Framework for Interactive Personalised IPTV for Entertainment

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ABSTRACT

Interactive IPTV is seen as the future for delivering TV services as it brings all the benefits of computer-based IP networking to the residential viewers. This paper presents the iPersonal IPTV framework that enhances the existing interactive IPTV solution with viewer-oriented personalisation and network and device-based adaptation. This framework is proposed in order to provide significant benefits in terms of viewers' Quality of Experience and to increase their satisfaction. The iPersonal IPTV framework is exemplified in the area of entertainment distribution to remote residential users.

Categories and Subject Descriptors

H.4.3 [**Communications Applications**]: Computer conferencing, teleconferencing, and videoconferencing
J.3 [**Computers in Other Systems**]: Consumer products

General Terms

Algorithms, Performance, Design.

Keywords

Personalisation, network and device adaptation, IPTV, Quality of Experience, user modeling.

1. INTRODUCTION

Nowadays a fundamental change is taking place in the area of television by a mass migration from analog to digital TV and lately to interactive TV (iTV) that allows the viewers to interact with a multimedia-based application responsible for providing requested services. Simultaneously a sustained increase in residential broadband IP network connectivity is experienced which provides a low-cost high-bandwidth infrastructure and enables the distribution of rich content services based on very popular IP-based applications. This facilitates the distribution of multimedia IP applications, including IP-iTV. Companies such as Magnet Network (Ireland), Microsoft (IPTV), Novamedia (Iceland), Fastweb (Italy) are already offering IP-iTV services, but their widespread success highly depends on both the cost of the service and the viewers' Quality of Experience (QoE).

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In order to reduce the price paid for the IP-iTV service, cable TV operators may determine an increase in the number of viewers served by a given infrastructure. Therefore, the load on the delivery infrastructure increases and significant variations of traffic and/or loss result. These have negative effects on the transfer of multimedia, affecting viewers QoE. The viewers will also want to have access to information through various devices such as TVs, PCs, PDAs or mobiles. In this context if the multimedia content is not tailored for viewer devices, their QoE may suffer.

At the same time, with the presence of many alternative programs, digital TV viewers have access to hundreds of channels with an abundance of shows available and large amount of multimedia-based material that can be retrieved from digital video archives. Consequently, the viewers are exposed to an information overload, they may feel lost in informational space and may perceive a lower QoE. In this situation an informed selection of one's preferred choice is almost impossible. As a result, TV viewers waste a lot of time browsing through available options or end up watching programs in which they are not so interested and missing the ones they would really love to see.

Therefore, given the heterogeneity of viewers, who differ in interests, skills and performance expectations, variability of network conditions and the variety of device types that could be used for accessing the IP-iTV service, it is very clear that the future digital television will have to take personalisation, IP network-traffic variations and device-based customisation issues into account in order to offer high viewer QoE.

This paper presents an ***iPersonal IPTV*** framework that represents a solution to improve viewers QoE in all these situations. iPersonal IPTV system provides multimedia content personalised and adapted in real-time to viewers desire, users network and device characteristics in a solution that complements the current non-adaptive IP-iTV services.

2. RESEARCH ON PERSONALISED IPTV AND ADAPTIVE MULTIMEDIA

Personalisation in interactive and digital television aims in tailoring content to individual viewers by adapting the content based on users characteristics, interests and goals. Various

