Adaptive Multimedia Content Repository Framework

Terefe Hordofa
HiLCoE, Computer Science Programme, Ethiopia
terefeho@gmail.com

Fekade Getahun
HiLCoE, Ethiopia
Department of Computer Science, Addis Ababa University, Ethiopia
fekadegetahun@gmail.com

Abstract

In the current trend of computing knowledge transfer, multimedia service delivery is increasing due to Internet explosion. Concurrently, with continuous increase of multimedia content access, user expectations of content access have also increased. Thus, this mismatch between rich content and user experience is a challenge in providing content accessibility and user preference. To address this challenge, this paper aims to design an adaptive multimedia content repository framework based on content adaptation approach. To achieve this aim the realm of multimedia content adaptation related work review analysis, prototype development and evaluation of the prototype are conducted.

Multimedia services delivery system is typically a massive scheme that is expensive and challenging to maintain and develop. Via advances of Service Oriented Architecture, a content-based approach can be applied to multimedia services delivery development. A complex and large scale multimedia service delivery scheme can be split into smaller and reusable contents. These contents can be composed in diverse ways so that the development of multimedia services delivery model can be flexible and the resulting content-based system is more maintainable, reliable and scalable. As a result, an adaptive multimedia content repository framework is proposed. It uses context of multimedia content to address content serviceability and variability to satisfy user preference and accessibility need.

The prototype, which illustrates an adaptive multimedia content repository, is developed and evaluated by individuals from different professions. The evaluation result shows that the prototype provides an efficient content accessibility with 81.1% accuracy in overall prototype evaluation.

Keywords: Multimedia Content; Content Adaptation; Pervasive Computing; Semantic Content

1. Introduction

Recently application demanding multimedia service delivery models are increasing. The main factor for such service delivery model is Internet which has been extended rapidly to pervasive access. In multiform, a pervasive device processes combination of characteristics such as memory space, network bandwidth utility, CPU power, screen size, data transfer rate, and user input interface. Hence, in content delivery process, the presentation must be modified as per the capability of the target device to suit format and features. Such process not only experiences the overhead on content authoring, but also delays the dissemination of information over pervasive computing platforms.

As stated in recent research works, emerging multimedia services, such as video conferencing, media on demand and multimedia streaming demand scalable and adaptable architecture for providing better multimedia service [1]. The adaptable service architecture enables the flexible composition of multimedia services and improves quality of non-functional requirements. The quality requirements of multimedia services and the Quality of Experience (QoE) of end users regarding the perceived service quality are becoming major concerns for multimedia service providers. The guaranteed quality of service provisioning, even in case of failures and reliable

multimedia services composition are challenging tasks that are to be addressed at various layers such as service provider, request, and business process.

When the need of depending on pervasive computing devices is increasing intensely, there is a growing need for applications to bring multimedia content to the devices. Conversely, by the reason of limited device capabilities in terms of display size, storage, processing power, and network access there are new challenges for designing applications that allow these devices to successfully access, store and process multimedia content. The developments of pervasive computing, advances in storage, networking and authoring tools are driving the production of large amounts of rich multimedia content. The result is a growing mismatch between the available multimedia content and the capabilities of the client devices to access and process it. This mismatch impacts several multimedia applications.

Content adaptation is effective in solving the mismatch problem, resource limitation and satisfy users' preferences in heterogeneous environments such as pervasive systems [2]. Multimedia content adaptation refers to the process of improving content to suit to the user's computing environment such as location, device capability, network bandwidth, user's preferences and usage context [3].

Since content adaptation has become one of the research interests in pervasive computing, different approaches have been proposed: server-based [4], client-based [5], and proxy based [6]. Server-based adaptation degrades the performance of the server and client-based adaptation is very difficult and sometimes impossible due to limited processing power of pervasive devices such as Smart phones. Hence, most of the existing adaptation systems choose the proxy-based approach. To alleviate the overload problem of content adaptation processes, distributed approaches were proposed in [7, 8, 9].

