Real-Time Transcoding and Video Distribution in IEEE 802.11b Multicast Networks

R. Asorey-Cacheda
Dep. Ingeniería Telemática
Universidad de Vigo
ETSIT, Campus, 36200 Vigo, Spain
rasorey@det.uvigo.es

F.J. González-Castaño
Dep. Ingeniería Telemática
Universidad de Vigo
ETSIT, Campus, 36200 Vigo, Spain
javier@det.uvigo.es

Abstract

In this paper, we propose a real-time transcoding system to generate contents for mobile networks. Video transcoding is widely used to change storage formats. However, as far as the authors know, it has not been proposed to generate real-time contents. We implement and evaluate an indoor video service that delivers transcoded contents to wireless Pocket PCs via IEEE 802.11b multicast. We propose a generic methodology for mobile video planning.

1 Introduction

Many new digital video services have been recently proposed. It has been necessary to develop new transmission protocols (DVB-S [1] for satellite, DVB-T for terrestrial TV, DVB-C for cable, RTP for Internet...) and media encoding standards (MPEG-2 [2], MPEG-4 [3]...).

Among those services, we have witnessed the exponential growth of media stations that transmit their contents via the Internet, including TV companies that transmit the same contents they deliver via traditional transmission systems. MeasureCast [4] reported that Internet audience of media stations had a growth of 129% in 2001.

On the other hand, IEEE 802.11 wireless LANs have been very successful in the last two years. The rapid growth of this technology has opened new horizons in telecommunications and has suggested new services that rely on user mobility [5]. Wireless LANs may expand the audience of Internet media stations to mobile users.

In this paper, we propose a real-time transcoding system to generate contents for mobile networks. Video transcoding is widely used to change storage formats. However, as far as the authors know, it has not been proposed to generate real-time contents. Although the philosophy in this paper can be extended to alternative video sources (all major open TV channels are broadcasted via terrestrial radio, cable and satellite), we have chosen satellite TV because of its ubiquitous access. We implement and evaluate an indoor video service that delivers transcoded contents to wireless Pocket PCs via IEEE 802.11b multicast. We have focused on IEEE 802.11b because it has been the first legal sub-standard in the European Union. Due to EU regulations, IEEE 802.11a was not immediately adopted and this situation influenced the development of the new sub-standard IEEE 802.11h, a variation of IEEE 802.11a [6]. However, the extension of this work to other sub-standards is straightforward. Finally, we propose a generic methodology for mobile video planning.

The rest of this paper is organized as follows: section 2 describes the background of this research. Section 3 presents our digital TV transcoding/distribution system for IEEE 802.11 wireless LAN networks, and proposes a generic methodology for mobile video planning. Finally, section 4 concludes.

2 Background

Digital TV is usually distributed via satellite, terrestrial radio and cable as MPEG-2 data streams over the DVB transport protocol. Alternatively, it is possible to distribute video via 100 Mbps cable LANs, using protocols such as HTTP and RTP over IPv4. However, despite all the advantages of LANs, they are not scalable: IPv4 mobility, QoS and multicast are possible but extremely difficult to implement and manage in large-scale systems. It is expected that this situation will change with the advent of IPv6 [7].

In the field of Internet domestic access, there have been notable advances in the last decade that have allowed new multimedia services, such as live Internet radio or video. The key access technologies are basically xDSL lines and cable networks. These access networks require specific protocols to exploit user bandwidth efficiently. One of the most

Proceedings of the Eighth IEEE International Symposium on Computers and Communication (ISCC'03)
1530-1346/03 $17.00 © 2003 IEEE

extended is RealNetworks RTSP, to display Internet videos in real time. Besides, home PVR and DVR devices, which will boost broadband multimedia services, will become increasingly popular in the next years, thanks to the integration of media protocols in interactive television platforms. New content providers will offer video-on-demand, personalized contents, etc.

