A WLAN DESIGN FOR VIDEO TRANSMISSION IN RURAL ENVIRONMENTS FOR AGRICULTURE AND ENVIRONMENTAL RESEARCHES AND EDUCATIONAL PURPOSES

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Abstract: - There is a lot of literature about indoor WLANs. Researchers try to find the best design to provide large coverage and high performance taking into account wall looses and other issues. WLAN outdoor deployments are usually set up in cities to provide Internet access for citizens. In this article we are going to show other type of WLAN applications: 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 show the issues of a rural environment design and the wireless coverage area mathematical design taking into account signal looses given in rural environments. Next, we will show our deployment and how do visitors see it. Finally we will show the number of octets and the number of messages per second taken from a natural park installation.

Key-Words: - WLAN design, Wireless Video Streaming, TICs for rural environments, Agriculture new Technologies.

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 necessity of 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].

Since the appearance of Wireless Local Area Networks, based on IEEE 802.11b and 802.11g standards [5] [6], 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. The modulation scheme used in 802.11g is orthogonal frequency-division multiplexing (OFDM) for the data rates of 6, 9, 12, 18, 24, 36, 48, and 54 Mbps, and reverts to CCK (like the 802.11b standard) for 1, 2, 5.5, and 11 Mbps. Even though 802.11g operates in the same frequency band as 802.11b, it can achieve higher data rates because of its similarities to 802.11a. We have chosen IEEE 802.11g standard because it is able to operate at bigger maximum raw data rate than IEEE 802.11b.

Today the installation of these networks at home, or at office environments, is straightforward and technically affordable [7] [8] [9]. 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 networks [10]. There are many possibilities for using that unlicensed radio band technology and simple models, such the one we are going to present in this paper, will be useful for these tasks.

In order to support continuous media, we require a real time video and audio transmission protocol. Interactivity and timeliness are crucial, so low latency communications are necessary without the reliance on excessive packet retransmission. In this kind of situations, robust wireless communication and error resilient video codecs become vital. We have chosen MPEG-4 [11] (an ISO/IEC Standard developed for video compression). 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 at the same time that provides audio and video quality. 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 [12].

This paper is structured as follows. Section 2 gives our motivation and describes the rural area. Section 3 explains how a rural environment is and what issues to design the wireless network we have to take into account. Section 4 shows the mathematical issues to design the radio network. How our design has been deployed is shown in section 5. Real measurements for MPEG-4 video IP cameras are shown in section 6. Finally, in section 7, the conclusions are summarized.

2 Motivations and Rural Area Description

The rural area where we have implemented our design is a natural park. It is called "El Encín" and it is managed by IMIDRA[1]. IMIDRA is entirely dedicated to research, innovation and scientific spreading tasks. The rural environment has a circular form, and it has 2 Km diameter (see Figure 1). It is placed in Alcalá de Henares (Madrid), N-II road, 38.2 kilometer.

"El Encín" is a land where cereals (wheat, barley, oats, maize, etc.), vegetables (chick-peas, lentils, peas, etc.), grapevines and other plants, with different production systems, are cultivated. It has different kind of trees such as black poplars, sequoias, and so on. In addition, it has several bird species, which are native of the Madrid Community.

IMIDRA has developed a scientific spreading project called "Explora el Encín". Its intention is to present the surroundings closest to Madrid, its agriculture and its researches. One of the main goals of this project is to design, to develop and to set up an optimized wireless network to acquire, transmit and show real-time videos in tactile screens placed inside the building of the research center. The project's objetive is to show interesting, or difficult access places, to people who have any physical or sensorial diminution from an interactive room at the beginning of the rural area route. It will bring "Explora el Encín" to everybody and, from now, physical or sensorial conditions will not be limitations to see the rural area.

Functional objectives are:

- To develop a technologic solution that has to be able to join Information and Communication Technologies with food, agriculture and environmental researches and with disabled people.
- To develop IMIDRA's technologic image and concretely its spread scientific project "Explora El Encín".
- To use emergent Technologies in environmental education and to bring them closer to handicapped people.
- To show "Explora El Encín" to all citizens, letting the interactive visualization of the natural patrimony and their scientific researches be more attractive.

Nowadays, "Explora el Encín" has a web server where everybody can see and hear different species from birds, trees, cultivated plants, etc, using photos, videos and sounds [13]. But it wants to offer more to its visitors, so they want to install a system of cameras in the rural area in order to let people see the natural park in real time as if they where inside.

3 Problem definition

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. So, 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, the solar panel bigger is).
- The video camera has to be very small to reduce visual impact for animals; it needs enough quality to obtain good images.
- Enough bandwidth is needed to be able to stream video from different video acquisition devices.

