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Adaptive Multimedia Content Delivery in Ubiquitous Environments*

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Abstract. Due to the dramatic technology development in Internet and wireless communication, it becomes possible to access multimedia contents and services using handheld devices. However, most multimedia contents and services on the Web are optimized for desktop computing environment. Even though multimedia contents can represent rich semantics, they are not suitable for handheld devices with limited resources and computing capabilities. Moreover, depending on user preference or usage scenarios, not all the data are relevant or critical to the application. In this paper, we present an adaptation scheme of multimedia contents on the wireless devices for QoS-aware delivery. Especially, we seek to adapt multimedia contents based on available system and network resources, client terminals, user preferences and some other environmental characteristics.

1 Introduction

Over the past few years, the volume of multimedia contents has increased a lot. Similarly, mobile devices such as PDA and mobile phone have grown in popularity and performance. Along this trend, people have become enthusiastic about watching multimedia contents through their handheld or mobile devices. The capabilities of such devices vary widely but are usually limited in terms of network bandwidth, processor speed, screen display, and decoding capabilities. As a result, there are many restrictions in viewing multimedia contents through mobile devices. Therefore, there is a growing need for delivering multimedia data to a variety of devices while adjusting its quality based on the resources available.

Ubiquitous computing is the ability to extend applications and services normally conducted on personal computers to handheld and wireless devices, which eventually enables any where, any time, and with any device access to multimedia information systems. Ubiquitous computing environment involves a variety of devices with different capabilities in terms of processing power, screen display, input facilities and network connectivity which can vary between wired and different types of wireless

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links. The diversity of these devices will make it difficult and expensive to tailor multimedia contents separately for each individual type of device. Therefore, adapting multimedia contents to such diverse client devices becomes critical in this heterogeneous environment. Multimedia information needs to be customized according to user preference, client capabilities, network and natural environment characteristics. This customization process includes transcoding (format conversion – e.g. XML to WML), scalable coding (spatial and temporal resolution reduction – e.g. bit-rate reduction) and transmoding (modality conversion – e.g. video to image, video to audio). In general, adaptive multimedia content delivery systems have been focusing on specific problems such as varying network conditions and devices [1, 2]. The purpose of such adaptive systems is to deliver multimedia contents to users any time, any where on any device. In order to achieve this kind of adaptation, we exploit both MPEG-7 [3] and MPEG-21 [4] standards under the heterogeneous environment.

The organization of the rest of this paper is as follows. In section 2, we briefly introduce several related adaptation schemes. In section 3, we describe the overall system architecture for our QoS adaptive multimedia delivery. In section 4, we show the profiles for the content adaptation. In section 5, we present the implementation details of the system, and in section 6, we conclude the paper.

2 Related Work

Content adaptations can be classified into two main types depending on when these different content variants are created [5]. In the static adaptation, for example, when the client requests the video, the server analyzes the context and selects the best alternative form of the multimedia content and sends it to the client. With the static adaptation approach, the content provider can have a tight control over what is transcoded and how the result is presented [6]. In the dynamic adaptation, desired multimedia contents are adapted and delivered on the fly according to the dynamic requirements presented to the server which could be based on the current characteristics of the client environment [7]. For example, when network bandwidth is unstable, we can reduce the frame rate, resolution or color depth of the video delivered.

In regarding to the location where the adaptation is performed, many researchers describe three possible places for implementing adaptation in computer networks [5, 8]. Adaptation operations can take place in the server, the client or the proxy. So far, fewer examples are reported in the server-based adaptation [9]. Although server or sender as content providers have full control over the content quality and have more computational power to make reliable adjustment on the content quality, this adaptation has a major drawback that additional computation and resource consumption are required on the server which lacks in scalability. There are many systems that implement their own adaptation scheme separately in a proxy between the server and the client. The advantages of this approach are scalability, cost effectiveness and transparent design. Although this approach has many advantages, it still has efficiency problems affected by computation resource and time. Finally, in the client-based adaptation, the client device is responsible for adaptation and uses the device information and its capability to guide the adaptation process. In the Odyssey system [10], all the adaptation processes are done by the client which is the receiver of data from a remote data sender. Such a receiver-initiated adaptation strategy has a benefit of scalability, since servers do not need to be changed when there are new applications requesting for adaptation.

