Modelling User Behaviour and Experience – The R2D2 Networks Approach

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Abstract. The rapidly increasing importance of multimedia services delivered over telecommunication networks has heightened the need for technologies that adapt efficiently to users' needs. It is of particular interest to understand users of such services. This paper proposes a unified approach to modelling users' behaviour and experiences in the context of new multimedia services. Static information on users' behaviour is integrated with users' real-time feedback about their experiences. A unified user profile is used for implementation of a media-aware, user-dependent, self-adaptive network resource manager. Our first experience shows that such a unified approach might be beneficial for network and service providers. The tool for gathering real-time user experience, we propose, might also be useful in other contexts, such as personalised content recommender systems.

Keywords: Quality of Experience, User Experience, User Profiles, Multimedia Services, User Feedback.

1 Introduction

The use of multimedia services delivered over telecommunication networks is becoming increasingly widespread. With triple-play services (IPTV, IP-telephony, and Internet), households have all their services delivered through a single broadband access link. Household members expect all of their services to work perfectly all the time, in spite of technical limitations. The R2D2 Networks project aims to make this possible by developing media-aware, user-dependent, self-adaptive networks [1]. To enable development of a self-adaptive network that dynamically changes in accordance with user behaviour and satisfaction, we need: (i) to gather knowledge on users, their behaviour, and experiences both a priori and in real-time, and (ii) to communicate this knowledge to the network manager. More specifically, we impose the following requirements on the information on users and usage:

- Usefulness. The provided information should be useful for different stakeholders in the telecom and media industry, including customers, market researchers, network planners, system managers, and service/content providers.
- Usability. The provided information should be in a format that is easy to use by humans and/or to transform into machine-readable forms.

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- Comprehensiveness. The provided information should describe different characteristics of users and types of their behaviour, such as answering the questions: who they are, where they are, which services they are using, etc.
- Granularity. The provided information should describe users' behaviour within different time spans (per hour, per day, per week, per year).
- Openness. The provided information should describe the events outside the network that might influence users' behaviour, such as the Olympic games.
- Correlation. The provided information should describe correlations between its different dimensions, e.g., types of services used by different age groups.
- Promptness. The provided information should capture real-time changes in user behaviour.

Whereas our previous work describes the studies we have conducted to understand users' behaviour [2, 3], this paper proposes a unified user profile, called the R2D2 Unified User Profile, as a means for communicating knowledge about users to the network manager.

This paper is organised as follows. Section 2 describes related work done in the area of modelling user behaviour. Section 3 proposes the R2D2 Unified User Profile. Section 4 describes the tool we developed for collecting real-time user experience, and Section 5 concludes and proposes future work.

2 Modelling User Behaviour

Modelling users' behaviour patterns has been done in several research areas. It originates from marketing research and aims to provide input to marketing strategies and product design. One widely applied technique is to segment customers by statistical and data mining techniques. It has been pointed out that many studies on user behaviour classify users based on demographic and background data and not on their actual behaviour, although a priori grouping of users is far from being exhaustive [4]. Within media and HCI research, several categorisations of users into distinct user types, called typology of users, have been proposed. In his survey of the field, Brandtzæg [5] analyses 22 media user typologies published from the year 2000. Based on this analysis, the author proposed a classification of user behaviours according to the following dimensions:

- Frequency of use (no use, low, medium, and high use)
- Variety of use (no variety, low, medium, and high variety)
- Content and activity preferences (non-users, sporadics, lurkers, entertainment users/socialisers, debaters, instrumental users, and advanced users)

This user typology is claimed to be universal across different cultures and stable over the time. It might therefore be a valuable framework for cross-country studies and studies of user behaviour over time.

In his study of user behaviour within the context of search engines, Stenmark [6] used log files to identify similar groups of users based on their actual search

behaviour. In his research, he identified the following groups: unsophisticated users, occasional users, fact seekers, interactive users, knowledgeable users, and intensive searchers. Although conducted in a different application domain, this research can provide some input in studies of triple-play and over-the-top services, as there are some similarities in user behaviour. The users of these services can, for example, browse meta-information on TV programmes to decide what they want to watch, or they might want to read a newspaper article behind a video they watched.

Aghasaryan et al [7] propose an architecture for multi-source profiling and multi-application personalisation consisting of three layers: service domains, enablement layer and content personalization applications. This architecture enables a holistic approach to service personalization by offering a means to gather users' behavioral data from several sources in real time.

In the study of P2P IPTV systems, Hei et al. [8] collected numerous statistics, such as: evolution of total numbers of peers in the PPLive network, distribution of peak number of peers among all channels, trend numbers of participating users, peer arrival and departure evolution of a popular movie channel, and peer download and upload video traffic. In their study of video-on-demand over IP, Yu et al. [9] analysed user access over time (hourly, daily, and weekly access patterns), user arrival distributions, session lengths, popularity distribution, rate of change in user interests, etc.

