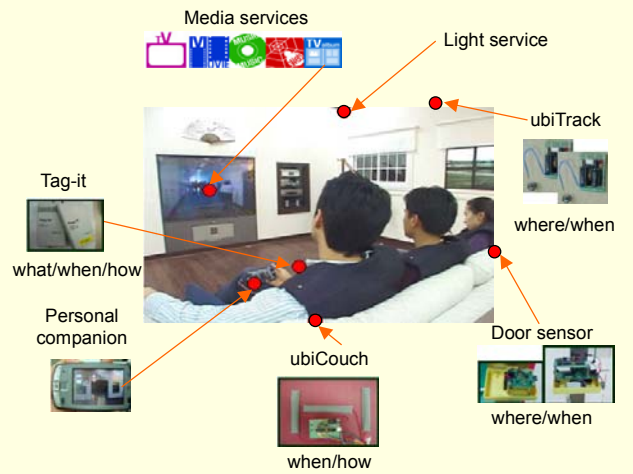

Fig. 6. ubiHome testbed.

by recommending and mediating users' preferred media contents. After conflict resolution, the conflict manager delivers a unified context containing the users' selected service as a conflict-free context to the context provider, a component which delivers contexts to the service provider and other media services.

As shown in Fig. 6, we then extended ubiService to several media services in ubiHome, consisting of five media services, namely, a TV service, a movie player, a music player, a web service, and an album service.

These services utilized the outputs of various kinds of contextual information obtained from smart sensors in a ubiHome: ubiCouches, a door sensor, and ubiTrack [19]. The ubiCouches are couch sensors comprised of on/off switches and a micro controller, to detect users' movements on a couch. The ubiTrack is an infrared-based location tracking system that tracks users' location in a smart home. In addition, we implemented a personal companion based on the ubiController, a situation-aware mobile user interface for ubiquitous computing environments [20]. The personal companion, a modified version of ubiController, primarily gathered the recommendation information and displayed it on the screen of the mobile device. In this way, users were allowed to explicitly control these media services and react to given recommendations.

With the various sensors and their convenient personal companions, residents have the ability to implicitly and explicitly interact with various context-aware media services in a smart home. For instance, a conflict occurring between family members wanting to share media services is managed by the conflict management method.

For instance, recall the previous scenario in which the father and son both wanted to access the TV service, and the mother wanted to access the music player. The father's preferences are {(news, 9), (drama, 7), (animation, 1)}, while the son's preferences are {(news, 5), (drama, 8), (animation, 9)}. When (1) and (2) are applied, the result is that the father's preferred item is "news" with a preference weight of 9, and the son's preferred item is "animation" with a preference weight of 9. Therefore, the TV service detects a service conflict between the father and son; the father has a high preference on "news", whereas the son has a high preference on "animation." In addition, there is another user, the mother, with the following preferences: {(classical, 9), (dance, 6), (jazz, 5)} on the music player. When the mother approaches the music player, it recognizes her preference of classical music before starting the service.

In this case, the music player delivers a wait notification to the TV service, to indicate that a shared resource is required. The TV service then attempts to detect the service conflict between the two contexts. According to (1), the media service occupied by the father and son is different from that of the media service accessed by the mother. Moreover, there is a shared resource, sound. Thus, the TV service detects a service conflict with the music player due to the sound resource. As a result, the TV service obtains the unified contexts from the users accessing the TV service, and also the unified context of the mother who is trying to access the music player.

Subsequently, the updated recommendation list consists of {(drama, 7.5), (news, 7), (animation, 5)} based on the preferences of two of the users. After conflict detection, there are two unified contexts in the TV service. The unified context for accessing the TV service represents two users and the unified context for accessing the music player represents one user. Then, in terms of the TV service, the utility of "news" is 15; derived from 2, the number of users, multiplied by 7.5, the user preferences of the father and the son for the item, according to (5). Similarly, the utility of "drama" and "animation" are 14 and 10, respectively. The utility of "classical" is 9, from 1 multiplied by 9, the user preference of the mother in the music player. Similarly, the utility of "dance" and "jazz" are 6 and 5, respectively.