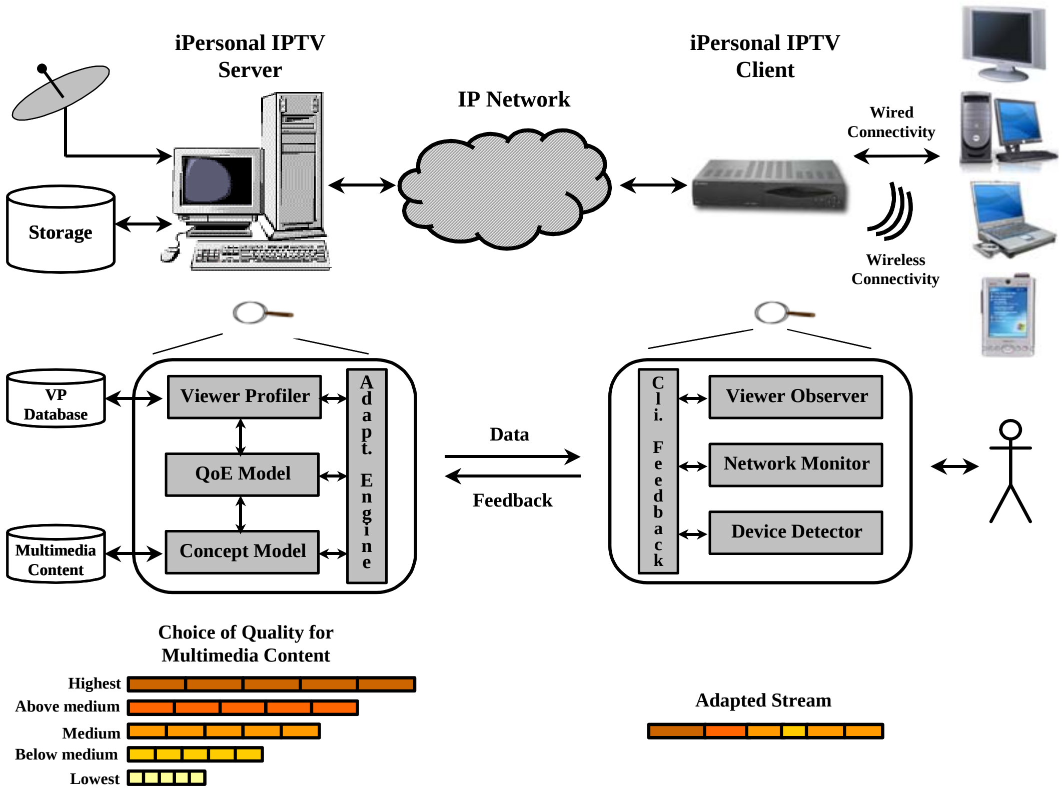

Figure 1. iPersonal IPTV Distributed Solution

researchers within Adaptive Hypermedia, User Modeling and Intelligent User Interfaces communities have focused on proposing solutions for context-aware and situation-aware interactive TV services that enhance the perceived quality of the delivered information.

The main directions of research include:

- the provision of ***personalised Electronic Program Guides*** (pEPG) that prevent viewers from "being lost in TV program space". pEPGs proposed in [1, 2, 3, 4] manage a User Model that stores the estimates of the individual user preferences for TV program categories and channels based on explicit user preferences, stereotypical information about TV viewers and information about the user's viewing behavior.
- the provision of ***context-aware interactive content*** that is personalised based on viewer profiles (e.g. name, gender, age, occupation, favorite channels), location and time [5, 6].
- the design of ***suitable user interfaces*** that enable TV viewers to perform advanced tasks in an intuitive and efficient manner [7].

However none of the proposed solutions takes into consideration the user device and network conditions that may change in time due to increase number of users that start to use the IP-iTV service at the same time. We believe that as various multimedia-enabled devices can be connected to the IP-iTV server, the personalised IP-iTV service should consider the device type in the personalisation process. Also as the companies that will provide IP-iTV are interested in increasing their benefit from assigning an increased number of customers to a given delivery infrastructure, it is expected that the network conditions will vary depending on the number of actual viewers. Consequently content adaptation will be required to maintain viewers QoE at good level.