3 System Architecture

Fig. 1 shows the overall system architecture to deliver multimedia content in a QoS adaptive way over wired and wireless connections. We have considered different types of client devices such as Laptop and Pocket PC (PDA). When the client device connects to the server under various network conditions, the server determines whether it is possible to display multimedia contents on the client device. If the server decides that the client device is not adequate for displaying, then it contacts the client to get the device features and current network information. The information may include client hardware, software, browser (or media player), and network condition. When the server receives this information, it assigns a unique ID to the client device and store the device, network and media content descriptions as a XML document in the MPEG-7 content description database.

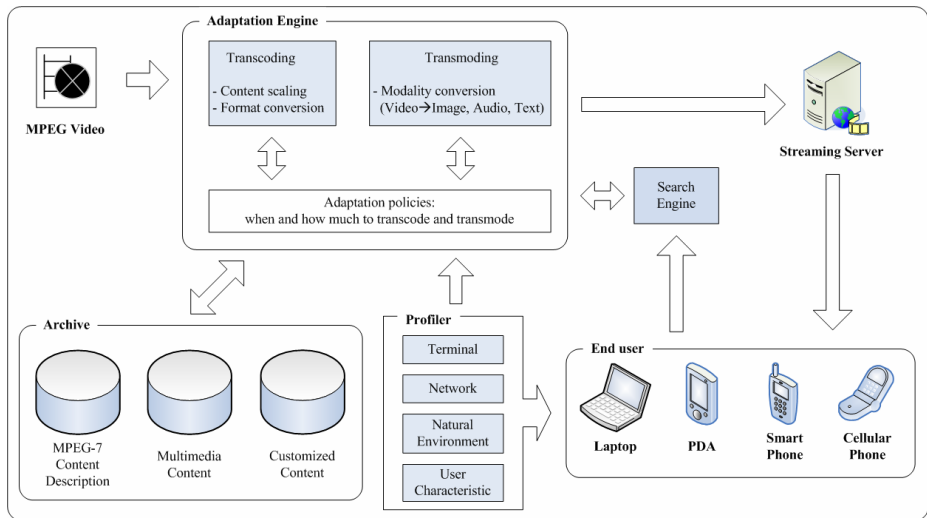


Fig. 1. Overall system architecture

The search and adaptation engines are the core components in the system. The search engine finds semantically meaningful segments from video using keywords with their start time and duration which are passed over from the adaptation engine. As we mentioned, the physical adaptation is a quality driven adaptation. The adaptation engine takes device description (terminal profile), network condition information (network profile), natural environment information (natural environment profile), and users request or their preference (user characteristics profile) for quality parameters. The parameters include start and end time of the video, bit rate, picture quality, frame rate, and frame size. The MPEG-7 content description for original content in multimedia content database is based on the high quality format (i.e., high resolution, high picture quality and high frame rate). However, when this description does not match with the parameters produced by the adaptation engine, we need to transcode/transmode the video from the original description to a new adapted profile.