To normalize these results, the utilities are divided by 3, the number of users. As a result, we can obtain a recommendation list consisting of {(drama, 5), (news, 4.7), (animation, 3.3), (classical, 3), (dance, 2), (jazz, 1.7)} ordered by the utility of each item.

Based on the recommendation information, the TV service starts to mediate while displaying available contents ordered by the users' preferences on the screen of their personal companions.

As shown in Fig. 7(a), the list of recommendations for the three users is shown on a TV screen. At the same time, each user's personal companion displays his/her preferred items, as shown in Fig. 7(b). Then, based on the mediation, they acknowledge the others' preferences through the recommended information. After discussing their preferred media contents with the recommended contents they subsequently decide on an appropriate program, thereby overcoming the conflict situation.

(a) TV screen (b) Personal companion

Fig. 7. Recommendations on (a) a TV screen and (b) a personal companion.

VI. Experiments

In the following experiment we wanted to obtain a firsthand impression of how users react to recommendations and mediation. In order to achieve this task, we surveyed the behavior of users regarding their use of the media services in a smart home environment. The experiment was based on two different scenarios with 20 people between the ages of 20 to 35. In the first scenario (ordinary TV watching) we tried to create a relaxed atmosphere as in a home environment. The participants were told to make themselves comfortable in the ubiHome (cookies and fruits were provided) and to do the things they would normally do when they come home from work or school. No service recommendations were given and only an ordinary remote control was provided. The second scenario was designed exactly like the first, with the main differences being that a recommendation list with the statistical means of the users' interests were displayed on both the TV and on each user's personal companion, the new device for mediating the input for the TV service. We assigned each user the same IndividualWeight to ensure that individual input was based on a majority rule. The value of the DecisionTimeout was set to 30 seconds, a reasonable period of time for gathering user inputs from novice users.

We also designed two questionnaires for the scenarios, in which the participants were asked to provide their responses during each experiment. In the first questionnaire we were primarily interested in determining the user's normal behavior regarding TV usage at home with their families. Additionally, we were interested to know if family members verbally fought over TV programs, and how satisfied they were with the decisions made about TV content at home. In the next questions, we took a closer look at the service recommendations and mediation. The goal of this technique was to support and enhance the normal behavior of family members in the decision-making process. The questions investigated the role of the recommendations and the mediation technique in supporting the ability of multiple users to make a decision which would be satisfactory for all users.

1. User Study on Ordinary TV Watching

First, we evaluated the questions regarding common TV usage in the participants' homes. Table 2 shows the questions for participants in scenario 1.

As shown in Table 2, it is evident that families fight about TV content to different extents, though this includes the fact that no user answered that his/her family does not fight over the TV content. This clear result shows that a primary goal for TV applications should be to prevent fights in families, and thus create a harmonious TV experience for all members.

Table 2. Question 1 for scenario 1.

(%)

	Questions	A	B	C	D
1	How often does often your family verbally fight over TV programs?	10	30	60	0

A: A lot, B: Sometimes, C: Occasionally, D: Never

Table 3. Question 2 for scenario 1.

(%)

	Questions	A	B	C	D
2	How do you feel about the TV decision-making process at home?	30	50	15	5

A: I get what I want, B: It's a trade-off, C: I sometimes feel passed over, D: I often feel passed over

As shown in Table 3 it seems to be common in families that the decision-making process regarding TV content is a trade-off between all family members. Additionally, the evaluation showed that 20 % of all participants felt passed over in the decision-making process.

Therefore, these results provided us with two important indications for our work. First, it seems to be common for program selection to be decided on a trade-off between family members, which could be easily supported by our proposed recommendation technique. The recommendation displays the mean of all conflicting users' interests and can easily assist family members in making a fair decision. Second, it is important to consider that family members feel passed over in the decision-making process of TV content. This feeling can also be lessened with our proposed recommendation list, displaying other users' interests and informing them of others' content wishes, too. Additionally, with personal-companion-based mediation as an equitable input device, family members can express their preferences to others, making it harder to ignore another person's content preferences.