Research in the area of IP multimedia networking [8, 9] shows that content adaptivity can increase the end-user perceived quality in highly loaded and variable delivery conditions when otherwise loss and variable delays affect the streamed multimedia quality. Different adaptive schemes were proposed in the literature and they were mainly classified according to the place where the adaptive decision is taken [10]. *Source-based adaptive control techniques* require the sender to respond to variations in the delivery conditions. Among them there are solutions based on probing tests [11], throughput model (e.g. TCP-Friendly Rate Control Protocol (TFRCP)-based adaptive scheme [12]) and heuristic knowledge, experimental testing and models (e.g. Rate Adaptation Protocol (RAP) [13] and Layered Quality Adaptation (LQA) [14]). *Receiver-based schemes* provide mechanisms that allow for the receivers to select the service quality and/or rate, such as Receiver-driven Layered Congestion Control (RLC) [15]. Among the *hybrid adaptive mechanisms* that involve both the sender and the receiver in the adaptation process, very important is the Quality-Oriented Adaptation Scheme (QOAS) [8, 16] that uses estimated end-user perceived quality in the adaptation process. *Transcoder-based solutions* focus on matching the available bandwidth of heterogeneous receivers through transcoding or filtering [17].

3. iPersonal IPTV FRAMEWORK

The proposed ***iPersonal-IPTV*** framework involves multimedia content selection and adaptation based on delivery conditions, viewers' interests and type of devices used. It enables distribution of personalised interactive multimedia content via an IPTV infrastructure and consists of a client-server solution (Fig. 1).

The server side includes the Viewer Profiler (VP), QoE Model (QoEM), Concept Model (CM) and Adaptation Engine (AE). VP models viewers' characteristics in terms of their interests, demographical data, history of visualised content and topics, access device, network connectivity and current status, saving viewers' profiles in a database. CM hierarchically organizes multimedia content in four levels: abstract concepts, topics, multimedia items and different quality versions (Fig. 2) and defines relationships between them such as link, exclusive and prerequisite. QoEM, based on both viewer profile and the concept hierarchy, makes personalised suggestions related to multimedia content characteristics. AE controls the adaptation of streamed multimedia content based on these QoEM suggestions as well as the reception of client feedback. This feedback is used to regularly update the viewers profile such as at any moment the most up-to-date information about the delivery performance and viewer QoE is available for taking the best adaptive decisions.

The client side includes: Viewer Observer (VO), Network Monitor (NM), Device Detector (DD) and Client Feedback Unit (CF). VO acquires data for the initialization of the server-located VM such as demographical data, subjective preferences, etc. and monitors the viewer behavior such as content selection, play, abort, etc. NM observes network performance-related parameters that include delay, jitter and loss and describes the status of the transmission medium. DD detects the characteristics of the used device. CF receives reports from VO, NM and DD, computes feedback grades and regularly sends them to the server.

We propose an adaptation mechanism that involves two phases:

- ***coarse grained adaptation (personalisation)*** used to select multimedia items and their versions that match viewer's interest, device and delivery conditions
- ***fine grained adaptation*** that seeks to optimise viewer perceived quality of a multimedia stream in real-time over the period of transmission through dynamic adaptation.

Real-time adaptive multimedia streaming involves adjustments of both multimedia quality and transmission rate so that it maximises viewers' QoE in existing delivery conditions. It is more beneficial to apply a controlled reduction in the quality that consequently reduces the quantity of multimedia data to be streamed than to allow random losses and increased delays to affect the viewers' QoE. Fig.1 indicates how from five different quality versions of the same encoded content, an adapted stream is sent to a viewer. These versions may have different encoding parameters such as the resolution and/or frame rate. They can be pre-encoded if there is enough storage space at the server for the case of non-real-time transmissions, generated on-the-fly for real-time transmissions or automatically trans-coded to the desired bitrate when streaming pre-recorded material.