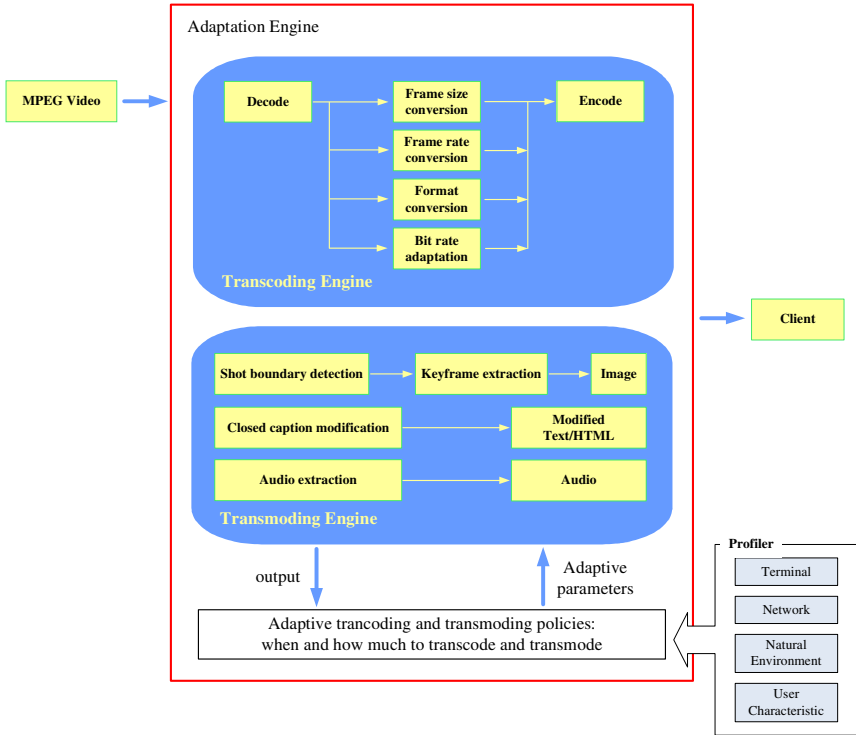


Fig. 2. Processes in the adaptation engine

Fig. 2 illustrates the overall steps in the adaptation engine to determine when and how much to transcode and transmode. Multimedia content adaptation proceeds in the three steps. In the first step, the profiler produces adaptive parameters for that particular context of device, network condition and user characteristics. In the second step, the profiler determines whether the content should be transcoded or transmode and then sends the adaptive parameters into the transcoding or transmoding engine, respectively. In the third step, the encoder takes the adaptive parameters and produces an adapted multimedia content for streaming through the transcoding engine. On the other hand, transmoding engine converts video into other modality such as image, audio and text/html using key-frame extraction from each detected video shot, audio extraction and closed caption modification, respectively. The adaptive multimedia contents are sent to the client device by the streaming server.

4 Profiles for Adaptation

The adaptation describes the terminal capabilities as well as network characteristics, natural environment, and user preference [4]. We outline more detailed information below with sample terminal and network descriptions.

- *Terminal capabilities*: User can adapt various formats of multimedia for viewing on a particular terminal by the terminal-side capabilities such as codec and I/O capabilities. Codec capability specifies the format that particular terminal is capable of encoding or decoding. I/O capability includes a description of display characteristics and audio output capabilities.
- *Network characteristics*: Network capabilities and network conditions affect multimedia adaptation for transmission efficiency and robustness. For instance, we can lower the network bandwidth of a video stream if the available bandwidth is insufficient. Network capabilities define the maximum capacity of a network and the minimum guaranteed bandwidth and network conditions describe network parameters such as the available bandwidth and delay characteristics.
- *Natural environment*: Natural environment pertains to the physical environmental conditions around a user such as lighting condition and noise level, or a circumstance such as the time and location.
- *User characteristics*: User characteristics include a description of user information, usage preferences and history. User preferences define preferences related to the user hardware such as PDA and handheld PC. For audio, the specification describes preferred audio power and equalizer settings. For visual information, the specification defines display preferences such as the preferred color temperature, brightness, saturation, and contrast.

5 Implementation

In this paper, we have implemented a prototype system for delivering multimedia content in a QoS adaptive way. The system selects appropriate multimedia contents through the adaptation engine based on the evaluation of various multimedia content alternatives to adapt the client device. The client platform is developed by Microsoft Embedded Visual Tools with the DirectX Platform Adaptation Kit (DXPAK). We have tested streaming video files encoded in Windows Media Video Format (.wmv), Advanced Streaming Format (.asf), and Audio Video Interleave Format (.avi) as in [11].

Fig. 3 shows a content adaptation process on the PDA client based on the device capability and user preference. According to the client's profile, the requested video is transcoded and displayed into different formats such as different frame rate and frame size. An adaptation example considering the network characteristics (mainly the bandwidth of the connection) is shown in Fig. 4. We evaluated the adaptation performance under various networking conditions. We first obtained the terminal and network profiles for each modality by monitoring the network condition. Then, the collected adaptive parameters can be fed into the adaptation engine for determining any degradation. When the network bandwidth is enough, the PDA client can display the video. However, under the scarce bandwidth, the adaptation engine might decide content degradation by transmoding. During this degradation stage, the user can still listen to the audio with key frame images or read the closed caption.

Fig. 5 and Fig. 6 illustrate cpu and memory usage when running a Windows file format such as .asf, .avi and .wmv. Files were encoded using both RGB and YUV.