An obvious possibility for mobile access is cellular network transport, like 2.5G GPRS and 3GPP [8]. 2.5G user bandwidth is severely limited ($\sim$ 100 Kbps). 3GPP is still not available and, if it is not deployed soon, IEEE 802.11 user networks may take its place to support broadband mobile services. Current previsions suggest that there will be a hard competition between wireless VoIP and 3G networks [9]. IEEE 802.11b can offer a low-cost VoIP alternative with up to 11 Mbps and 100 m cell range. Global ISPs, multinational companies and even public groups and initiatives can build cost-efficient networks in metropolitan areas. Moreover, future Wireless Metropolitan Area Networks (IEEE 802.16 [10]) will provide even higher speeds (120 Mbps per channel). For these reasons, we have chosen IEEE 802.11 to implement our mobile video service.

The rapid growth of the PDA market is another important factor in the evolution of mobility. Some reports point that global PDA retail revenues are likely to increase five-fold by 2006 as units shipments will be over 85 million units [11]. For this reason, it is expected that new PDA and hand-held devices will include wireless/telephony features among other advanced functions. This will enable the deployment of new broadband multimedia services.

A good solution to generate real-time video contents for mobile networks from available sources is a transcoding system. The transcoding concept is not new, and has been present in other fields, such as human-to-computer interface adaptation [12]. However, as far as we know, none of the existing applications work with real-time video feeds, such as those taken from satellite TV broadcast channels. Most of those applications work with records and webcam video feeds. Media servers such as Darwin Streaming Server [13], Helix Universal Server [14] or Windows Media Encoder [15] convert files and serve media streams encoded in proprietary formats, but do not take real-time streams as inputs. On the other hand, there are applications that are really transcoding-oriented, such as Transcode [16], a Linux stream processing tool that admits a wide range of formats and provides a high degree of transcoding flexibility. However, Transcode is not oriented to real-time applications and is not designed as a media server, and consequently is not useful for our purposes in its current form. Other examples of transcoding tools with similar limitations are FlaskMPEG [17] and VirtualDub [18].

The choice of satellite as media source is due to the following factors:

1. In Spain, like in many European countries, all open terrestrial TV stations are also broadcasted in digital satellite channels. Obviously, we are interested in digital sources, to simplify the transcoding process. On the other hand, terrestrial digital TV is currently being deployed in Spain, but it is not accessible everywhere.

2. High quality media sources may overload terrestrial networks. High quality is necessary because we might want to generate transcoder output for a broad range of user terminals, including high-resolution ones (such as set-top boxes). By attaching a satellite dish to the transcoding equipment, it is possible to obtain a high quality video source.

Transcoding performance is a critical issue. The transcoder must be capable of decoding the input stream and encode the output stream in real time. The satellite input stream has a binary rate of 15 Mbps, and the most efficient decoding approach is using a MPEG-2 hardware decoder (like those present in DVB reception cards). On the other hand, mobile user terminals are small and, consequently, have small displays. This means that the output stream may have a much lower binary rate, for a reasonable subjective quality. Also, in our TV application, we benefit from multicast transmission (it is not necessary to generate an output stream per user, just a single stream per TV station). Taking all these facts into account, we could implement the whole transcoding procedure by software, on a Pentium III running at 800 MHz.

3 IEEE 802.11b video distribution

3.1 IEEE 802.11

IEEE 802.11 wireless LANs have been around for over a decade, but are succeeding nowadays because of falling costs and improved implementations.

There are two different ways to configure a network in the IEEE 802.11 standard: *ad-hoc* and *infrastructure*. In the ad-hoc configuration, the mobile nodes form a network "on the fly". The second configuration is based on an infrastructure of fixed access points (APs) that support communications between mobile nodes. Obviously, the second configuration imposes less constraints on user terminals. For this reason, and since our application in section 3.2 is oriented to closed areas where AP installation is not a problem, we will follow the infrastructure configuration.

The physical layer transmits raw bits over the communication channel. IEEE 802.11b can support high data rates up to 11 Mbps. In addition, IEEE 802.11 uses *dynamic rate shifting*, allowing rates to be automatically adjusted under diverse conditions. IEEE 802.11b devices transmit at lower

Data Rate	Code Length	Mod.	Symbol Rate	Bit/ Symbol
1 Mbps	11 (Barker Sequence)	BPSK	1 MSps	1
2 Mbps	11 (Barker Sequence)	QPSK	1 MSps	2
5.5 Mbps	8 (CCK)	QPSK	1.375 MSps	4
11 Mbps	8 (CCK)	QPSK	1.375 MSps	8

Table 1. IEEE 802.11b data rates

rates (5.5 Mbps, 2 Mbps or 1 Mbps) if necessary. When the devices move back to places where a higher-rate transmission is possible, they select it. Table 1 summarizes all data rates available and their characteristics.