In studies conducted to investigate patterns of ICT users' behaviour in Europe, network traffic data and questionnaires from more than 270,000 individual users and households were analysed [3]. User accesses over time, as well as users' habits, preferences, and motivations, were identified. The results indicated that the daily and weekly profiles are determined, in general terms, by two factors: type of user (residential, academic, employee) and type of access, which basically considers whether it is fixed or mobile and the available bandwidth. Furthermore, the results indicated the stability of users' behaviour across countries and over time, and differences among the access types. The information on user behaviour, based on the network statistics and surveys, allowed the identification of current trends in terms of applications and content being used, as well as the demand for bandwidth.

3 R2D2 Unified User Profiles

A user profile is a collection of personal data associated with a specific user. Such profiles are typically related to usage of a particular web-based application such as Amazon or Google AdWords. Development of a self-adaptive network manager requires more complex user profiles that will take into account use of different services as well as users' experiences with them. We therefore propose the R2D2 Unified User Profile, which integrates a priori and real-time information on users, their behaviour, and their perceived Quality of Experience.

3.1 Data Acquisition

Data about users can be collected at different times, at different places, and by different means. In this context, we find it useful to distinguish between a priori and

real-time data collection. We also make a distinction between collection of information provided by users (explicit data collection) and collection of information by unobtrusive monitoring tools (implicit data collection).

We collect the following information:

- Information about users stored in companies' customer/user database. This includes:
  - Demographic data. This data comes from the customer databases. Although this information might be known on the individual or the household level, it is more appropriate to use the aggregate information about different segments of users (younger, older, males, females, and so on) as is typically done in market research.
  - Data related to their subscription to a service. This data also comes from the customer databases, and describes the types and characteristics of the contracted services. It is used on the individual or household level.
- Information coming from the content provider on events that may influence users' behaviour and network traffic, such as very popular sports events.
- Information about users and usage, either explicitly provided by users or deduced from their ICT usage. This includes:
  - General information about usage of Information Communication Technology (ICT) and media. This information is based on statistics of usage for a particular country or countries. Users are grouped in segments/user types based on their typical behaviour. These types describe users according to their frequency of use, variety of use, typical activities, and typical platform. Examples of such types are: non-users, sporadic users, entertainment users, instrumental users, and advanced users. Based on a simple questionnaire, users are placed in one of these categories.
- Self-defined user profiles. Users can provide information about themselves, their preferences, content they usually consume/produce, and the context of use. Users can update these profiles whenever they want.
- User feedback on Quality of Experience. Users provide their feedback on their perceived quality of experience. This information can be quantitative and qualitative. Whereas quantitative information, such as 'satisfaction with the sound' on a scale from one to five will be used for immediate adaptation of network parameters, qualitative information will be used for understanding the context of performance degradation and priorities related to QoE.
- Information about users and usage deduced from network traffic information. Users are categorised in different groups based on the traffic volume, applications used, and their daily and weekly traffic profiles.

3.2 Overall Architecture

Information about users and usage is used by the Network Manager to adapt the network in accordance with user behaviour and preferences, as well as relevant events. An adaptive system consists of two phases: user modelling and adaptation.

During the user modelling phase, one collects information about users, their usage and context of use, and transforms this knowledge into user profiles. During the adaptation phase, user profiles are used to derive policies that can be included in the subscription profiles: this means that requirements drawn from user profiles are mapped into parameters that can be understood by the network elements. The enforcement of these policies is implemented as a part of the Network Manager and is not described here.