Fig. 5 shows that avi file format needs more processing power compared to other format such as asf or wmv. From the figure, we can see that the average cpu time of avi format file is around 40 percent loading time while the average cpu times for rendering asf and wmv file format exhibit 20 and 17 percent on the average, respectively. As shown in Fig.5, three different curves are fluctuated between 6 and 26 seconds. This is because there is a peak in cpu time for each shot change in the video sequence. Fig. 6 shows the client memory usage for both asf and wmv format. Both used 50% of available memory on the average while rendering the file to the screen; however, the avi file format demonstrates a slight rise in memory usage towards the closing stages of the sampling period.

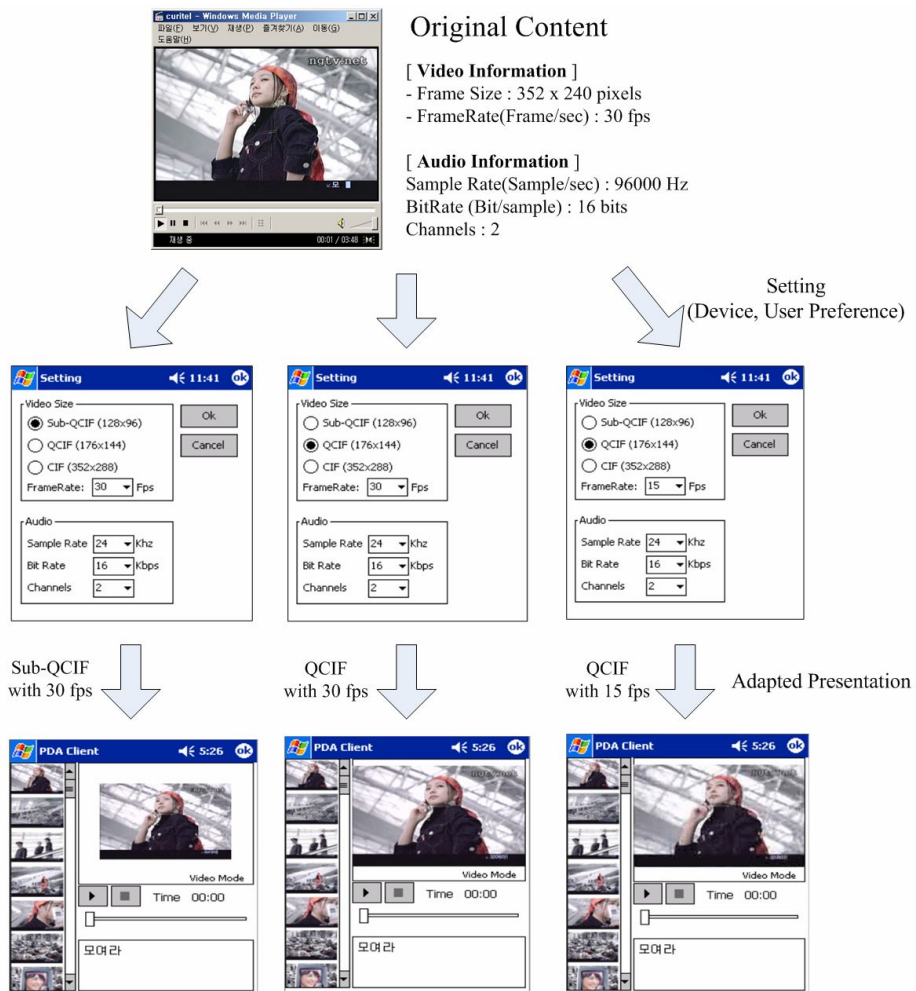


Fig. 3. Adaptation based on the device capabilities and user preferences

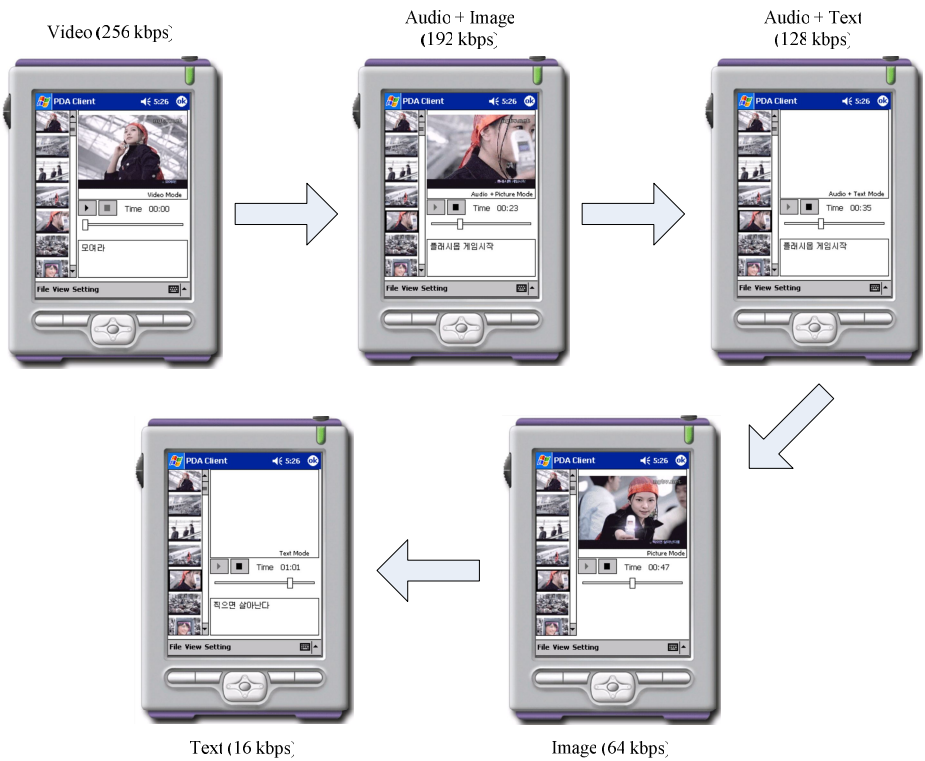


Fig. 4. Adaptability of the system by the network conditions

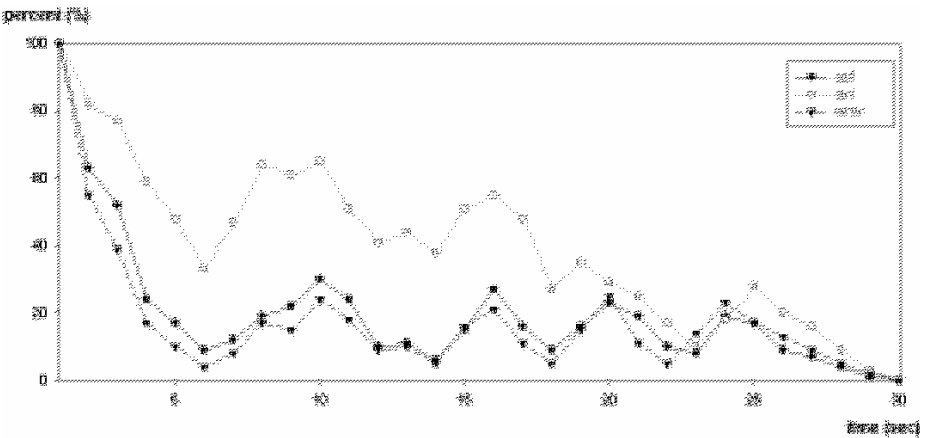


Fig. 5. CPU usage among the YUV encoded file formats (asf, avi and wmv)

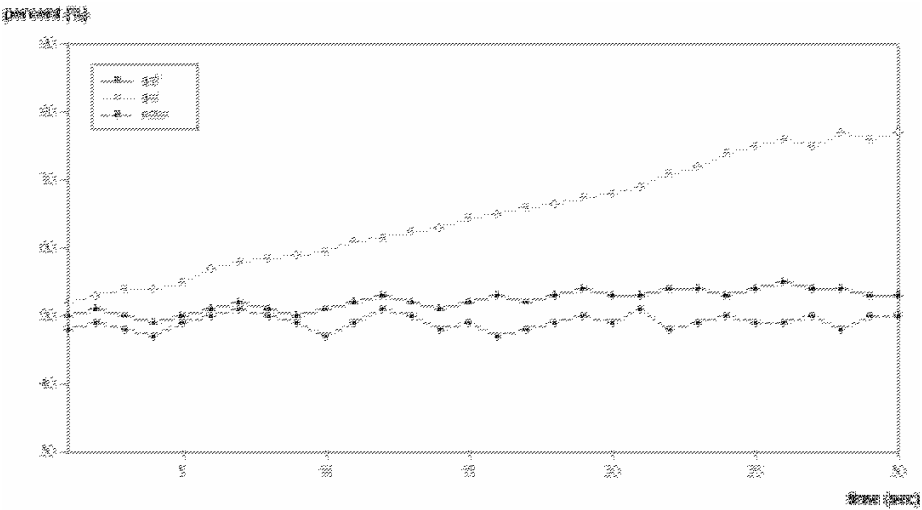


Fig. 6. Memory usage among the YUV encoded file formats (asf, avi and wmv)