Nevertheless, these approaches do not provide a general adaptation solution. This leads to a service-based distributed adaptation where adaptation tools are developed externally as services and accessible through standard web protocol [10]. The main reasons for the need to externalize adaptation processes are (1) it is not simple to have a single complete computing solution that can provide all the required multimedia content adaptation tools in one system; (2) using Web technologies such as Web Services, adaptation tools can be easily developed and make them accessible via standard web protocols; and (3) using third party specialized adaptation tools, an adaptation need can be realized as a composition of several adaptation services.

2. Related Work

A number of research works have been conducted to address multimedia service delivery model to be adaptive in terms of context in the pervasive computing environment. Multimedia content should have to be adaptable for accessibility and flexible management of specific multimedia content in case of user experiences. In this section, review of related research is done.

CLAM framework [11] offers a complete development and research platform for the audio and music domain. It offers an abstract model for audio systems and includes a repository of processing algorithms and data types as well as all the necessary tools for audio and control input/output. However, CLAM framework is not clear with content adaptation in terms of user preferences and content accessibility. The provision of an essential content access is needed to satisfy potential requirements, which will be driven by the heterogeneity of the technical environment and the expectation of the end user to have access to personalized content.

XML-based framework for semantics-based integration and management of multimedia data as an adaptation and extension of the federated database technology is proposed in [12]. The framework is based on the XML/M data model composed of media objects, relationship objects, and container objects. Work on XML warehouses or XML-based mediator is still not mature, with many problems remaining to be solved [13]. Thus, semantic description of

multimedia items is not sufficient in addressing multimedia content adaptation in terms of user preferences and content delivery. According to [14], a vital issue of multimedia frameworks is content adaptation to achieve universal multimedia access (UMA), i.e., to enable consumption of multimedia content independently of the given resource limitations, terminal capabilities, and user preferences. Most adaptive multimedia frameworks targeting the UMA vision do not consider utility aspects in their adaptation decisions. In this modeling scheme there are no adaptation methods for different contexts in terms of content accessibility need rather than adapting network characteristics. In terms of scalable context usage and presentation, multimedia content need synthesis contextually in line with user experiences via adaptive user interface to address seamless access.

A system that dynamically selects and plays multimedia files from a large data repository to produce a presentation is proposed in [15]. The presentation is generated based on the technical, semantic and relational textual annotation of the data as well as context-sensitive rules and patterns of selection during the preparation phase. However, this work has limitation in articulating multimedia context coordination to enhance multimedia content repository accessibility at the client-user interface. According to Scherp *et al.* [16], multimedia content today can be considered as the composition of media elements into an interactive multimedia presentation. Personalization of such multimedia content means that the content reflects the users' context, their specific background and interest as well as the heterogeneous infrastructure to which the content is delivered and in which it is presented. However, in this work, the proposed scheme is not evaluated in manifesting user expectation and content accessibility.

In [17] multimedia services such as media retrieval, transcoding, scaling, and display services are combined based on the preferences of the user to create Video-on-Demand multimedia service. But, in this work, content accessibility in case of context utilization specifically rather than adapting network characteristics is not addressed.

There are some limitations in the reviewed related works. There is no systematic approach that takes different types of context into consideration at the same time. Most of the approaches use only specific adaptation method, instead of a variety of adaptation methods for different contexts. There has been some research on adapting multimedia content to achieve the characteristics of networks and devices, but adaptation of user experiences and content accessibility needs have been rarely addressed. In this paper, adaptive multimedia content repository framework that focuses on addressing this gap is proposed.

3. The Proposed Solution

A multimedia service delivery should be able to be published, discovered and consumed like any other Web service. However, there is a major difference between multimedia service delivery and an ordinary Web service in the way that the data is transmitted between the two endpoints. A multimedia service delivery involves multimedia content. If the size of the multimedia content is small, it can be delivered as a binary attachment within the response.

However, if the size of the content is large, it will not be possible to transfer it in its entirety within the response. For massive multimedia content, it is appropriate to have an adaptive content framework capability between the two endpoints of the multimedia service delivery.

