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INVESTIGACIÓN

CCTV system design for monitoring transmilenio articulated buses using a Wimax network

Diseño de un sistema CCTV para el monitoreo de los buses articulados de transmilenio usando una red Wimax

Yuri Vanessa Nieto Acevedo[1], Héctor Iván Blanco Rodríguez[2], Oswaldo Alberto Romero Villalobos[3], José Fernando López Quintero[4]

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Resumen

El sistema de Circuito Cerrado de Televisión (CCTV) provee una herramienta eficaz para incrementar la seguridad al interior de los buses del sistema público de transporte de la ciudad de Bogotá, Transmilenio; debido a que provee la accesibilidad para monitorear los buses articulados a través de una arquitectura de video vigilancia combinada entre análoga y red; utilizando para ello el despliegue de una Red WiMAX dedicada para este servicio. Esta propuesta denominada TmTV, se basa en la arquitectura cliente–servidor, pilar de los sistemas distribuidos, dado que todos los equipos y dispositivos del sistema operan y se despliegan de manera transparente en la estación Central de Monitoreo.

Palabras claves: CCTV, DVR, Fibra Óptica, WiMAX, WMAN.

Abstract

The Closed Circuit Television (CCTV) system provides an effective tool to increase security within the public bus mass transit system of Bogotá's, Transmilenio; because it provides accessibility to monitor the articulated buses through a combined architecture video surveillance between analog and network, using rolling out a WiMAX network dedicated to this service. This proposal called TmTV, is based on the client-server architecture, mainstay of distributed systems; since all computers and devices on this system operate and deployed transparently in the Central Monitoring Station.

Keywords: CCTV, DVR, Fiber Optics, WiMAX, WMAN.

[1] Industrial Engineer, InformationScience and Communications Master Student, Corporación Unificada Nacional de Educación Superior (CUN), BogotáD.C, Colombia. Contact: yurivane89@gmail.com.

[2] Electronic Engineer, Information Science and Communications Master Student, Universidad Distrital Francisco José de Caldas, Bogotá D.C. (Colombia), blancor.hectori@gmail.com.

[3] Systems Engineer, S.P. Software Engineer, S.P. Roads Design, Traffic and Transportation and M.S. Industrial Engineering, Universidad Distrital Francisco José de Caldas, Bogotá D.C. (Colombia), oromerov@udistrital.edu.co.

[4] Systems Engineer, Computer systems engineering information and knowledge society M. Sc, CorporaciónUnificadaNacional de Educación Superior (CUN), Bogotá D.C. (Colombia), jflopezq@hotmail.com.

INTRODUCTION

A CCTV (closed circuit television), is a means of sending images from one place to another in real time (González, 2007). It is generally used as a video surveillance technology that allows monitoring various environments and activities; is essentially characterized in that all components are intertwined physically and/or wireless(Luna, 2012), hoping that a limited number of people have access to video cameras.

Transmilenio (TM) is the company's largest mass public transport in Colombia, created to transform public transport in Bogotá (Gilbert & Garcés, 2008). The capital of the Republic of Colombia has approximately 8 million people (DANE–Departamento Administrativo Nacional de Estadística, 2015) and it is estimated that over 25% of city residents use the service as a transport system Transmilenio(Transmilenio, 2015). Given that currently Transmilenio has only CCTV system within stations, this proposal describes a kindly monitoring solution within the articulated buses of TM System, through the installation of security cameras and using a WiMAX network as a means of data transmission to a monitoring center where it will take place in real time, to promote the comfort and safety of its users.

METHODOLOGY

The design of this proposal is based on client-server architecture as a distributed application model in which time video in real time is transmitted via a WiMAX network dedicated to this operation. The antennas of the network will be connected using fiber optics available at all stations or bus stops of TM System and as a means of redundancy will be interconnected to each other through the WiMAX network to ensure the operation of the service; finally this video is delivered to a central monitoring of Transmilenio.