2. User Study on Personal-Companion-Based Mediation

In the next questionnaire, we asked the participants before and after they experienced the second scenario about their view of personal-companion-based mediation as an example of a technically augmented social mediation. Our main interest was to determine if personal-companion-based mediation provides an equitable input device that can help all family members make harmonious decisions.

As can be seen in Table 4, question 3 clearly shows that the majority of the participants (60 %) responded that the personal-companion-based mediation provides an equitable input device. This result strengthens the idea that technically augmented

Table 4. Questions before scenario 2.

(%)

	Questions	A	B	C
3	Do you think that personal companion-based mediation can prevent one person from dominating the program decision-making process?	60	20	20
4	What do you think about personal companion-based mediation?	60	10	30

A: Positive answer, B: Don't know, C: Negative answer

Table 5. Questions after scenario 2.

(%)

	Questions	A	B	C
5	Did the recommendation help you to discuss program options?	70	10	20
6	Did the recommendation help you to make a satisfactory decision?	60	30	10
7	Did the recommendation list help to prevent verbal fights?	60	40	0

A: Positive answer, B: Don't know, C: Negative answer

mediation can prevent family members from feeling passed over in the TV content decision-making process. In question 4 we wanted to determine the general opinion of the users regarding personal-companion-based mediation (an instance of technically augmented social mediation). Our concern was that most people would find it boring and disturbing to use multiple personal companions as input devices for a context-aware TV service.

However, our evaluation showed that most people liked personal-companion-based mediation (60 %) and will accept this new equitable input device. Only 20 % answered that it is too laborious to use. This result indicates that personal-companion-based mediation is an acceptable approach for providing equitable input, but that we should consider the fact that some users felt disturbed by this new mediated input technique.

After the observation of the users in the second scenario, we observed that the recommendation list encouraged people to discuss each other's interests. As soon as the recommendation list was displayed on the TV screen and on the personal companion, most participants immediately started to talk about the recommended content. Additionally, we directly asked the participants what they thought about this new technique.

Table 5 shows the participant's answers to the questionnaire. According to question 5, 70 % of the participants answered that they felt supported by the recommendation list in the discussion process. This indicates that the visualization of other people's interests enhances the discussion. However, aside from merely determining whether there was support for discussing the TV content, we were additionally interested to know if the recommendation technique could assist users in the decision-making process. Discussion is only the first part of selecting satisfactory TV content for families. The goal of the recommendation list is to support discussion that allows for a fast and convenient decision to be made. The whole process should be supported by visualizing each family member's preferences.

Analysis of the results confirms that 60 % of the participants in the experiment felt that the recommendation list supports the decision making process, as shown in the results of question 6. This seems to indicate that the recommendation list is a proper technique for harmoniously choosing the TV content in a home environment.

In the last question we directly asked the participants if they thought that the recommendation list could prevent verbal fights over TV content. This would be an important factor in harmonizing the selection of TV content between multiple family members. The responses to question 7 clearly show that most users think that verbal fights can be prevented, though a more interesting observation is that no one disagreed with this assertion. Accordingly, it seems that recommendations and mediation can be used to harmoniously resolve conflicts between multiple users.

VII. Conclusion

In this paper we proposed a user-centric conflict management method which exploits the use of personal companions to resolve media service conflicts among multiple residents in a smart home. The proposed method was found to detect service conflicts and recommend harmonized service contents based on users' preferences and service profiles. Through experimental analysis, we determined that discussion and mediation among residents are meaningful in resolving conflicts between users and that the proposed method can provide support for making a harmonious decision. Residents can be made more aware of service conflicts and other residents' preferences through the recommendations. In addition, most participants expressed the opinion that discussions and mediation are useful in resolving their service conflicts. Therefore, the proposed method has the potential to play an important role in resolving service conflicts among residents by considering the preferences of all users.

In future work, we will investigate conflict resolution among users to observe changes in resident's preferences and habits. In addition, we want to take a closer look at dealing with conflicts by considering ambient applications such as light or temperature. Furthermore, we will enhance the recommendations to efficiently provide users with related information according to their context.

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