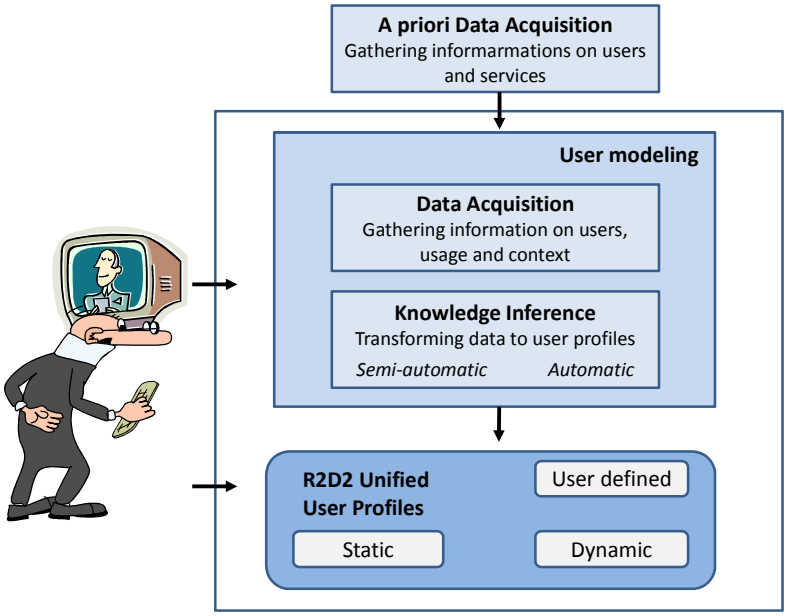

Fig. 1. High level model of R2D2 user modelling and user profiles

Figure 1 gives more details. We distinguish between data collection before usage of a particular service (A priori Data Acquisition) and data collection during the usage of a particular service/application. During the knowledge inference phase, we transform the collected information into user profiles. This can be done semi-automatically or automatically. The user profile consists of three parts: user-defined information, and static and dynamic information. User-defined information will typically be information on preferences and context given by users, such as 'football fan' or 'watching TV at home'. Static information is information that is relatively stable, such as a contracted Service Level Agreement. Dynamic information is information that changes in real-time, such as perceived QoE. User preferences and patterns of usage change over time and users may, for example, move from being sporadic users to being advanced Therefore, their profiles will have to be updated accordingly on a regular basis.

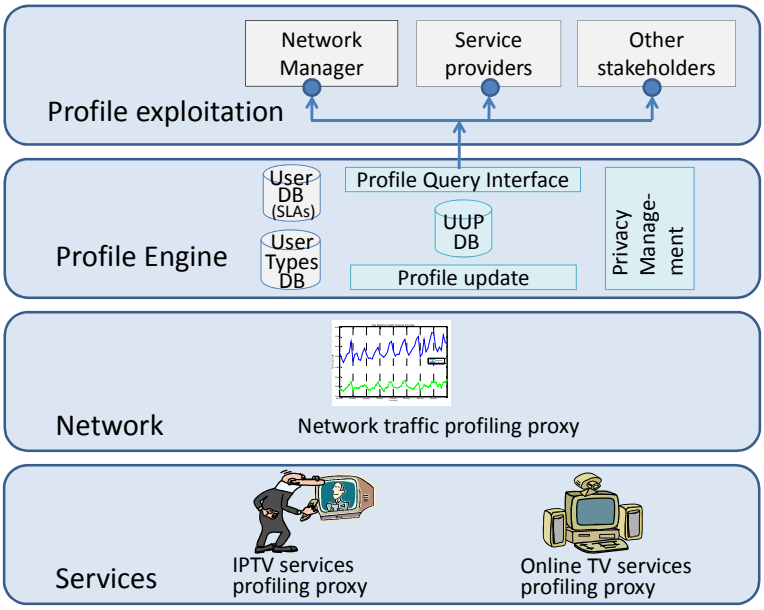

Fig. 2. High level model of R2D2 user modelling and user profiles

Figure 2 presents the R2D2 profiling architecture. We propose collection of data on users and usage at all points of the content journey from content providers to end-users, and exploitation of this information by different stakeholders; the architecture is designed to enable this. At the service layer, we have service profiling proxies that collect information on service usage for each service we are considering. At the network layer, we have a network traffic profiling proxy. It collects network traffic data that will be used for generating Unified User Profiles. At the profile engine level, we have:

- Two databases (User DB and User Types DB) populated by the a priori collected data on users and usage
- A Unified User Profiles DB, which is a central component of the profile engine. This is a temporal DB that consists of relevant information from the above-described databases and tables describing real-time users' behaviour
- Profile update component, which is a set of algorithms for real-time and regular updating of user profiles. This component will, for example, analyse daily network traffic profiles for a user once a week and update his category accordingly. For example, it might include a statement such as: 'if average downlink daily traffic > 3700 MB and number of applications > 20 then user_type := "advanced user"'. It will also respond to users' feedback on QoE in real-time and update the relevant information. For example, it might include a statement such as: 'if sound quality < 4 and video quality < 4 then QoE_action := "immediate intervention"'.

- A privacy management component, which addresses access rights to different information by different stakeholders. The end-user/customer should be able to easily and clearly define who has access to what data. A user can, for example, view his automatically-generated profile and decide which parts of the profile will be available to the network provider. Furthermore, as we envisage that different providers will collaborate in order to deliver the best possible service to the end user, their access to each others' data has to be limited and in accordance with their mutual agreements. For example, an online-TV provider can have access to the top 10 viewed programmes from its own production, and access to the general interests of a user (football, movies…), but not to the QoE problems related to their competitor.
- A Profile Query Interface, which allows different stakeholders to consult R2D2 Unified User Profiles. Network Manager, for example, will be interested in information needed to adjust network parameters, whereas content providers will be interested in information related to content consumption and production.