Technical Specifications

Video surveillance systems can be divided according to their architecture into two types: analog Architecture, and IP Architecture (Cohen & Gattuso, 2009). Analog Architecture is a technology that uses analog video surveillance equipment; so the recording, storage and playback signals corresponding becomes this video frequency spectrum (Axis Communications, 2015) and proposed for video recording inside the buses. In Network Architecture all devices are connected by network (Mata, 2010) which was used for data transmission. In the proposal for TmTV is combined these architectures, so to operate the following equipment and devices are required:

Cameras. Hidden surveillance cameras will be connected directly to the DVR using a BNC connection and power supply. They will be installed within the Transmilenio articulated buses hidden way to prevent public access. Depending on the bus, four cameras for each articulated bus, and six cameras for each bi-articulated bus will be installed as shown in Figure 1. The specifications of this equipment are required:

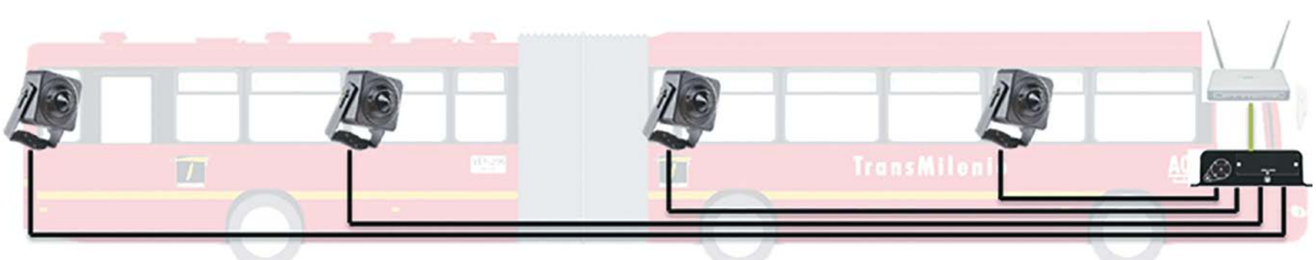

Figure 1. Design installing cameras inside articulated buses

Source: Own author.

- 3.5 mm lens with viewing angle of°.
- Image Sensor ⅓ "Sony Super HAD CCD II.
- Signal System: PAL / NTSC
- Video signal 1 Vp-p output (75 Ω / BNC)
- 700 TVL high resolution.
- Wide Dynamic Range 75dB, so that objects that are located behind bright backgrounds are easily described.
- OSD Menu.

DVR. This device is a video hub that is responsible for receiving the signal from 4 or 6 cameras depending on its model. Video transmission performed by stream and stores up to 2TB. The DVR is installed inside each bus, feeding of the same electrical system; WiMAX Router connected directly to an Ethernet connection. In this device the recording resolution can be modulated: QCIF (Full frame), CIF (Full frame), 2CIF (15 fps), DCIF (12 fps), 4CIF (6fps); as shown in Figure 2.

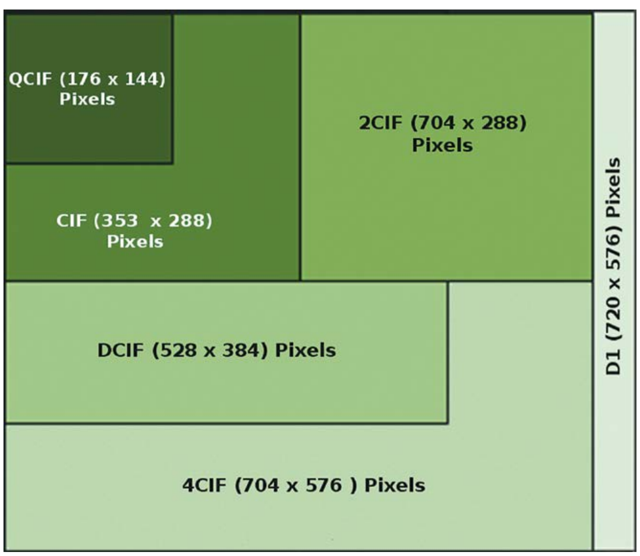

Figure 2. Standard resolution video

Source: (HIK Vision, 2012)).

Within the standard video compression and transmission of H.264, the video recording parameters are selected to improve the performance of bandwidth. Among these are: Bit Rat, Rat Frame, Video and Data Quality Rata.

