802.11g WLANs Design for Rural Environments Video-surveillance

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Abstract

There is a lot of literature where researches show the best way to develop WLANs inside buildings. Their approaches try to provide large coverage and high performance taking into account wall losses and other issues. WLAN outdoor deployments are usually used to provide Internet access for citizens. In this article we show all parameters taken into account and the measurements taken to develop a new type of WLANs: WLAN for rural environments video-surveillance. These types of Wireless networks are usually covered by other wireless frequencies, not by 802.11g. First we will start from the election of the MPEG-4 codec that will be used for transmission. It will be chosen as a function of the devices used in the deployment. Second, we will show the issues of a rural environment design and the wireless coverage area mathematical design. We will take into account signal losses given in rural environments. Finally we will show the number of octets per second, the number of messages per second and the network utilization in % measured from a public natural park deployment.

1. Introduction

Video-surveillance has evolved by leaps and bounds. These systems went from analogical capture and transmission to the use of techniques that allow to capture digital video and to transmit it over distributed IP infrastructures [1] [2]. Video streaming allows video surveillance and storage from remote stations with low infrastructure cost and maintenance. The greatest inconvenience for IP video transmission is the needed bandwidth to provide high quality of service between end systems. WLANs have this limitation because of technology restrictions [3]. In this case, it is necessary the use of high compression algorithms with low bandwidth consumption [4].

There are many codification techniques. Some of them are based on image spatial compression (such as Motion-JPEG), others, such as H.261 and H.263, are based on temporal video sequence compression (they analyze the motion variation between an image and the next one).

MPEG-4 [5] is a video compression ISO/IEC Standard. The application fields where it can be applied are Digital Television, interactive graphical applications and interactive multimedia. MPEG-4 provides high audiovisual data compression to store or stream video and, at the same time, it provides audio and video quality. MPEG-4 compression is based on visual-objects coding [6]. It defines an audiovisual scene as a representation of codified objects that have relationship over the time and the space. These objects are organized hierarchically, where the basic objects are static images, video objects and audio objects. Objects have some properties enclosed such as special coordinates, the scale, locality, zoom, rotation and so on. These characteristics allows a user reconstitute the original video after decoding all layer of objects. MPEG-4 can vary the bitrate from 9600 Bits/s to 5 Mb/s. The compression is based on Discrete Cosine’s Transform with I-frames (keyframe), P-frames (predictive) and B-frames (bidirectional). It offers better performance than MPEG-1 and MPEG-2 at low bitrates. MPEG-4 standard is being used in many video-surveillance systems because it is able to transmit good video quality using low bandwidth.

Since the appearance of Wireless Local Area Networks, based on IEEE 802.11b and 802.11g standards [7] [8], a spectacular market growth has been experienced because of several factors: the simplicity and the features offered by devices developed, transmission equipment low costs and the use of the license-free portion of the 2.4 GHz band. We have chosen IEEE 802.11g standard because it is able to operate at a maximum raw data rate of 54 Mbit/s. IEEE 802.11b maximum raw data rate is 11 Mbit/s.

Today the installation of these networks at home or at office environments is straightforward and technically affordable [9] [10] [11]. WLANs are widely developed around the world with interesting
projects, sometimes promoted by the city councils that want to offer wireless coverage to their citizens, or by groups of users that want to establish their own particular network [12]. There are many possibilities for using this unlicensed radio band technology, and simple models such the one we are going to present in this paper, will be useful for these tasks.

This paper is structured as follows. Section 2 shows a study of three common MPEG-4 variants in order to know which one is the best to use depending on the environment characteristics. Section 3 explains how is a rural environment and what issues we have to take into account to design the wireless network. Section 4 gives the mathematical expressions we have used to design our proposal. Real measurements for MPEG-4 video IP cameras are shown in section 5. Finally, in section 6, the conclusions are summarized.

2. MPEG-4 codecs comparison

There are three main public MPEG-4 codecs: DivX, Xvid and H.264. The following are their main features:

- **DivX codec**: It is a free codec, but the professional version has to be purchased. There are four speed modes for codification. It has a psychovisual enhancement based on DCT. It carries out preprocessing using spatial and temporal filters. The codec allows choosing the number of I, P and B frames, the maximum keyframe intervals, the motion compensation, the type of quantization (H.263 and MPEG-2) and the interleaving method.