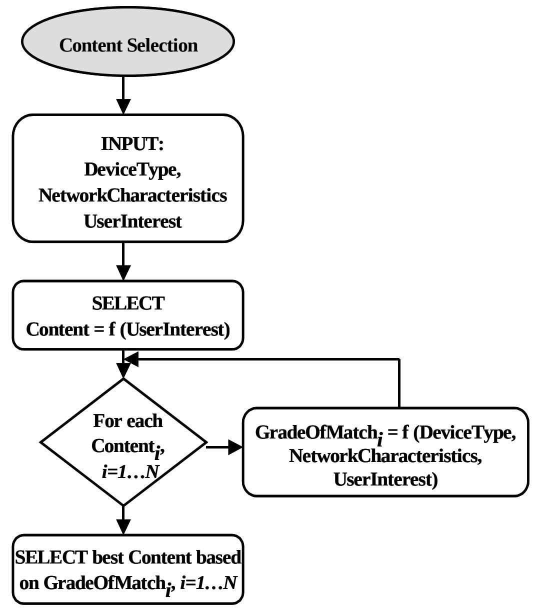

Figure 2. Coarse Grained Adaptation Algorithm

4. ADAPTATION PRINCIPLE

The *Adaptation Engine* performs the adaptation of the multimedia content delivered to a viewer in a two-step process.

Coarse Grained Adaptation (Personalisation)

The goal of coarse-grained adaptation is to choose content that is optimally suited to the user's interests, device type and current network delivery conditions. A basic algorithm is described in Fig. 2 and involves three stages. In the first stage the algorithm includes the selection of the content that matches user interest based on the information from the *Viewer Model*. Each piece of selected multimedia content has associated a degree of match with the user interest. In the second stage the degree of match with the user interest is combined with the result of match between the content properties and both viewer device type and delivery network characteristics. The *QoE Model* provides this information. A *GradeOfMatch* score is computed for each piece of multimedia content on which the viewer has at least certain level of interest. The final stage involves the selection of the multimedia material that has associated the best *GradeOfMatch* and its delivery to the viewer.

Fine Grained Adaptation (Dynamic Adaptive Streaming)

Fine-grained adaptation is performed dynamically and continually during streaming of selected multimedia items. Multimedia delivery requires significant bandwidth resources and spans over a longer period of time in which delivery conditions can vary. In highly loaded network conditions high and variable delays and loss have negative impact on end-user perceived quality.

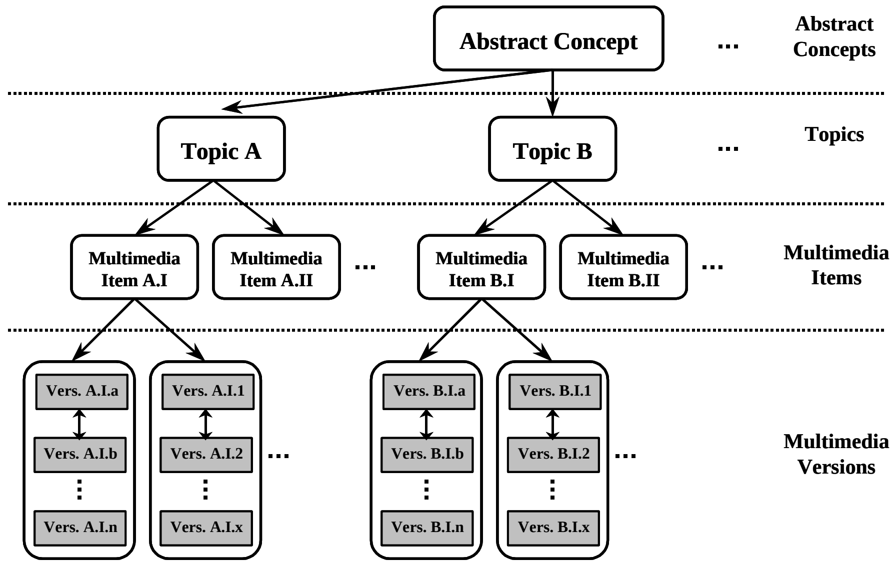

Figure 3. Four-Level Hierarchical Organization of Multimedia Content in the Concept Model

Therefore the *Adaptation Engine*, following *QoE Model*'s adaptive suggestions made based on the client feedback received, may decide to dynamically vary the quantity of information transmitted to suit the delivery conditions. Research related to adaptive multimedia streaming, including an adaptive scheme for multimedia streaming [8, 9] has already shown that significant benefits in terms of end-user perceived quality are obtained if random loss that occurs in loaded delivery conditions is replaced by a controlled reduction in the quality of transmitted stream.