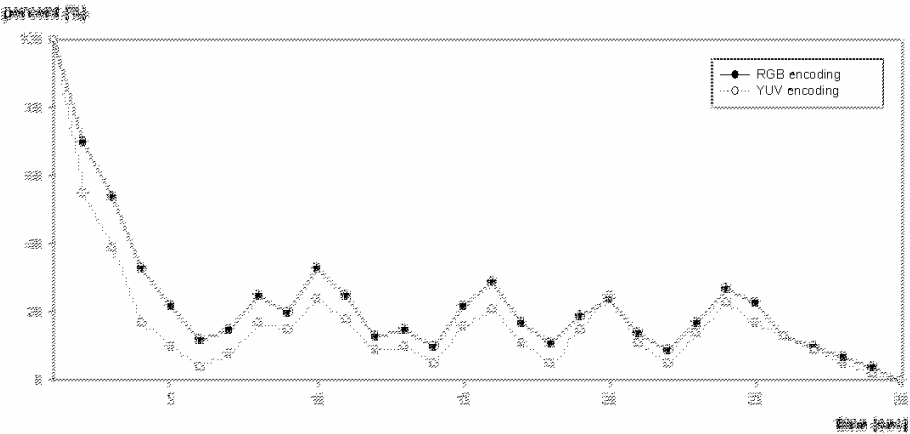


Fig. 7. CPU usage of RGB and YUV encodings for wmv format

Small video size such as 352×240 would be inappropriate for the most desktop and laptop platform and would be the most appropriate for the PDA. Fig. 7 and Fig. 8 compare the cpu and memory usage when rendering files with RGB encoding format and YUV encoding format. From these figures, we can conclude that the most bandwidth-friendly format is .wmv because it saved both memory and cpu usage while rendering the file to the PDA screen.

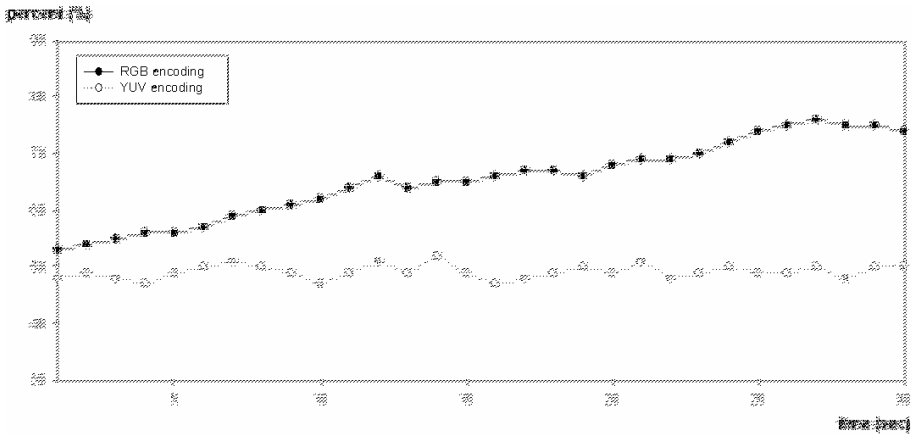


Fig. 8. Memory usage of RGB and YUV encodings for wmv format

6 Conclusion

In the coming ubiquitous computing environment, same multimedia contents may have to be transcoded or transmoded into different forms according to network condition and device capabilities. Content adaptation is one of the key issues that need to be dealt with for developing an adaptive multimedia delivery system. Towards this, we present a QoS aware adaptation scheme for ubiquitous applications. For the adaptation, the scheme considers various factors such as current system and network condition, client device, user preference and natural environmental characteristics. In this paper, we use the dynamic multimedia content adaptation to reduce bandwidth required for delivery. We also design an adaptation engine and implement the framework for adaptation driven by user perceived quality rather than just bit-rate reduction. Our system support media adaptation not for video only but cross-media adaptation using other media components such as audio, image and text.

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