Calculating the required storage space in MB disk, is accomplished using the formulas provided by the manufacturer of the device (HIK Vision, 2012), the equation (1).

$$q_i = \frac{d_i}{8} \times 3600 \times 1024 \quad \text{D (1)}$$

Where di is given bit rate in kbit/s.

Next, the storage space required for each video channel is calculated as shows equation (2).

$$m_i = q_i \times h_i \times D_i \quad (2)$$

Where hi is the number of hours of recording and Di day the amount of recording.

The minimum space required for storing video from all cameras is performed using the equation (3).

$$q_r = \sum_{i=0}^{c} m_i \quad (3)$$

Where c is the total number of channels in DVR.

According to these formulas provided by the manufacturer and according to the recording quality DCIF to 12 fps and optimal video quality, you get a bit rate of 1.25Mbps approximately of 2.17 TB for 30 days continuous recording 24 hours per DVR is for each articulated.

WiMAX Router. Each articulated bus will have a WiMAX router that receives the video signal from the DVR for later sent by the WiMAX system network(WiMAX Forum, 2012). The WiMAX router based on the IEEE 802.16 standard is driven by the radio interface based on FDMA, the latest in wireless technology that increases the bandwidth for wireless access (BWA). It uses MIMO (Multiple Input Multiple Output) that increases the system capacity, coverage and the rate of return. WiMAX router connection to DVR is done via Ethernet.

WiMAX Base Stations. The antennas receive the signal transmitted by the WiMAX router and sent to the monitoring station. The operating band of the system must be greater than 5 GHz, which does not require licensing operation and function as a private network for providing this service. Each base station must have a system to ensure power supply for 24 hours.

The base stations must comply with the following features:

- WiMAXcertification(WiMAX Forum, 2012).
- Operating frequency 4900–5350 MHz and 4900–5350 MHz.
- Duplexing technology: TTD.
- OFDMA modulation.
- Extended Support Range: 39Km

Video Wall. The connection of 27 LCD monitors 42″ high performance where video cameras at the Transmilenio buses is displayed in real time. Because the monitoring will be held centrally and which acts as the client or end user of TmTV system. There's video of more than 7,000 cameras installed in over 1,400 articulated buses will receive the TM system.

CCTV System Architecture

The proposal is based on the deployment of a dedicated WiMAX communication network for transmitting video that covers all routes through which the mass transit system Transmilenio. In Figure 3 the overall CCTV system architecture shown monitoring, considering data transmission and equipment described in the previous section.

Because the transmission of video and simultaneous monitoring of more than 7000 cameras requires an extensive bandwidth and a great team, the proposal includes the installation of a panic button, so that in case of emergency, alert was sent to the Transmilenio Central Monitoring where you can check real-time video of the articulated bus, optimizing consumption in the bandwidth of the communication channel WiMAX. Similarly, the plant operator decides that monitor buses; from there you can download the video content in each articulated DVR. Eventually when the DVR cannot communicate with the Central Monitoring, the system continues autonomously recording and rewriting of the

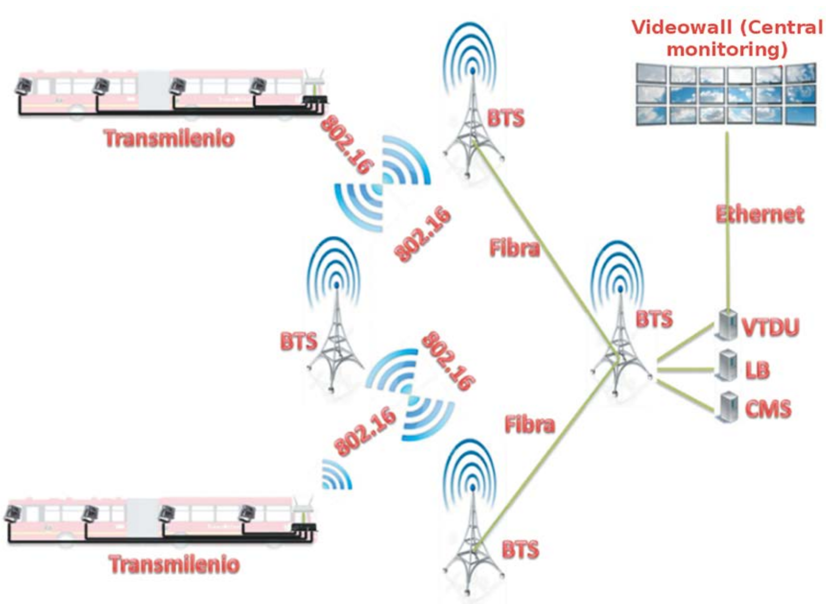

Figure 3. Main architecture video surveillance system TmTV

Source: Own author.