The quality version adjustment performed by the *Adaptation Engine* involves variation of multimedia stream characteristics such as resolution, frame rate, etc. that determine the average bitrate of the stream. This process can involve selection of existing pre-recorded content or dynamic generation of content through transcoding.

5. SOLUTION MODELLING

5.1 Concept Model (CM)

In order to perform personalisation the application domain needs to be structured. Therefore CM provides a four level-based hierarchical organisation of the multimedia content (e.g. movies, shows, news, etc.), available at the iPersonal IPTV Server –side, as a finite set of concepts among which logical relationships exist (Fig.3). Each concept has associated a *conceptID* that uniquely identifies it. These are different types of concepts:

- *Abstract concept* - corresponds to an abstract representation of a piece of information (e.g. news cast or movies)
- *Topic* (e.g. RTE News). Multiple topics can be combined into an abstract concept by defining relationships among them. A topic may also have a list of sub-topics (e.g. RTE News 1st Dec 2005 6pm)
- *Atomic concept* - corresponds to a fragment of information represented as a *multimedia item* (e.g. whether section or sport section from one RTE News cast). An atomic concept can be extracted from a digital video information using automatic indexing techniques.
- *Version* - a multimedia clip that has certain formatting-related characteristics. Often the same multimedia item can have associated multiple versions that differ in quality. These multimedia versions may be pre-recorded or generated on-the-fly by transcoding. An appropriate version is selected during adaptation to be delivered to the viewer.

5.2 Viewer Model (VM)

The VM maintains individual user data such as demographic information (e.g. name, age, gender, qualification), viewer's current interests on the concepts defined in CM, history of visualised content, device type and viewer's connection performance characteristics (e.g. bandwidth, delay, loss, jitter). Both explicit (via registration) and implicit (through content selection and normal visualisation) information gathering is used to generate and update the VM.

The overlay-based modelling method is used to construct the VM, to analyse the viewer profile and to derive new facts about a person (e.g. possible topics of interest). In an overlay model for each concept defined in the CM a value is stored. This value estimates how interested the viewer is on that concept; it can have discrete or probabilistic values. Therefore, the overlay VM is represented as a set of "*conceptID-value*" pairs that provides an accurate representation of the user interests on all the CM concepts.

5.3 QoE Model (QoEM)

QoE Model models ***the selection of the multimedia items*** based on both viewer profiles and the concept hierarchy, and ***the real-time adaptation during streaming process*** of the selected multimedia items. The former is performed once at the beginning of each streaming process, whereas the latter is performed continually during streaming. Quality of Experience (QoE) term refers to users perception of delivery performance relative to their expectations [18].

Multimedia items selection involves the analysis of the current viewer profile, the selection of the multimedia items that match viewer's interests (based on the "conceptID-value" pairs from VM) and the right version of each selected multimedia item that matches user's device and delivery conditions. *Stereotype-based modelling technique* is used for the determination of the optimal characteristics of a multimedia stream that would provide high end-user QoE for a given device and network delivery conditions. The QoE stereotype-based model proposed in [19] generates a list of suggestions on the multimedia characteristics that is used for the selection of the multimedia item version.

The QoE stereotype-based model consists of a collection of stereotypes $T = (T1, T2, \ldots, Th, ..., Tl)$, each characterising a class of user's QoE. The collection of stereotypes is ordered based on a goal to be achieved (e.g. degree of QoE). Each stereotype Th consists of two components:

- *a group of features* (attributes) $F = (F1, F2, \ldots, Fi, \ldots, Fn)$ that defines the stereotype and
- *a group of suggestions* $S = (S1, S2, \ldots, Sj, \ldots, Sm)$ on multimedia stream characteristics

Features are device type, network bandwidth, loss rate, average delay, whereas suggestions are average transmission rate, resolution, frame rate, etc.