Multicast transmission is subject to an additional constraint. Since there is a single transmission for all terminals in the multicast group, it is necessary to set the same AP data rate for all of them. Thus, the clients of IEEE 802.11 multicast transmissions do not benefit from dynamic rate shifting.

3.2 Satellite-to-IEEE 802.11 testbed

The testbed is composed by the following elements:

- A satellite dish oriented to Hispasat 1C. This satellite covers West Europe and South America and offers all major Spanish TV channels.
- A transcoder/media server. Its main features are:
  - Pentium III running at 800 MHz with 512 MB of RAM.
  - Linux (Debian 3.0) operating system.
  - A satellite card (Fujitsu-Siemens Activy 300 DVB SAT board).
- An IEEE 802.11b AP (D-Link DWL-1000 AP), attached to the transcoder.
- A PDA (iPAQ H3790) with an IEEE 802.11b card (D-Link DCF-650W) (Figure 1).
- A laptop (HP Omnibook XE3) with an IEEE 802.11b card (D-Link DWL-650).

3.2.1 Transcoded data rate for subjective quality

In the first experiment, we estimated the transcoded data rate required to achieve subjective quality on a PDA screen. The transcoder computer obtains the source stream from the satellite, transcodes it to a suitable format and serves it at an HTTP port. The laptop emulates the presence of multiple clients and measures average bandwidth consumption in the wireless LAN. Finally, a real video client runs on the PDA, to evaluate subjective quality of video output from the point of view of the user.

- The transcoder receives a MPEG-2 stream corresponding to a Spanish TV channel (composed by a 15 Mbps video stream and a 128 Kbps stereo audio stream). This stream is placed in a FIFO (*FIFO A*) for further processing.
- *FIFO A* contents are transcoded to a MPEG-1 stream. The choice of MPEG-1 is due to the limited number of formats supported by PDA software at the time this paper was written. The transcoded stream is finally placed in a second FIFO (*FIFO B*), to be served via the mobile network.
- *FIFO B* contents are served to the mobile clients by an HTTP server at port 8080. Although HTTP is not the best protocol to transmit video data, it was adequate for the purposes of the subjective quality experiment. The bandwidth overload we observed was remarkably low ($\sim$2 Kbps).

The transcoding software is based on the following libraries:

- LinuxDVB is an auxiliary library to extract video and audio streams from a satellite stream. It is part of Siemens DVB Linux drivers [19].
- The transcoder core is based on FFmpeg [20], a library to decode and encode MPEG streams.

The media server for subjective quality evaluation was written in Perl. It was a simple HTTP server that could handle multiple connections, and could be configured to limit the maximum bandwidth served per connection. As described in section 3.2.2, in the second stage of the study it was replaced by a multicast channel server.

The multiple-terminal emulator was also written in Perl. Finally, the PDA client used to visualize MPEG streams was PocketTV [21].

The minimum rate to guarantee subjective quality was 512 Kbps (in our implementation, a 224×176 448 Kbps video stream and a 64 Kbps stereo audio stream). During the tests, and depending on content nature, transmission rates varied between 496 Kbps and 530 Kbps. This video channel rate allows the transmission of several channels in a multicast IEEE 802.11b LAN.

Figure 1. PDA terminal to evaluate subjective quality

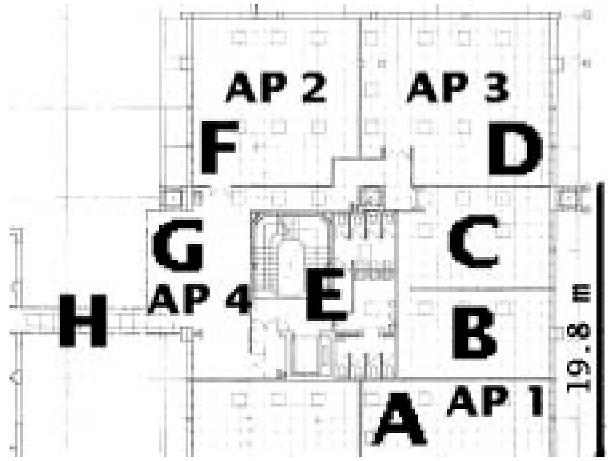

Figure 2. Floor map of the test area

3.2.2 IEEE 802.11b multicast testbed

In order to evaluate IEEE 802.11b multicast for video transmission, we added two additional modules to the system:

- *A multicast channel server*: a Linux program to serve multiple streams to multicast IP addresses, encapsulated in 1-KB UDP frames. This frame size guarantees that video data is not fragmented by lower layers [22].
- *A multicast client application* that receives one or more channels from the channel server. This application was developed for both Windows XP and Pocket Windows 2002, to be used on a laptop and an iPaq H3790 PDA, respectively. The client application measures variables of interest in each video channel, such as UDP packet error rate, packet size and bandwidth received.

	1 Mbps	2 Mbps	5.5 Mbps	11 Mbps
A	0.00%	0.00%	0.01%	0.02%
B	0.02%	0.02%	0.27%	0.32%
C	0.02%	0.05%	0.28%	0.33%
D	1.29%	1.30%	16.20%	
E				
F				
G				
H				

Table 2. AP 1 UDP packet error rate

3.3 Planning methodology

Figure 2 shows a floor map of the test area where we evaluated the system. APs 1 to 4 were placed in rooms A, F, D and G, respectively. System performance was measured in rooms A-H.

Tables 2 to 5 show UDP packet error rate in IEEE 802.11b multicast transmissions from APs 1 to 4, for all possible data rates. A blank entry indicates that the corresponding AP is unreachable. The target area is not homogeneous: the results are influenced by wall distribution and by water pipes and elevator gear installed in the wall that separates room E and rooms A-C.

We observed the following:

1. Subjective quality is guaranteed for error rates lower than 0.33%.

	1 Mbps	2 Mbps	5.5 Mbps	11 Mbps
A				
B	0.40%	0.95%	1.55%	3.21%
C	0.19%	0.60%	0.91%	0.98%
D	0.06%	0.21%	1.03%	2.35%
E				
F	0.00%	0.00%	0.03%	0.01%
G	0.40%			
H				

Table 3. AP 2 UDP packet error rate

	1 Mbps	2 Mbps	5.5 Mbps	11 Mbps
A	0.04%	0.08%	0.15%	0.72%
B	0.02%	0.05%	0.10%	0.62%
C	0.00%	0.04%	0.08%	0.54%
D	0.00%	0.00%	0.01%	0.02%
E				
F	0.01%	0.02%	0.03%	0.10%
G				
H				

Table 4. AP 3 UDP packet error rate

	1 Mbps	2 Mbps	5.5 Mbps	11 Mbps
A	1.86%			
B	9.27%			
C	10.15%			
D	10.69%			
E	0.01%	0.02%	0.02%	0.04%
F				
G	0.00%	0.00%	0.01%	0.02%
H	0.01%	0.01%	0.02%	0.02%

Table 5. AP 4 UDP packet error rate

2. In that case, UDP multicast over IEEE 802.11b has an efficiency better than 90% (delivered data rate-to-transfer rate ratio), which is coherent with protocol overhead: the packet headers of the different layers involved (PLCP, MAC, IP and UDP) add 85 bytes to our 1-KB data packets. This limits the maximum number of channels to be transmitted, for a given IEEE 802.11b transfer rate.

3. Obviously, all APs must transmit the same channels, to allow terminal roaming.

With all these constraints in mind, we propose the following *generic planning methodology* to optimize system usage:

i) *Determine the reachable region for each transfer rate*, satisfying the error rate constraint. All reachable regions in our target area are shown in table 6.

ii) *For each transfer rate with full coverage, minimize the number of APs*. In the case study, we need at least three APs (AP1, AP3 and AP4) to achieve full 11 Mbps coverage, and at least two APs (AP3 and AP4) to achieve full 5.5 Mbps coverage. This corresponds to $\sim$ 20 and $\sim$ 10 PDA video channels, respectively. It is not possible to save more APs by reducing the transfer rate, if we wish to guarantee full coverage.