oldest video files; thus changing constantly hard drive is avoided. When the DVR regain connection to the Central Monitoring, the operator is able to retrieve any piece of video recorded during the lost connection with the articulated bus.

The OSI (Open System Interconnections) is a framework for defining architectures for interconnecting communications systems. The model is divided into seven layers: Physical, Link, Network, Transport, Session, Presentation and Application (Ordinas & Griera, 2009). Each layer has a specific function for communication system and has its own protocols connecting the WiMAX system framed (WiMAX Forum, 2012)in the OSI model is shown in Figure 4.

Physical layer. The physical layer is responsible for the physical connections to the various devices on the network, specifically the physical transmission medium. For this particular case becomes a Wireless Network metropolitan area with a single carrier. (WMAN- SC, Wireless Metropolitan Area Network, Simple Carrier) (Rao, Bojkovic, & Milovanovic, 2008)which has the following features:

- Operates in the bands 10-66 MHz.
- Supports TDD (Time Division Duplex) and FDD (Frequency Division Duplex).
- FDD supports full duplex transmission.

OSI Model WIMAX	
Layer	**Protocol**
Application	
Presentation	
Session	
Transport	
Network	
Link	Logical Link Control (LLC)
	Media Access Control (MAC)
Physical	OFDMA, OFDM, SCa, SC

Figure 4.OSI Model WIMAX System

Source: (Ordinas & Griera, 2009).

Network layer. The network layer is responsible for providing connectivity between devices, selecting the connection paths between devices in geographically different networks. Layer is the Media Access Control (MAC) and multiplexing of traffic over the physical medium, which in this case is wireless; among its features are:

- Segment or concatenate service units (SDU–Services Data Unit) received from the upper layers into data units (PDU–Protocol Data Units).
- Select the burst profile and the level of power used for transmission of MAC PDUs.
- Provide security for key management.
- Provide support to the upper layers for mobility management.

Coverage of WiMAX base stations

To evaluate the coverage of WiMAX base stations, must take into account the technical characteristics of the antennas of each base. TmTV in design, have the following antennas(American Radio Relay League, 2011):

Omnidirectional antennas. Are those uniform power radiating in all directions, ie 360°.

Figure 5. Omnidirectional Antenna (a) and Sectored antenna (b)

Source: (American Radio Relay League, 2011).

Sectored antennas. A mixture of directional and omnidirectional antennas. The sector antennas emit a broader directional beam but not as broad as an omnidirectional. Similarly, its scope is greater than an omnidirectional, and less than a directional. For 360º coverage (as an omnidirectional antenna) and long range (as a directional antenna) we install, three sector antennas of 120° or 4 sector antennas of 80°. This system 360° with sector is called "Array".

Figure 6. Heat map trunk 80th street

Source: Own author.

The sector antennas are usually more expensive than directional or omnidirectional antennas.

Heat maps Transmilenio trunk route. The creation of these maps were made using Google Earth, because it allows the calculation of areas and perimeters rightly and through office tools the coverage area of each of the antennas is outlined. Each map describes the coverage radius of the antenna connected to the base station and trunk route along which the articulated buses of Transmilenio. Figure 6 shows the coverage of omnidirectional antenna for the trunk of 80th Street, with additional coverage for the trunk of Suba Avenue, covering a distance of 7.8 Km.In Figure 7(a), the range of the base station for Suba Avenue trunk covering a distance of 9.6 Km is observed, and a base

Figure 7. Heat map trunk Suba Avenue (a) and Heat map trunk highway north (b)

Source: Own author.

station which will be located 2.8 km from Portal de Suba be used.For the trunk highway north, the omnidirectional antenna covers a distance of 10Km as shown in Figure 7(b), and will be located 4 km North portal. The missing stations were connected by a base station that is beginning in the trunk of Caracas Avenue and include a longer journey.