Each feature Fi has associated a pre-defined ordered list of linguistic terms (attributes values) $LFi = (LFi1, LFi2, \ldots, LFik_i, \ldots, LFip_i)$. Each linguistic term $LFik_i$ is assigned a numeric value (value estimate) $PFik_i$, between 0 and 1, representing the probability that the feature Fi is equal to the linguistic term $LFik_i$ for this stereotype Th: $PFik_i = P(Fi = LFik_i \mid Th)$. A similar structure is defined for each suggestion Sj, which has associated the linguistic terms $LSj = (LSj1, LSj2, \ldots, LSjr_j, \ldots, LSjq_j)$ and probabilistic values $PSj = (PSj1, PSj2, \ldots, PSjr_j, \ldots, PSjq_j)$.

A classification process determines which stereotype classes an instance (e.g. delivery conditions plus device type) belongs to and with what probability. Since the stereotypes' suggestions are similar, but with different strengths, the final suggestions on the optimal characteristics of a multimedia item are determined after a process of weighted merging of the individual suggestions associated with the stereotypes the instance belongs to.

Multimedia streaming adaptation process employs the QOAS adaptive solution [8, 16] that dynamically adjusts both multimedia quality and transmission rate of the material selected for streaming such as viewers' QoE is maximised in existing delivery conditions. The adaptation relies on the fact that it is more beneficial to apply a controlled reduction in the quality that consequently reduces the quantity of multimedia data to be streamed with no loss than to allow random losses and increased delays to affect the viewers' QoE when watching content streamed at high bitrate. This adaptation involves sending a different multimedia version (pre-recorded or dynamically generated) that differs in characteristics such as average bitrate, resolution, frame rate, etc.

Multimedia streaming adaptation is performed dynamically, during the streaming process, allowing content adjustments to reflect current delivery situation. This is based on feedback received regularly from the ***Client Feedback Unit*** located at the viewer side that includes network, viewer and device feedback.

Network feedback involves quality of delivery grades that are computed based on network performance parameters such as loss, delay and jitter which are monitored by the ***Network Monitor***. When computing these grades the relative importance of these parameters as well as their short term and long-term variations are considered. Short-term variation monitoring is important for learning quickly about transient effects such as sudden traffic changes and for fast reacting to them. The long-term variations are monitored in order to track slow changes in the overall delivery environment such as new users in the system which need a reaction to.

Viewer feedback is considered in terms of estimated perceived quality that is computed by the ***Viewer Observer*** based on the values of the objective moving picture quality metric (MPQM) [20]. Explicit subjective viewer feedback may also be taken into account in conjunction with the objective feedback.

Device feedback refers to device characteristics such as battery power, screen size, processing power, etc. as determined by the ***Device Detector***.

QoE Model receives feedback from the viewer side of the system and, based on it, suggests multimedia stream characteristics. The model employs *stereotype-based modeling* in order to determine these suggestions that consist of a set of characteristics that best describe the formatting of the multimedia content that matches network, viewer and device constraints. These characteristics include encoding scheme, resolution, frame rate, bitrate, etc.

Following these suggestions the ***Adaptation Engine*** performs multimedia stream quality adaptation that involves the transmission of the most appropriate version.

This adaptation process takes place continually during multimedia streaming and may involve switching between multiple versions. Consequently the viewer receives an "adapted stream" (Fig. 1).

6. CONCLUSIONS

This paper proposes the ***iPersonal-IPTV***, an IPTV-based adaptation framework that supports the selection and adaptive delivery of rich media content according to viewers' interests and preferences, network situation and access device in order to increase both viewers' Quality of Experience and their satisfaction.

iPersonal-IPTV is seen as the first step towards personalised adaptive IPTV entertainment services that will open the door for other services such as adaptive and personalised multimedia-based multi-device learning, advertisement distribution, distance education, shopping via the IP-iTV infrastructure. These rich content services will contribute to the enhancement of viewers' experience, providing high quality, comfort, flexibility, choice of content and device.

7. ACKNOWLEDGMENTS

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