- **XviD codec**: Its origin is DivX 4 and it is based on the same libraries. It is an open source code, and there are many developers improving the codec. It has several profiles that allow DivX players compatibility. These profiles allow choosing the video resolution and bitrate. The main profile features are the number of images I, P and B, motion compensation, adaptable quantization and luminance hiding, type of quantizer and interleaving. It allows searching in motion.

- **H.264 codec**: It was designed to use for videos that need low bitrate but medium/high definition, e.g. for video streaming over Internet and for high definition applications such as cinema or DVD. The compression process has seven states: (1) motion estimation, (2) Intra-Estimation, (3) transformation, (4) quantization, (5) filter path and (6) entropic quantification.

2.1. Testbed

In order to know what is the best codec for our purposes, we have chosen a digital video camera that captures in DV format (720x576 resolution and 25 fps). Scenes captured are outdoor and mainly with green and brown colours. The camera was connected to an Intel Celeron-S a 1300 MHz computer using a IEEE 1394 interface. The computer had 320 MBytes of RAM. The operative system was Microsoft Windows XP Professional ®.

The desktop application used to code the video was VirtualDub v.1.6.2 (freeware). The codecs used for comparison were DivX version 5.2.1, XviD 1.0.3-20122004 (Koepi) and H.264 version x264vfw_rev120. The desktop application to gather measurements was Microsoft management Console 2.0 ©. The application allows us to measure the computer performance while the VirtualDub process was running. There were not other processes running while we were taking measurements. The application was started when video coding began and it was finished when the coding process ended. The coding was done without audio, without any codec filter and using Fast Recompress VirtualDub mode.

2.2. Codec measurements

First, we want to know which codec is the best one depending on the luminance of the images captured. In order do it, we acquired images at 9:00 and 12:00 in the morning and at 17:50, 18:20 and 19:30 in the afternoon. These ours have different sunlight and, therefore, images with different luminosity. Image sequence has been coded using 5 bitrate types: 909, 1649, 2389, 3129 y 3869. Results shown in figures 1 and 2 have been taken at 12:00 and at 19:30 hours respectively. There we can appreciate that XviD has higher compression factor (we compared the video without compression versus the video compressed with every codec). This difference is higher when there is less luminosity (at night) in video images. When the bandwidth is a video-surveillance system limitation (like our case), the best codec is XviD.

To compare the time needed to compress a second of a video, we have captured 5 minutes in DV format and then we have used each one of the three codecs to compress it. Figure 3 and figure 4 shows the time needed to compress a second of video at 12:00 and at 19:30 hours respectively. We can see that when the more dark is the more time is needed to compress a second of video.
On the other hand, the higher is the bitrate chosen, higher is the time needed to codify a video-second (this difference is higher in H.264). DivX is the best codec when it is needed low compression times, although XviD is very close to it.

Now we want to compare the number of In and Out (I/O) operations in order to know which codec will need more process capacity. In figure 5 we show an example of the number of I/O operations (the video was captured at 19:30 and with bitrates 909 and 3869). We can see that DivX has higher I/O operations (and quite more in its startup), and the lowest is H.264. We have observed that I/O operations for all codecs do not vary as a function of the luminance of the images, except during the DivX startup compression, where I/O operations values are quite different as a function of the luminance, but it does not bother us because the codec is going to be used for a long time, not for a short time. So the number of I/O operations depends on the codec and the bitrate.

Now we can state the following:

- We have to choose a codec depending on the implemented system limitations or its features.
- When the limitation is the network bandwidth, XviD is the best one.
- When it is needed short time compressions, DivX and XviD are the best ones.
- When the limitation is the video acquisition device (because it is a computer that needs to capture from several cameras or because it has several processes running), H.264 is the best one.