3.1 The Proposed Architecture

Figure 1 shows the adaptive multimedia content repository framework that is proposed according to service oriented architectural component-based approach. It consists of multimedia content adaptation manager and adaptive content presentation panel. As a sub-architectural component multimedia content adaptation manager has three components: content synthetization, content synchronization and adaptation control.

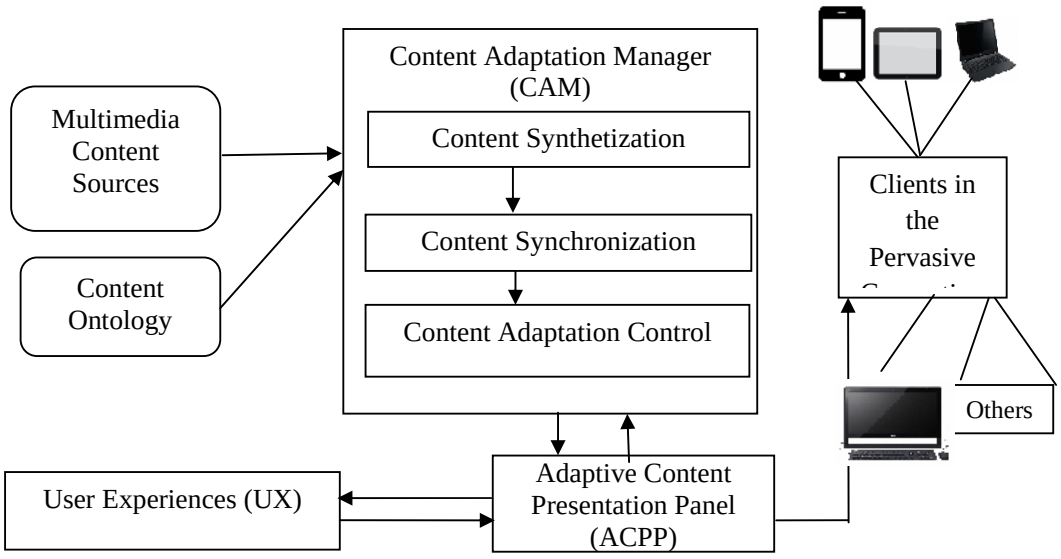

Figure 1: Adaptive Multimedia Content Repository Framework (AMCRF)

A. Multimedia Content Adaptation Manager

Multimedia content adaptation manager is composed of three sub-architectural components: content synthetization, synchronization and adaptation control. This component mainly acts as core engine of multimedia content adaptation to enhance multimedia content delivery. Each sub-component is described below.

i. Content Synthetization

To enhance multimedia repository service delivery in line with user preference, multimedia content should have to be analyzed and synthesized. Our main target is to provide a more efficient tool for multimedia content navigation. To synthesize multimedia content, we intended to use two components (levels) such as semantic content and multimedia relationship objects (for instance, key frames, video clips, shots, scene and audio). Therefore, transmission of the synthesized multimedia content stream usually requires much less bandwidth than the original content since redundant information in the background does not have to be transmitted. Key frames corresponding to highlight segments in a video sequence are organized in a hierarchical structure to facilitate efficient browsing. The structures in the hierarchy can be based on temporal semantic classification.

ii. Content Synchronization

Multimedia content synchronization is a process of coordinating multimedia content along three alignments: multimedia object's relationship, space and time. Automatically, it optimizes multimedia content matching. It addresses the convergence of networked and multimedia content combined with the increased use of continuous, time-based objects.

iii. Content Adaptation Control

This sub-component is intended to address client-based multimedia content adaptation to achieve user experience (see Figure 2). Most of the current studies state that there is a gap in addressing client-based content adaptation due to the complexity of multimedia objects' feature. Thus, it is targeted to attempt the adaptive multimedia content delivery. It is mainly focused on the interaction of user and multimedia content which are available on the client-side to adapt to user preferences and content accessibility needs.

a. Content Accessibility

To achieve user expectation in case of content access, multimedia content accessibility is an essential aspect of multimedia repository service delivery. So, to obtain seamless access of multimedia content via heterogeneous environment efficient allocation of contexts of content is significant. Thus,

to provide this perspective some features of content accessibility are attempted as follows.

