MINPAY: a Multi-device INternet PAY-as-you-watch system *

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Abstract

New mobile communication technologies are expected to be broadly available in the near future. Those technologies (multimedia-enabled devices and broadband access to the Internet) will enable new services involving video transmission. Service providers are likely to want the customer to pay for contents, whereas they will also want their intellectual property protected. We present a system that integrates content, fine-grain pay-per-view and copyright protection with a rich variety of multimedia output devices and transmission networks.

Keywords: *Video services, Pay per view, Content distribution networks, Micropayments, Copyright protection.*

1 Introduction

Electronic commerce over the Internet allows easy trading with digital content, for instance with digital audio and video. The rise of mobile telephony, the appearance of personal digital assistants (PDAs) and, above all, the access of those devices to the Internet with broadband IP connections (GPRS, UMTS and wireless LAN) naturally lead to the proliferation of new pay-per-view video related services, such as movie channels, music videos, news broadcasting, online gambling, etc. In order to accomodate in a single web site the rich variety of users, devices and media associated to those new services, a new web architecture (servers, clients and middleware) must be designed and implemented.

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1.1 Contribution and plan of this paper

This paper describes MINPAY, a Multi-device system for an INternet-based PAY-as-you-watch. The system, which is part of the STREAMOBILE project, allows on-demand streaming of videos with three main features: Fine-grain pay-per-view: the customer pays only while the contents are being downloaded; copyright protection through identification of illegal copies; device-specific bitrate coding of the streamed video.

Section 2 deals with pay-per-view and copyright protection issues. The variety of users and devices MINPAY can work with is described in Section 3. Section 4 describes the essentials of the MINPAY system and discusses some related problems. Section 5 traces some conclusions and identifies some issues for future work related to a testbed prototype.

2 Pay-per-view against piracy

Audiovisual content distribution is a business that involves huge turnover and revenue for the audio and video industries. Thus, as portable multimedia devices are becoming available to a large population of potential audio and video consumers, efforts are under way to develop pay-per-view mobile multimedia services.

The new platform on which this content distribution services will be deployed is to be an outlet for testing and implementing new techniques: pay-as-you-watch and copy detection techniques. These should be considered when designing a web-based multimedia distribution system that benefits customers and vendors in a fair way.

2.1 Pay-as-you-watch

Pay-per-view is currently a word related to television. Digital TV platforms allow viewing of a pack of

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channels by paying a fixed amount per month. The customer can view the so-called pay-per-view events (football matches, movie TV premieres, etc.) if she pays in advance for the full content. A problem can arise if the customer does not like the movie at all, or she has simply selected the wrong item to buy and view: the customer is losing a part of her money.

In contrast to pay-per-view, *pay-as-you-watch* is defined as paying as the content is being watched[1]. The user joins a pay-as-you-watch Internet service and makes a small value payment, say every minute. The video server sends a block of data to the customer only if she has made the corresponding payment. When the customer stops paying (switches off the so-called "purse" software) she has only paid for the minutes she has viewed so far. This kind of fine-grained pay-per-view services is likely to attract many potential users of mobile video-based services.

In these systems, a micropayment scheme, such as PayWord[2], can be used to perform frequent small-value payments. The customer is provided with an electronic purse in order to carry out these payments, usually through a broker. MINPAY implements the PayWord micropayment scheme in order to provide fine-grain payments.

2.2 Copyright protection

One of the properties of digital data is that they can be easily copied without any quality degradation. This is a serious threat to multimedia e-commerce profitability and to the intellectual property of digitally delivered content.

Preventing unlawful copying requires some kind of hardware enforcement and has failed in scenarios where players had special-purpose specifications, as in the case of DVD players[3]. As copy protection systems appear, most of them are broken by hackers in a relatively short time. Thus, copy detection techniques appear as the main solution for protecting the copyright of content in electronic format. The idea here is not to prevent copying, but to track whether copying has taken place. The so-called fingerprinting techniques[4] –that identify the user who has bought the copy of the content– allow copies to be tracked and customers that illegally distribute their copies to be identified. MINPAY embeds collusion-secure fingerprinting codes[5, 6] by using robust watermarking techniques[7].

3 Multiple users, multiple services

The MINPAY system handles two kinds of entities: customers (the users of the system) and contents. Banks will also be contacted in a real deployment of the system, as explained in Section 4.1. Several considerations concern the customers and the quality of service they are paying for. This quality is mainly related to the device and connection they are using to stream and play a video from the Internet.