3. Rural environment design.

A rural environment video-surveillance design is very different compared to home or enterprise designs. It involves next issues:

- We have to minimize the impact of a data network in the rural environment. We have chosen a wireless network to avoid data wires over the land.
- We have to avoid the use of electric wires because it could damage animals, so the devices power has to be obtained using solar panels. It implies that the devices have to be low power consumption to minimize costs and visual impact (because the more power consumption bigger solar panel).
- The video camera has to be very small to reduce visual impact for animals; it needs to have enough quality to obtain good images.
- It is needed enough bandwidth to be able to stream video from different video acquisition devices.

Our design election, taking into account that we are going to transmit digital video, implies one or several 802.11g access points (depending on the number of video acquisition devices) placed on a visible position from all parts of the rural area. The video acquisition devices have to have high gain antenna (to reach large distances) and it has to focus to the access point. The access point antenna has to be a high gain sectorial antenna (see figure 6).
Anyone from the wired distributed system (where the access points will be connected) could see images acquired from the video acquisition devices. All video acquisition devices will have an IP address and these images could be seen from Internet.

Starting from this design, there are four main possibilities (others could be a derivation of them):

1. Embedded PCs with three or four video cameras connected to them and with a wireless network interface card. It could have high performance and high quality images. Video compression will be done by software and codecs could be changed as desired. But this solution suffers from a main drawback: It needs so many electrical power.

2. Wireless IP cameras that will transmit their images directly to the central access point. It seems to be interesting if they have high resolution and they consume low power.

3. Wired IP cameras connected to an access point, which will transmit the video images to the central access point. It will need an access point for every camera (if the cameras are so far), and they will need more electric power than when it is used a single camera.

4. Analogic cameras connected to a wireless video IP server that will convert video images to digital video and will transmit them to the central access point. On one hand, the analogic camera and the wireless video server for 802.11g will need more electric power than a single wireless 802.11g camera, and, on the other hand, the cost is high due to the wireless video IP server.

We think the best solution is the use of a Wireless IP camera as the video acquisition device. This solution implies to install small solar panels because it is the solution with lower electric power consumption. It also gives lower visual impact than the others because it is only one device and it is small. Its cost depends only on the camera features. Now, taking into account the MPEG-4 codecs comparison shown in section 2, the best MPEG-4 codec for the system proposed is XviD.

We have estimated the maximum power consumption for a wireless IP camera to 8 Watts when it is moving.

A wireless system in a rural environment presents some problems such as:

- A rural area is usually plenty of trees, animals and vegetation. These objects decrease the received power, so we must be sure that the transmitted signal has enough power.
- Nowadays an 802.11g WLAN has a maximum bandwidth rate of 54 MBps, so we have to test how many cameras could transmit to a single access point without having a video quality reduction.

### 4. Mathematical issues.

In order to design this system we have studied the signal loss during its path in a rural environment.

First, our devices work at 2.44 GHz, so we can calculate the far field start using equation 1.

\[
R \geq \frac{2D^2}{\lambda}
\]  

(1)

Where D is the beam diameter at the output coupler. When D is equal to 1, we have far field condition at the 16,266 meters. Now, we need to know which is the maximum distance the Wireless IP camera could be to receive enough signal power. To calculate this parameter we use the power balance formula (given by equation 2). This equation states that the received signal power, in dBm, is equal to the transmitted power plus the transmitter and receiver gain, minus the basic loss and minus other losses produced by objects (such as trees or humidity) [14].

\[
P_r (dBm) = P_t (dBm) + G_t (dB) + G_r (dB) - L_a (dB) - L_{other} (dB)
\]  

(2)
In our system, basic losses can be calculated by the free space propagation equation. Its value, expressed in dB, can be obtained using the equation 3.

\[ L_s (dB) = 10 \cdot n \cdot \log d \]  

(3)

Where \( n \) is the attenuation variation index. \( n = 2 \) for air medium and \( d \) is the distance between the transmitter and the receiver. We have considered other losses such as rain loss, which depends on the place where the wireless system will be installed and vegetation loss that depends on the number of trees closer to the signal path between the transmitter and the receiver (see equation 4). The value of these losses can be obtained from references [15] and [16].