	1 Mbps	2 Mbps	5.5 Mbps	11 Mbps
A	AP1,AP3	AP1,AP3	AP1,AP3	AP1
B	AP1,AP3	AP1,AP3	AP1,AP3	AP1
C	AP1,AP2,AP3	AP1,AP3	AP1,AP3	AP1
D	AP2,AP3	AP2,AP3	AP3	AP3
E	AP4	AP4	AP4	AP4
F	AP2,AP3	AP2,AP3	AP2,AP3	AP2,AP3
G	AP4	AP4	AP4	AP4
H	AP4	AP4	AP4	AP4

Table 6. Reachable regions

Therefore, in our case study, 5.5 Mbps is a good compromise between performance and cost.

4 Conclusions

In this paper, we have proposed a combination of transcoding and IEEE 802.11 wireless networks to distribute real-time video to mobile terminals. This combination may be useful in environments where mobility is necessary, such as airports, train stations, restaurants, etc. Another interesting application is video surveillance (security personnel may consult security cameras from mobile PDAs). The results in section 3.3 show that it is possible to serve several PDA video channels using multicast IEEE 802.11b with satisfactory subjective quality.

Future work is oriented towards using transcoding technology to save bandwidth in core networks. We propose the installation of satellite transcoders in xDSL access centrals, so that TV channels can be offered to end users without imposing any burden on the backbone.

5 Acknowledgments

This work has been partly supported by EU project IST-2000-26418, *Next Generation Network Initiative*, EU action COST 272, *Packet-Oriented Service Delivery Via Satellite* and CESGA (Galician Center for Supercomputing).

References

[1] ETR 101 200 DVB-Cookbook. A guide to how to use the DVB standards and specifications.

[2] ISO/IEC 13818-1:2000. Information technology – Generic coding of moving pictures and associated audio information: Systems.

[3] ISO/IEC 14496-1. Information technology – Coding of audio-visual objects - Part 1: Systems.

[4] MeasureCast. WWW. http://www.measurecast.com, 2001.

[5] L. Goldberg. *Wireless LANs: Mobile Computing's Second Wave*. Electronic Design, June 1995.

[6] Status of Project IEEE 802.11h. WWW. http://grouper.ieee.org/groups/802/11/Reports/tgh_update.htm, Sept. 2002.

[7] W. Fritsche, F. Heissenhuber. *Mobility Support for the Next Generation Internet*. IPv6 forum white paper. WWW. http://www.ipv6forum.com.

[8] PacketVideo. WWW. http://www.packetvideo.com/prodtech, 2002.

[9] Petri Possi. *Wireless voice over IP*. WWW. http://www.umtsworld.com/articles/c0001.htm.

[10] IEEE Std 802.16-2001. IEEE Standard for Local and Metropolitan Area Networks.

[11] *Strategy Analytics predicts about 85 million PDA shipments by 2006*. WWW. http://uk.gsmbox.com/news/mobile_news/all/54170.gsmbox.

[12] F. J. González-Castaño et al. *A New Transcoding Technique for PDA Browsers Based on Content Hierarchy*. Lecture Notes in Computer Science 2411, 2002.

[13] Darwin Streaming Server. WWW. http://developer.apple.com/darwin/projects/streaming.

[14] Helix Universal Server. WWW. http://www.realnetworks.com/products/media_delivery.html.

[15] Windows Media Encoder. WWW. http://www.microsoft.com/windows/windowsmedia/wm7/encoder.asp.

[16] Transcode. WWW. http://www.theorie.physik.uni-goettingen.de/∼ostreich/transcode.

[17] FlaskMPEG. WWW. http://go.to/flaskmpeg.

[18] VirtualDub. WWW. http://www.virtualdub.com.

[19] DVB drivers. WWW. http://www.linuxtv.org/download/dvb.

[20] FFmpeg. WWW. http://ffmpeg.sourceforge.net.

[21] PocketTV. WWW. http://www.pockettv.com.

[22] B.P. Crow, I. Widjaja, J.G. Kim, P. Sakai. *Investigation of the IEEE 802.11 Medium Access Control (MAC) sublayer functions*. INFOCOM 1997, vol. 1, pp. 126-133.