In the trunk of Caracas Avenue and the trunk 10th Avenue, portals include: Usme, Tunal and 20 de Julio with a coverage of 26.9 km and five base stations as shown in Figure 8.

Figure 9 shows the heat map trunk of Avenue of the Americas, covering a distance of 14.5 kilometers through the use of two base stations.

For the trunk of 26th Street a total of 9.6 km is covered with the installation of an omnidirectional antenna which includes the portal of El Dorado as shown in Figure 10 (a).

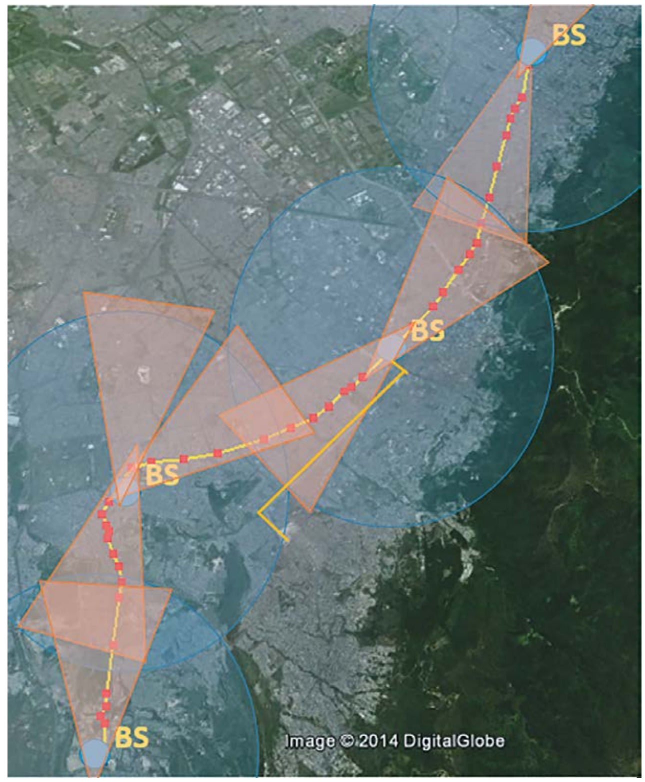

Figure 8. Heat map trunk Caracas Avenue and 10th avenue

Source: Own author.

Figure 9. Heat map trunk of Avenue of the Americas

Source: Own author.

In order to cover the 17.3 km of trunk NQS avenue to include South portal, installing a base station is proposed as shown in Figure 10 (b).

Risk analysis of the proposal

In order to reduce and control the probability of negative impact of eventualities for the project were identified and assessed the risks of the project, which the risk heat map as shown in Figure 11 is obtained.

Risks A2: Partial Fall in the communication link system and A3: Loss of reliability of the information transmitted by the network are the most critical and probability of occurrence. Of the four identified risks A1: partial increase in the budget