\[ L_{\text{other}} (dB) = L_{\text{rain}} (dB) + L_{\text{vegetation}} (dB) \]  

(4)

Joining equations 2, 3 and 4, for our environment we obtain equation 5.

\[ d = 10 \left( \frac{P_{\text{rx}} + G_{\text{rx}} + G_{\text{tx}} - L_{\text{rain}} - L_{\text{vegetation}} - P_{\text{rs}}}{20} \right) \]  

(5)

In order to calculate what distance it will be able to cover, we are going to fix some parameters. On one hand, the theoretical transmitted power is \(-40.2\) dBm for an 802.11g WLAN device at a distance of 1m, and we estimate \(-80\) dBm threshold power for the far-away IP camera to have enough quality of signal for video transmission, so our received power must be greater or equal to this mark. Let’s use a 20 dBi 120 degree panel antenna for the access point (\( G_{\text{rx}} \)) and 12 dBi directional yagi antenna for all wireless IP cameras (\( G_{\text{tx}} \)). On the other hand, this study has been done in Europe. Europe has two main hydrometric areas: area H and area K [17], so looses because of the rain, in the worst case, have a value of 0.026 dB for two kilometres. To know looses because of the vegetation, we have used the recommendation given in reference [16], so we can assume a loss of 1.2 dB/m. Equation 6 shows the formula needed to design the system.

\[ d = 10 \left( \frac{71.77 - 4.2 m}{20} \right) \]  

(6)

Where \( m \) is the metres of vegetation. Figure 7 shows the coverage distance (where we can place a wireless IP camera) as a function of the metres of vegetation through the light of sight path. We can see that more than 34 meters of vegetation is not allowed because the camera distance will be closer.

5. Camera bandwidth consumption

We have measured a wireless IP camera transmitting XviD-codec compressed video over HTTP protocol in order to test the number of octets per second and the number of messages per second in the network. The video resolution was 320x240 at 30 fps. The wireless IP camera also transmitted audio at 24 Kbps. We have measured, during 2 minutes and 30 seconds, next situations:

- 1st Situation: The camera is acquiring video from a fixed place that there is not any motion, and the camera is not moving.
- 2nd Situation: The camera is acquiring video from a fixed place that there is motion, but the camera is not moving.
- 3rd Situation: The camera is acquiring video while it is moving.

5.1. Number of octets per second

Figure 8 shows the number of octets per second for 1st, 2nd and 3rd situations. We can observe that the worst case is when the video acquired has motion. On the other hand, we think that the moving camera situation is rampant because of the bandwidth used to control the camera. No case has more than 140000 octets per second (1,12 Mbps).

5.2. Number of messages per second

Figure 9 shows the number of packets per second for 1st, 2nd and 3rd situations. We can observe that the worst case is when the video acquired has motion. The moving camera sends messages in a rampant manner.

6. Conclusions

MPEG-4 codecs try to achieve higher compression rates without loosing video quality. In order to know which codec is the best one for our design, we have checked some factors such as compression factor, time for compression and video acquisition device performance. We have observed that codecs behave in a different way depending on the sunlight when the video is compressed.

We have proposed a wireless design for rural environments video-surveillance based on IEEE 802.11g. Other considered solutions do not meet the requisites aforementioned. We have designed trying to minimize the material cost to implement it in rural zones without diminish video image quality and taking into account the 802.11g WLAN performance.
Our design is scalable because we can add access points easily and increment the number of wireless IP cameras attached to these access points. Moreover, it is easy to add emergent Technologies.

The implementation of these types of WLANs can contribute for the following:

- Video images could be used for the observation of animals. Animal researchers could use it avoiding physical contact with the animals.
- Video acquired could be used for intrusion detection surveillance in rural areas.
- Video images could be processed in real time for detecting fires in forests.
- Images acquired from places with many visitors could be used to monitor their impact in natural parks and to offer them alternative paths to visit.

Real bandwidth wireless IP camera consumption measurements shows that the system supports many wireless IP cameras because a single camera needs less than 1,12 Mbps. Future works will test the system performance with more than 20 cameras in a single access point.

7. References