3.1 User devices

Adapting the streamed content to fit the device through which the media is streamed and watched is essential in order to provide a certain quality of service. A broadband user does not receive any quality of service if she receives a video which is too compressed. On the other hand, a customer with a small display should not be sent high-resolution videos. Thus, three kinds of users can be considered depending on their equipment: (i) *Desktop PC* users would like to enjoy a full-screen video. Several broadband access providers offer full-screen Internet-based video-on-demand systems. But, in most cases, a 25 frames/second full-color 320x240 video already has enough quality. (ii) *Multimedia-enabled personal digital assistants* usually have a display of 240x320 pixels, and about 32K or 64K colors. Market forecasts predict shipments up to 60 millions of units in 2007, so providing access to video contents from an Internet-enabled PDA is more than justified. Several PDA manufacturers sell GPRS-enabled PDAs, which can also be connected to the Internet through a wireless LAN point of access. (iii) *Mobile (smart)phone* manufacturers and operators expect a growth of cellular data services. While the development of data services has steadily increased in Japan over the last years, the European market has stayed relatively flat since the relative failure of WAP[9]. In recent months, a plethora of multimedia enabled smartphones[10] have made their way to the market. The resolutions of those new devices vary from 132x166 to 176x220 and they are usually equipped with HTML browsers, rather than WAP-only mini-browsers. These devices can display up to 64K colors. While most of the current mobile phones have a low-resolution monochrome display, smartphones and PDAs are likely to become the largest share of the mobile market in the near future. Instead of using the low data transmission speeds of second-generation mobile networks, these phones will use faster data accesses, such as GPRS or UMTS.

It must also be considered that there will be customers that will use public devices to obtain these pay-

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per-view services. The use of smart cards in order to identify a user (when at home or when traveling and using public Internet browsers) is a key issue in these systems.

3.2 Access networks

The kind of network the customer uses to enter the portal and access the contents determines the available bandwidth and, therefore, the quality of the video streamed to the user's player. As a consequence, the video stream must be encoded to fit various different bandwidths: the bandwidth available to users of *xDSL and cable* technologies can reach several megabits per second. A pay-per-view user with such bandwidths must be supplied with high quality videos, instead of receiving the same data that is served to customers with less bandwidth. *Old telephone systems users* should have videos compressed because of the very small bandwidth. A standard such as MPEG-4 is the one that best fits this requirement. Fairness in video payment requires that the video bit rate be substantially below the customer's bandwidth. Streaming full quality videos over a narrowband connection will increase the size of the player's buffer (see Section 4.2). *Mobile users* may use wireless connections such as GPRS. In volume-based tariffing, it is essential to strike a tradeoff between video quality and bitrate; optimal compression codecs must be used for that. Recently reported experiments on video transmission over a GPRS network[8] yielded 15 frames per second at a quality of 176x144 pixels per frame. Wireless LAN users are likely to enjoy a broadband connection. In that case, the way the user pays for this connection is relevant. If the user pays for a monthly downloading limit, she should be informed on the bitrate of the videos.

As mentioned above, the use of a smart card to identify the customer is recommended due to the security requirements of payment services. In the current situation where smart cards are not yet widespread, passwords can be a viable temporary alternative.

4 System architecture

There are several components involved in the MINPAY system architecture. At the front-end and back-end there are the customers and the contents, whereas other parties act as intermediate systems. These elements and their interaction are explained next. The *web portal* is the entrance to the web service. When entering the site, a customer check is performed (reading a cookie or some data from the smart card is attempted on the customer's side). If the customer is already registered, the main page redirects her to a device-oriented web (in order to show the portal adapted to the display of the device). If the customer is not registered, the browser sends a simple page with information about the services and allows the user to join them. Once registered, a user profile is stored in the database. The *player device* allows the customer to watch the streamed content. This device can be any of those described in Section 3.1. A smart card can be plugged into the customer's device to cryptographycally assure the customer's identity and perform micropayments instead of using the purse software. *Content streams* can be obtained either from video data files or can be directly grabbed from video capturers (*i.e.* for live events). Video files are stored at highest quality. Several resolutions and compression ratios are possible, but a resolution of 320x240 pixels should be enough for high-quality videos.