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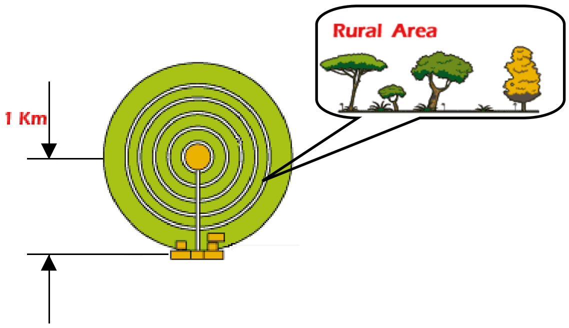

Figure 1. "El Encín" Rural Area

- The rural area is plenty of trees, animals and vegetation. These objects diminish the received power, so we must be sure that the received signal in our wireless network 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.

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 2).

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 and with a wireless network interface card. It could have high performance and high quality images, 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, that will transmit the video images to a central access point. It will need an access point for every camera (if the cameras are so far), and they will need more power than a single camera.
4. Analogic cameras each one connected to a wireless video IP server that will convert video images to digital and will transmit them to a central access point. The analogic camera and the wireless video server will need more energy than other solutions. On the other hand, a wireless server for 802,11g costs more than a wireless 802.11g camera.

We think the best solution is the use of a Wireless IP camera as the video acquisition device.

4 Propagation Losses

In order to design this system we have studied the signal loss during its path in a rural environment. Now, we need to know how far the Wireless IP camera could be to receive enough signal power. To calculate this parameter we use the power balance formula (given by equation 1).

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].

$$P_{rx}(dBm) = P_{tx}(dBm) + G_{tx}(dB) + G_{rx}(dB) - L_b(dB) - L_{other}(dB) \quad (1)$$

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

$$L_b(dB) = 10 \cdot n \cdot \log d \quad (2)$$

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 that 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. The value of these losses can be obtained from references [15] and [16]. Joining equations 1 and 2, for our environment, we obtain equation 3.

$$d = 10^{\frac{P_{tx}+G_{tx}+G_{rx}-L_{rain}-L_{vegetation}-P_{rx}}{20}} \quad (3)$$

In order to calculate what distance it would be able to cover, we are going to fix some parameters.

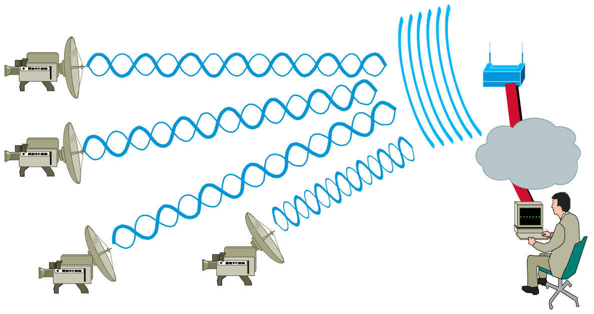

Figure 2. Video-surveillance design election.

On one hand, theoretical transmitted power is -40.2 dBm for an 802.11g WLAN device at a distance of 1 meter, 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 than this mark. Let's use a 20 dBi 120 degree panel antenna for the access point (Grx) and 12 dBi directional yagi antennas for all wireless IP cameras (Grx). 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 kilometers. To know the 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 4 shows the formula needed to design our WLAN.

$$d = 10^{\frac{71,77-1,2 \bullet m}{20}} \qquad (4)$$

Where m is the number of meters of vegetation. Now we are able to predict the number of meters of the coverage area taking into account the number of meters of vegetation through the line of sight.

5 Deployment and Web Page Design

In this section we are going to explain the solution we have chosen. It is the one that adapts better to IMIDRA's necessities. Then, we are going to explain how we have deployed the WLAN in the rural area.

First, we have installed four digital cameras in places where they perform low visual impact. Figure 3 shows the position of four Wireless IP cameras in the rural area. Those places are the following:

- A feeder: We have obtained very good results in wintertime because several bird species have been eating there at the same time. We are thinking on putting 2 places: one for small size birds and another for pigeons and blackbirds.
- Watering hole: The water is limited during summertime in this zone of Spain. The birds visit it very much.
- The rural area centre vision: The plantation and agricultural experiences could be viewed there.
- Wide vision: This camera shows the walk of the rural area and the weather can be seen.

Chosen cameras are powered by electrical wires, but in the future, electrical current will be powered by solar panels (chosen cameras have low power consumption, it is around 5,5 Watts) because new digital cameras will be installed in places where electrical energy could not be provided by wires.

These cameras transmit MPEG-4 standard video compression, which has higher compression and quality compared to other standards. It also consumes low bandwidth. MPEG-4 is commonly used in video streaming over IP environments. The video is streamed using the HTTP protocol (we have chosen this protocol to facilitate the video visualization) with very good results. In future works, IMIDRA wants to offer the natural park visualization, not only in their tactile screens, but in their public Web page for Internet users.