Context filter: To improve multimedia content access context filter is necessary as a functional requirement to achieve user's accessibility needs (e.g., special content access user, deaf user, blind user) and adaptation of user preferences in case of what adaptations are preferred under different circumstances.

Context Protection: Context protection is required to address content authority feature to achieve content privacy access.

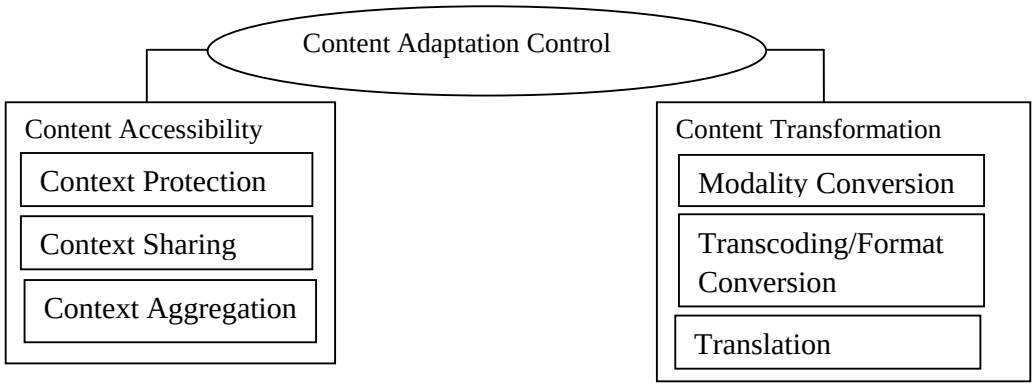

Figure 2: Multimedia Content Adaptation Techniques

Context Sharing: It is to enhance multimedia content in terms of user's content access expectation with other users across other platforms like social media networks (Twitter, Facebook, etc.) through context of multimedia content rather than sharing the whole content.

Context Aggregation: is used to provide content cross referencing in case of combining within randomly consecutive multimedia context of content through time space and with other multimedia content sources via URL. It is essential to enrich multimedia content cross referencing which is very common with text format document processing like word, pdf and others. Regarding multimedia content, for instance video content is composed of video scenes which are arranged consecutively according to time space, so it is possible to aggregate one part with other.

b. Content Transformation

Content conversion or transformation is used to define the process of transforming content (for instance audio to text, etc.) without changing the representation of the content (e.g., audio, video) rather than format conversion (gif to jpg, AAC to MP3, etc.) to achieve user preferences, devices and network characteristics constraints.

Modality Conversion: also known as content transmoding transforms content from one modality to another. In our framework it is used to achieve pervasive access of multimedia content according to realized constraints such as user preferences, devices and network characteristics. It addresses content representation change (audio to text, etc.).

Transcoding/Format Conversion: Content format conversion is essential to convert content from one format to another (gif to jpg, AAC to MP3, etc.) to facilitate user's consumption of content using their preferred aspects by selecting the most suitable transcoding operation from multiple alternative options.

Translation: It is used to achieve user preference in terms of multimedia content to transform content from one to another language.

B. Adaptive Content Presentation Panel

Multimedia adaptive content presentation panel is a means to handle what and how to present (deliver) to the user according to user preferences and

accessibility needs. It deals with the taxonomy of multimedia content. Formally, it is used as terminal client application interface that assists the delivery of multimedia content repository in pervasive computing environment. Within this architectural component, resource description framework (RDF) is used in enriching multimedia item description based on semantic qualification method (for instance, metadata description).

Most of the current research indicates that client-based multimedia content adaptation is challenging due to the complexity of multimedia objects features. That is why we focused on this sub-component as a container panel to enhance multimedia content repository presentation scheme.