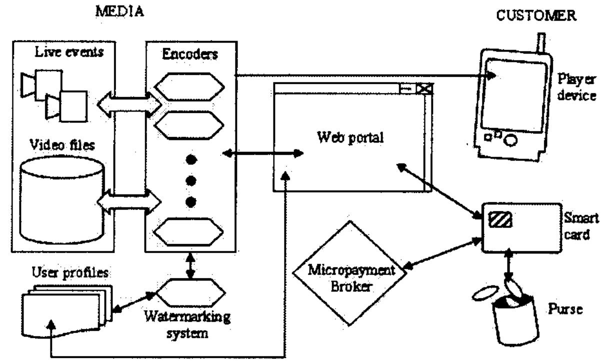

Figure 1. Components of the MINPAY system

4.1 Intermediate systems

In addition to the web server that will serve HTML content to the customer, there are several other intermediate systems between the customer and the content. The *video encoders* take content streams as inputs and recode them in order to match the bit rate that best fits the needs of the customer. Either hardware or software encoders may be used, but the cost of having an encoder for each active customer stream has to be analyzed. Hardware encoders certainly increase the price of the system, whereas software encoders seem a better solution when there are encoding processors running on several computers. On the other hand, the system may have several videos encoded at different bitrates and simply stream the data to the customer. Anyway, the main purpose of the

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system must be to achieve a bitrate as close as possible to the customer's bandwidth, in order to avoid the buffer problem (see Section 4.2 below). Each video is watermarked by the *watermarking system* while being streamed. The embedded information can be related to the copyright owner and the customer that buys the copy of the video. Watermarking allows an "invisible" mark (containing a copyright notice or any other information) to be embedded in the content. A standard requirement on watermarking systems is imperceptibility, *i.e.* there should not be any noticeable difference between the original and the watermarked content. Embedding algorithms may differ depending on the content handled, but the basic idea is to embed the message where it can barely be perceived by humans. For instance, an audio stream can be watermarked using the first bit of a sample, which causes an imperceptible noise to be added to the sound. The use of collision-secure fingerprinting [5, 6] prevents copyright marks from being erased from the source. Robust watermarking schemes are be used in order to prevent the marks from being damaged by accidental or intentional content transformations. The *micropayment broker* interacts with the customer in order to obtain and validate micropayment coins. These microcoins are aggregated and sent to the banks in order to settle the accounts of content providers and customers (for instance, once per month). The way payments are performed is not an issue of this paper (see [1]).

When a video streaming is requested, a user-dedicated video encoder interacts with the watermarking system and they both contribute to generate a stream with customer-specific bitrate and watermarks.

The same customer may, on different occasions, be using devices which can cope with different bandwidths. The system allows a user profile to contain several device specifications. When a customer logs into the system, if her profile contains several device specifications, she is asked about which device she is currently using.

Concurrently, the system asks the micropayment broker to request several micropayments to the customer in order to get paid for the service. The server process sends the stream to the customer's player at a specified bitrate, as explained in next section.

4.2 The buffer problem

Streamed data must be presented to the viewer at a specified bit rate, whereas the network delivering the content has a different and fluctuating bandwidth. A common solution is to use an internal buffer which carries out an isochronous transmission. The buffer will not deliver any data to the video decoder until it has accumulated enough data to guarantee a constant bit rate. For things to run smoothly, the network bandwidth should be slightly greater than the video bitrate[11].

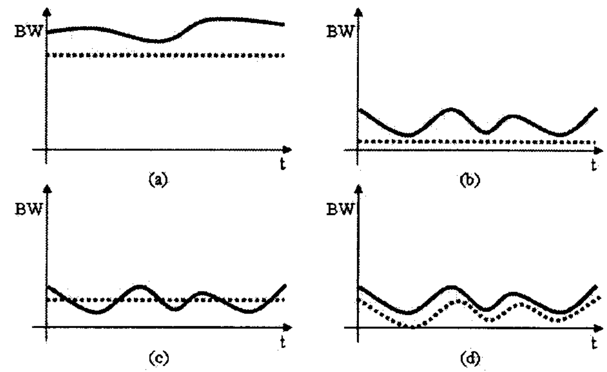

Figure 2. Bandwidths (thick line) and bitrates for encoding video (dotted line) for ADSL (a) and GPRS (b,c, and d) connections.

Some initial payments will probably be needed in order to fill the buffer with enough data to start viewing some movie frames; at this moment, the customer has paid but she has seen nothing of the movie. Besides, the streaming buffer will always keep some data until delivery ends. However, the difference between the amount of content paid for and the amount viewed is usually small as compared to the size of the entire content. In spite of all precautions taken, the customer's player buffer is likely to be swamped with data if network bandwidth is high and the content bitrate (quality) is low. The explanation is that the network tends to bring to the user as much data as it possibly can. Note that the customer pays for all data entering the player's buffer, even if she quits watching before viewing the entire buffer content.