Chosen cameras are able to stream video with a resolution of 320x240 using 25 fps (PAL system) and they are able to transmit audio in both directions (from the camera and to the camera). Their working temperature is between -5.5º C and 75º C.

To see the video captured from the cameras, we have developed a Web page that is able to receive the streams of video received from 4 Wireless IP cameras in real time. Images are shown without jumps and there is not any quality images reduction. Figure 4 shows the developed web page. When an user wants to see that images, it opens an explorer with the URL of the server where our designed Web page is placed (in the touch screens computers), and all 4 video streams are transmitted from the Wireless IP cameras to the web page client through the access point. The access point is placed close to the touch screens. Touch screens must have Javascript enabled.

Clicking the icons placed on the right of every video image, we can access to the control Web page for each camera. This web page (see Figure 5) shows a greater image with the same quality as the main one and we can change its vertical (till 90 degrees) and horizontal (till 270 degrees) orientation. We can also vary the zoom lens to a 10x value and focus the video image (it can be done automatically).

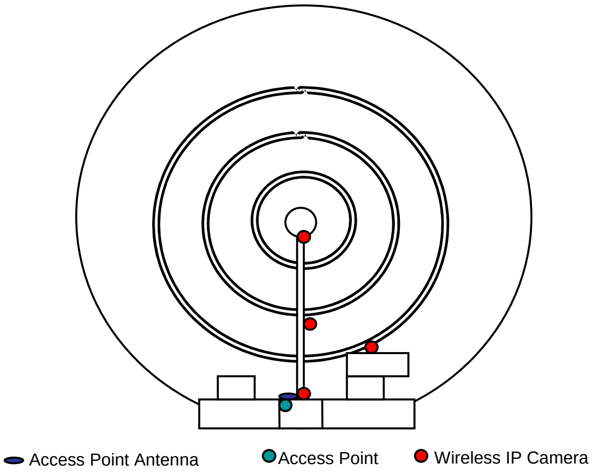

Figure 3. Position of the cameras in the rural area.

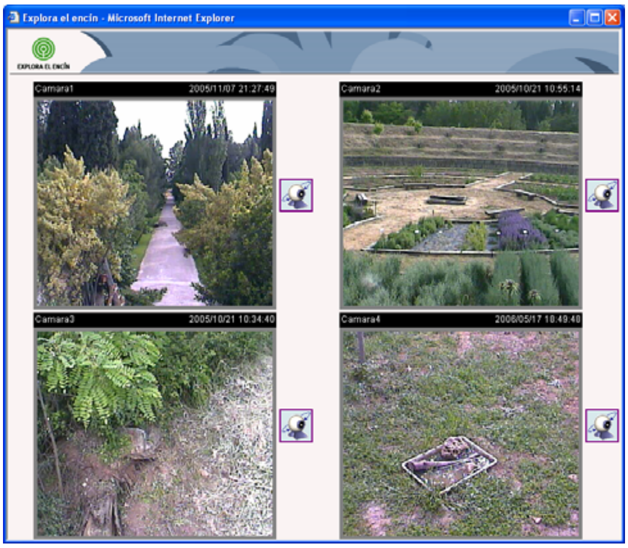

Figure 4. Main Web page.

We can vary the Iris lens to obtain a better visualization and we have enabled two buttons called “Auto pan” and “Auto patrol” that moves the camera automatically to have a panoramic view of the place. Finally, we have enabled a button to pick up photographs. This option is helpful for the IMIDRA researches because it allow them to see animal and plants evolution.

All cameras can be accessed independently and their control are independent, so users can access to a camera and control it without any disturb.

6 Real Measurements

We have measured all four wireless IP cameras transmitting MPEG-4 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.

Figure 5. A single camera visualization Web page.

The video resolution was 320x240 at 25 fps. The wireless IP camera also transmitted audio at 24 Kbps. We have measured them during 15 minutes.

6.1 Number of octets per second

Figure 6 shows the number of octets per second. We can observe that there is not more than 800.000 octets per second in the wireless network. Measures show us that the implemented system can support video streaming from all four Wireless IP cameras without problems. Supposing a maximum rate transmission of 30 Mbps in 802.11g Wireless LAN, the designed system can support up to 30 Wireless IP cameras.

6.2 Number of packets per second

Figure 7 shows the number of packets per second. We can observe that it is not more than 1200 packets per second in the wireless network, so there will be not so much messages through the medium at the same time. We could add one more access points, so the system is scalable.