At the Profiles Exploitation level, different stakeholders can develop their own applications allowing them to view information they are interested in and to produce different reports. The focus of our research was on enabling a self-adaptive network manager, and therefore we only implemented the Network Manager component of the Profile Exploitation Layer. At the Profile Engine Layer, we had no need for the Privacy Management component at this stage of the project. More details on the implementation and evaluation of the network manager and its evaluation can be found in [10].

4 Real-Time Quality of the Experience Collection Tool

To collect Quality of Experience (QoE) as experience by users in real-time, we needed a tool that can do it in a way that allows users to continue with their activities, such as watching TV. Furthermore, we wanted to collect this data in vivo. The approach we have used could be considered a form of experience sampling [11] and feedback collection [12]. The basic principle is that users of a service are asked for their feedback on QoE at different times while using a service. Each such request for feedback is called a probe. Users might be asked general questions such as 'What do you think about the quality of Service X?' or more specific questions such as 'Do you now have better video quality?' Users might answer by rating the quality of the service on a scale from one to five or by describing their experience. Users may also see and comment on the feedback given by other users and by the Network Manager. Depending on the goal of QoE evaluation, the probes can be: i) triggered at random points, ii) triggered at regular intervals, iii) user driven (users provide feedback whenever they have a problem or feel it is appropriate), or iv) event/manager driven (users are asked to provide feedback if something specific happens, such as assigning them extra broadband or fixing problems they experience). The tool enables users to be in dialogue with each other and with their network/service providers.

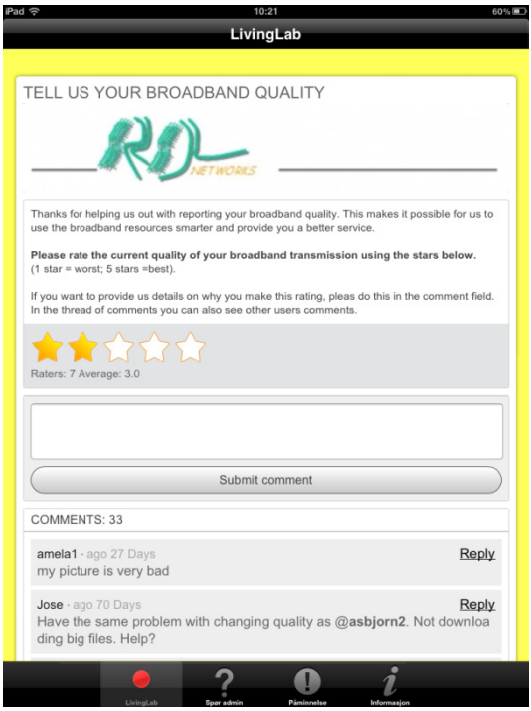

Fig. 3. Example of QoE probes

The tool is currently implemented as an app for iPhone and iPad (Figure 3), available at the Apple AppStore. All feedback collected through the app is stored on a dedicated server for the tool. The feedback is then made available to the R2D2 Network Manager via an XML feed.

5 Conclusions and Future Work

The purpose of this document is to propose an architecture enabling collection and usage of information on users' behaviour and experiences in a common framework: the R2D2 Unified User Profile, and a four-layer enabling architecture. Within our model we collect:

- information about users stored in the companies'/user database, including demographic and subscription data
- information coming from the content provider about events that might influence users' behaviour
- information about users and usage either explicitly provided by users or deduced from their ICT usage, including general knowledge on Information Communication Technology usage, self-defined user profiles, and user feedback on Quality of Experience
- information about usage deduced from network traffic information

We propose a general architecture (R2D2 profiling architecture) where data on users and usage are collected at all points of the content journey from content providers to end-users, and exploited by different stakeholders. At the service layer, we collect information on usage of each service we are considering. At the network layer, we collect network traffic data. At the profile engine level, we have databases populated by relevant information on users and their behaviour, including a Unified User Profiles DB, a profile update component responsible for updating user profiles, a profile query interface, and a privacy management component. At the profile exploitation level, different stakeholders will develop their own applications enabling presentation of the relevant information.

The architecture we propose is similar to the architecture proposed by Stenmark [7]. However, our approach has several novelties: including (a) real-time feedback on QoE, (b) information on usage of services including typology of users based on statistics of ICT usage in Europe and (c) integration of this information with the network traffic information and the subscription profiles. The purpose of the implementation is to test these concepts, and only some parts of the database will be implemented. Other available methods and tools for collecting user experience when using services, such as myServiceFellow [13], or collecting longitudinal user experience over time, such as iScale [14], can easily be integrated with the proposed architecture.

Our future work will include implementation and validation of the proposed model of user behavior and experience, as well as its improvement and refinement.

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