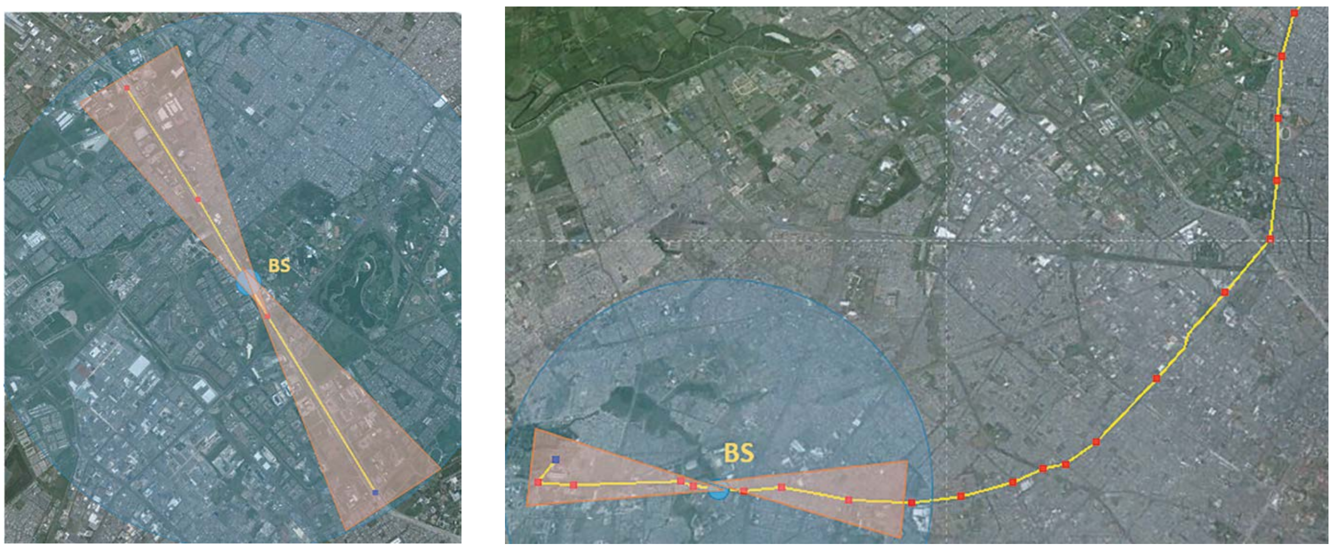

Figure 10. Heat map trunk of 26th street (a) and Heat map trunk of NQS Avenue (b)

Source: Own author.

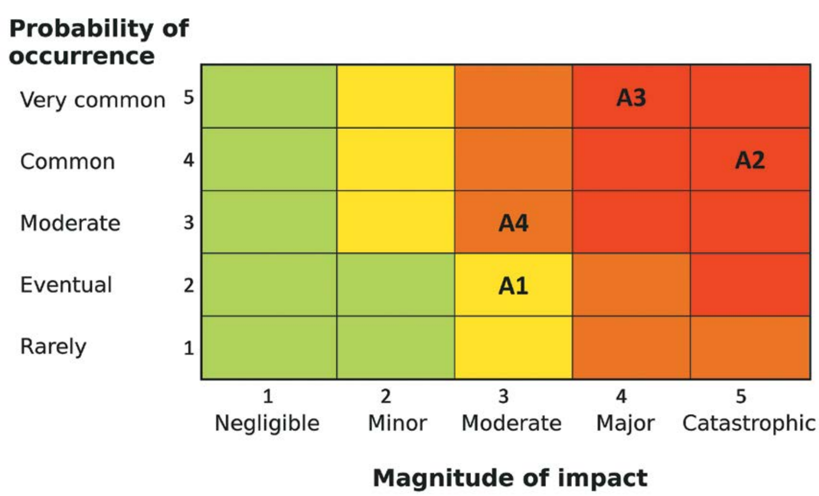

Figure 11. Heat map of risks identified in TmTV

Source: Own author.

of the project and A4: Partial loss of information and cost overruns for replacement of equipment and devices are the least impact. Once the project as well as the mechanisms proposed risk control is implemented, these will mitigate much as 35% being all fully controllable.

CONCLUSIONS

The system CCTV is a proposal highly viable for real-time monitoring within the articulated buses of the public transportation system Transmilenio. Given the size of the video files to be transmitted and once the technologies available for this operation evaluated, it is concluded that the optimal technology to carry out this process is the installation and deployment of its own network WiMAX, operating in a bandwidth greater than the 5 GHz to avoid licensing costs, which can subsequently be used to provide internet service free to users of the system. For optimal monitoring is recommended that the transmission of video is not performed continuously and simultaneously for all articulated buses, but rather considering the inclusion of a panic button actuated by the driver sends a warning to the Central monitoring so that perform video transmission that particularly articulated bus. To implement required 4 sector antennas and 9 omnidirectional antennas for a total of 13 WiMAX base stations covering a total of 87.5 km of linear coverage for Transmilenio trunk roads, such as a WiMAX network for the monitoring of articulated buses encourages opportunities for the safety of its users.

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