7 Conclusion

We have proposed a wireless design for rural environments video-surveillance based on IEEE 802.11g standard. Other considered solutions do not meet our prerequisites. We have designed it trying to minimize the material cost for its implementation but without diminishing the quality of the video 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.

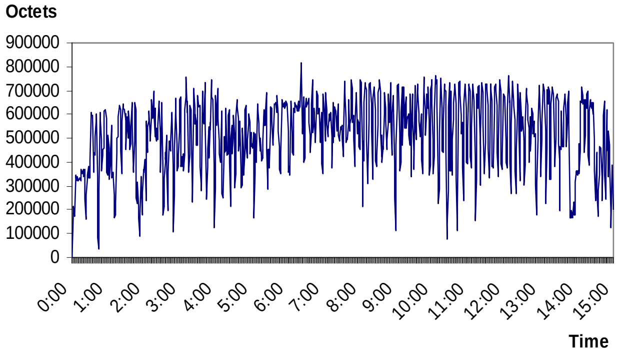

Figure 6. Number of octets per second.

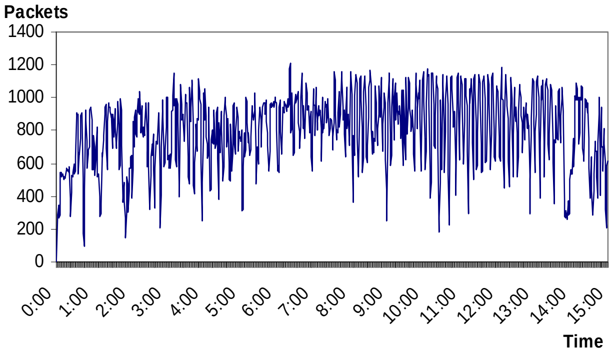

Figure 7. Number of packets per second.

The implementation of these types of WLANs can contribute to 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.
- Images obtained 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. After some tests and proves, we have calculated that we can add up to 30 Wireless IP cameras without adding more network devices, only buying more cameras. Future works will test the system performance with more than 30 cameras in a single access point.

References:

[1] R. T. Collins, A. J. Lipton y T. Kanade, “A System for Video Surveillance and Monitoring”, American Nuclear Society Eight International Topical Meeting on Robotics and Remote Systems, 1999.

[2] Y. Ivanov, C. Stauffer, A. Bobick y W.E.L. Grimson, ”Video Surveillance of Interactions”, 2nd IEEE Workshop on Visual Surveillance, 1999.

[3] A. Smolic, K. Müller, M. Droese, P. Voig y T. Wiegand, “Multiple View Video Streaming and 3D-Scene Reconstruction for Traffic Surveillance", 4th European Workshop on Image Analysis for Multimedia Interactive Services, 2003.

[4] M. Bramberger, J. Brunner, B. Rinner y H. Schwabach, “Real-time video analysis on an embedded smart camera for traffic surveillance”. Real-Time and Embedded Technology and Applications Symposium, 2004.

[5] IEEE Std 802.11g/D1.1-2001, Part11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications: Further Higher-Speed Physical Layer Extension in the 2.4 GHz Band.

[6] IEEE 802.11g, “Further Higher-Speed Physical Layer Extension in the 2.4 GHz Band” 2003.

[7] Jeffrey Wheat, Designing a Wireless Network, Syngress Publishing, Rockland, 2001

[8] M.S. Gast, 802.11 wireless networks: the definitive guide, Ed. O'Reilly, Sebastopol, 2002

[9] B. O'Hara, The IEEE 802.11 handbook: a designer's companion, IEEE Press, New York, 1999.

[10] Chou, Yuntsai. A Seamless City: The Case Study of Taipei’s Wifi Project. 16th European Regional Conference. Porto, Portugal, Sept. 2005.

[11] R. Koenen, “Overview of the MPEG-4 standard”, ISO/IEC JTC1/SC29/WG11 N1730, Luglio 1997.

[12] T. Stockhammer, M. Hannuskela and T. Wiegand, H.264/AVC in Wireless Environments, IEEE Transactions on Circuits and Systems for Video Technology, Vol. 13, July 2003.

[13] “Explora el Encín” web site at: http://www.imidra.com/exploraelencin

[14] A. Smith, "Radio frequency principles and applications. The generation propagation, and reception of signal and noise", IEEE Press. New York, 1998.

[15] Recommendation UIT-R P.838, at http://www.itu.int/itudoc/itu-r/archives/rsg/1998-00/rsg3/029r1e.html

[16] Recommendation UIT-R PN.833-1, at http://www.itu.int/itudoc/itu-r/archives/rsg/1998-00/rsg3/037e-es.html

[17] Recommendation UIT-R PN.837-1, at http://www.itu.int/itudoc/itu-r/archives/rsg/1998-00/rsg3/043r1e.html