4. Implementation and Experimental Results

An adaptive multimedia content repository system is developed based on user experiences. In this section, we present different tools and technological development environments that are used to develop the prototype. In addition, concept of ontology construction and screen shots are presented to show the outputs and the user interface of the system. Finally, we have evaluated our design framework based on the experimental method using multimedia digital resource collections of UNECA.

a. Ontology Creation

In distributed computing, the concept of ontology is the working model of entities and interactions in some domain of knowledge applications. We have created audio-visual conference domain ontology to show how concept formulation is done through ontology based concept synthesis.

b. Prototype

A prototype is developed to show the validity of the proposed adaptive multimedia content repository framework. User interface facilitates a user to access and process multimedia repository according to adaptive content scheme as shown in Figures 3.

User intends to filter a specific context according to its needs from the coordinated content.

User is accessing the specific context

Figure 3: Contextually Coordinated Multimedia Content Access

c. Evaluation

Once the prototype is developed, it is evaluated to show the validity of the framework in addressing adaptive multimedia content repository service delivery. Thus, it has been tested on different network characteristics (for instance, wireless connection), devices and other circumstances. User reviews are collected to evaluate the prototype by UNECA multimedia Institutional Repository staff. The results shown in Table 1 have been obtained. The aim is to check if the prototype's functionality is correct or not. If its functionality is not correct, the prototype needs some improvement.

Table 1: Evaluation Result

No.	*Functionality*	*No. of times functionality is tested*	*No. of times correctly functioned*	*Percentage*
1.	R1	11	9	81.8
2.	R2	25	21	84
3.	R3	23	19	82.6
4.	R4	18	14	77.8
5.	R5	19	13	68.4
6.	R6	24	20	83.3
7.	R7	16	15	93.8
8.	R8	27	20	74.1
9.	R9	22	19	86.4
	Total	*185*	*150*	*81.1*

It has been checked 185 times by 35 UNECA multimedia Institutional Repository staff under different situations in different times. The evaluation criteria are provided to evaluators in the form of questionnaire which they used to evaluate the effectiveness of the prototype. It has been performed based on the percentage of user satisfaction in terms of user preferences and content accessibility requirements which are stated as follows.

R1 (Variability): Multimedia content is contextually variable and clear in addressing content adaptation to realize user preferences and accessibility need.

R2 (Understandability): Multimedia content is understandable and usable.

R3 (Cohesiveness): Multimedia content is contextually connected with the semantic content to enrich utility need.

R4 (Discoverability): Content discovery is clear, findable and related to the actual content.

R5 (Accessibility): The multimedia content feature or approachability of being at hand when needed is addressed well in terms of content access.

R6 (Utility): Content usefulness is used to provide user satisfaction in case of access need.

R7 (Scalability): Multimedia content is scalable in terms of pervasive content access.

R8 (Recoverability): Content recovery is clear, reusable and related to the actual content.

R9 (Serviceability): Multimedia content is contextually useful for functional requirements regarding content accessibility need.

In some functionalities, like “R7”, the evaluators’ evaluation of the prototype is efficient in addressing this functionality. In other functionalities, for example “R5”, the prototype is not that good in approachability when needed according to preference and content accessibility need.

Out of 185 attempts to determine the functionality of the prototype, it has correctly satisfied the evaluator’s preference and content accessibility need in 150 of them which makes it 81.1% accurate. The functionality that has been incorrect is about 35 out of the 185 attempts.

5. Conclusion

In this paper, we proposed an adaptive multimedia content repository framework based on component oriented service architectural approach for the improvement of multimedia repository content to address user experiences requirement in pervasive computing. As a service architectural model, it is composed of multimedia content adaptation manager and adaptive content presentation panel. Multimedia content adaptation manager is initiated as content adaptation engine in optimizing effective multimedia service provision. It has three sub-components: content synthetization, content synchronization, and adaptation control.

To evaluate our modeling scheme, we developed a prototype. It has been evaluated using different

evaluation criteria and it has been found to be 81.1% accurate.

This research work discovers different contexts of multimedia content that can be further adapted as well as some components that should be implemented and integrated for better accessibility of content. Accordingly, dynamic content customization of multimedia content services delivery in line with the aspect of content security features and quality of services optimization techniques are future works.

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