A solution to the above problem is to use a real pay-as-you-watch system, rather than a pay-per-receive system. In pay-as-you-watch, payments should be performed by the player as the customer watches the content, regardless of the amount of data held in the player input buffer. The shortcoming of this solution is that an additional special viewer should be downloaded and stored into the wireless player (PDA or smartphone); this can be problematic due to resource scarcity of this kind of devices. Trying to control the bitrate at which the content is sent to the user remains the most practical solution.

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4.3 Encoding at the optimal bit rate

Due to the buffer problem, coding must be done so as to produce an output stream that ensures that the customer's buffer as empty as possible. One solution is to measure the maximum sustained bandwidth from the server to the customer[12], and encode the video at approximately the same bitrate. In the case of wireless connections, where bandwidth fluctuation is higher than for fixed IP networks, that would imply offering poor qualities to these users. For that kind of users, a periodic monitoring should be used in order to encode at a variable bandwidth (see Figure 2). In Plot (a) of Figure 2, an ADSL connection bandwidth is depicted that is sustained enough to allow fine quality video encoding at constant bitrate. A GPRS connection is depicted in Plot (b) which leads to very poor quality because the streaming bitrate has to be below the lowest possible bandwidth fluctuation. If higher bitrates are used (as in Plot (c)), some data will be lost. In the case of GPRS customers, the best solution would be to use coding with a variable bitrate, as shown in Plot (d).

5 Conclusions and future work

The diverse nature of devices and networks that can be used to access and use Internet video services has been described. The MINPAY system aims at integrating several kinds of player devices and access networks under the same web service architecture. Fine-grain pay-as-you-watch content payment, copy detection by using fingerprinting techniques and customer-specific variable bitrate for content delivery have been shown to be issues that need to be addressed. A prototype implementing the MINPAY system is currently under development. This prototype will be used as a testbed for several kinds of devices (PDAs, laptop computers and smartphones) and some network accesses (in particular, wireless LAN, GPRS, ADSL and analog modem dialling). A first working prototype for STREAMOBILE has already been implemented. The prototype allows fine-grained pay-as-you-watch[1]. Moreover, several fingerprinting schemes have been designed, tested and published. They are currently implemented as standalone prototypes. Future work will address the integration of the fingerprinting module and the implementation of the specific and variable bitrate video encoders. Future work will also involve performance testing and measurement for several hardware platforms and architectures. Possible settings include a single centralized machine running all the system or several machines running different encoding processes.

References

[1] J. Domingo-Ferrer and A. Martínez-Ballesté, "STREAMOBILE: Pay-per-view video streaming to mobile devices over the Internet", in *Proceedings of the 13th International Workshop on Database and Expert Systems Applications (DEXA'2002)*, Los Alamitos CA: IEEE Computer Society, 2002, pp. 418-422.

[2] R. Rivest and A. Shamir, "PayWord and Micromint: Two simple micropayment schemes", Technical Report, MIT LCS, Nov. 1995.

[3] `http://www.lemuria.org/DeCSS`

[4] S. Katzenbeisser and F. A. P.Petitcolas (eds.), *Information hiding: techniques for stenography and digital watermarking.* Norwood MA: Artech House, 2000.

[5] D. Boneh and J. Shaw, "Collusion-secure fingerprinting for digital data", *IEEE Trans. on Information Theory*, vol **IT-44**, no. 5, pp. 1897-1905, 1998.

[6] F. Sebé and J. Domingo-Ferrer, "Scattering codes to implement short 3-secure fingerprinting for copyright protection", *Electronics Letters*, vol. 38, no. 17, pp. 958-959, Aug. 2002. ISSN 0013-5194.

[7] F. Hartung and B. Girod, "Digital watermarking of raw and compressed video", in *Proceedings of SPIE*, vol. 2952, pp. 205-213, 1996.

[8] R. M. Bernárdez, J. M. López, A. Farreras, J. L. García, J. Rufino and J. Lorente, "Video services on mobile networks of newer generation" (in Spanish), *Comunicaciones de Telefónica I+D*, no. 21, Jun. 2001.

[9] B. Hunt, "Industry ready to bring up revenues from mobile data", Finantial Times IT and FT journal, Nov. 2002.

[10] `http://www.orange.co.uk`

Norwood MA: Artech House, 2001.

[11] L. Hanzo, P.J. Cherriman and J. Streit, *Wireless Video Communications: Second and Third Generation Systems and Beyond.* Willey, 2001.

[12] ISONIFY, Internet Audio and Video Technologies, `http://www.insonify.com/`

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0-7695-1916-4/03 $17.00 © 2003 IEEE