MULTI-AGENT AND EMBEDDED SYSTEM TECHNOLOGIES FOR AUTOMATIC SURVEILLANCE

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Abstract: Supervisory Control and Data Acquisition (SCADA) systems have traditionally used text-based Human Machine Interfaces (HMI). We propose a system which integrates multimedia information in SCADA systems in order to improve and support the telecontrol tasks. This system has been deployed in a real environment and we have obtained satisfactory results. Then, we also propose an improvement for this system. This improvement allows telecontrol operators to use the system without needing any experience with computers and also it allows an automatic surveillance of the elements in the utility environment. The development of this improved system is accomplished by using the main advantages of embedded and multi-agent system technologies.

1 INTRODUCTION

The main goal of every SCADA (Boyer, 1999) system is the remote supervision and control of devices –mostly sensors and actuators– which are located at remote facilities.

The information provided by these devices, for example the measurement of the current in a power line is short, not longer than a few dozen bytes. As a result, the traditionally used technologies are still suitable for the delivery of devices data, and probably will be in the future.

However, transmission and networking technologies are not the only fields that have dramatically been improved over the last years. Multimedia compression techniques have also evolved in such a way that digital video and audio can now be processed by cheap PCs, obtaining good quality displays using relative low bit rates. Modern codecs such as MPEG-4 (ISO/IEC, 1991) allow for the compression of high resolution video signals so they can be meaningfully represented using less than 1 Mbps.

Human Machine Interfaces, used to make the management of the SCADA network operators easier, typically display the status data as text strings, and in some cases, in the form of symbols representing the state of the device. Complementing that information with video or audio can be of much help when operating wide SCADA networks, where there is usually no staff at remote stations.

Automatic surveillance or videoconference (Romero, 2004), are other bonus features that multimedia information could bring to SCADA systems.

2 MULTIMEDIA IN SCADA SYSTEMS

Rather than talking about integrating multimedia data into SCADA systems, it would be better to think about integrating SCADA data into modern network systems.

Typical transmission links and protocols used on SCADA networks do not fulfil the bandwidth requirements that multimedia data deployment impose, as data acquired from SCADA devices is usually transmitted over low-bandwidth links using serial protocols.

Another important key factor is that temporal requirements on the reception of the acquired data are very tight on SCADA systems; cycle time on

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SCADA buses generally ranges between 10 ms and 100 ms. Furthermore, transmission reliability is also very important as loss of data might cause a big impact to the integrity of the system.

We have successfully injected SCADA data into an Ethernet system, using a custom SCADA bridge (Figure 1). Data transmitted using the IEC870 (IEC, 1990) protocol from a Multitrans PLC device –which gives data about the voltage and intensity of a power line, among other features– is injected into an Ethernet network using bidirectional serial-to-Ethernet converters.

The converter we have used, named the IS-Server device, takes serial data from the Multitrans device and converts it into TCP packets. It sends them to a predefined IP network address. If the control system needs to receive data in its original serial form, the inverse process may be applied using another IS-Server device.

In our tests, status data, which is periodically polled from a Multitrans device, travels between two Ethernet-based LANs connected via a 100Mbps fiber optic link, resulting in the SCADA data being received in less than 10 ms, even when a raw multimedia stream, which needs nearly all the available bandwidth, was also sharing the fiber optic link.

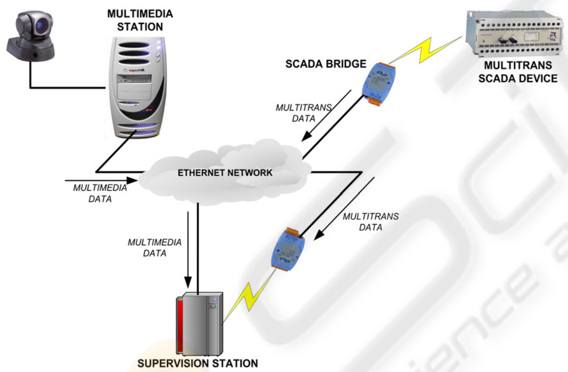

Figure 1: Ethernet SCADA bridge.

As proven above, from the time point of view, sharing the physical medium between SCADA and multimedia data is possible in Ethernet networks, but transmission reliability must also be considered. Ethernet hub devices use CSMA-based medium sharing techniques (ISO/IEC, 1993), which can lead to packet loss in a high traffic scenario, due to packet collision. Therefore, switches should be the starting point on the design of any multimedia SCADA system.

Network management techniques such as Quality of Service (Arindam, 1999) might also be used to ensure SCADA data always gets the bandwidth it needs. QoS allows packet prioritization and bandwidth provision, based on one or more factors, such as the IP address of the sender.

3 IDOLO SYSTEM STRUCTURE

3.1 Interface

We have built IDOLO's interface as a web-based software system, supported by a database system, which manages all needed system configuration and allows operators to easily have access to all multimedia information of the SCADA system.

Being web-based means it can be independently run from an existing SCADA/HMI system, and at the same time it can be integrated into HMI systems supporting web navigation. HMI software supporting ActiveX technology can easily integrate the IDOLO software system via an embedded ActiveX web browser.

Furthermore, some web browsers, such as Internet Explorer, also support ActiveX components; so software components specific to the IDOLO system have been developed as ActiveX controls.

The IDOLO navigation system has been developed using PHP programming language on the server side, and Javascript on the client side. PHP is used to control the content and layout of served HTML pages, and to serve as the interface between the IDOLO system and a MySQL database server that holds all system configurations, such as data about cameras or the design of multimedia synoptics of each station. Using Javascript permits interfacing with web-browser, allowing the IDOLO system to be informed of user input events (e.g. mouse clicks) or control specific browser properties.

3.2 Camera Management

From a logical point of view, the IDOLO system is formed by 2 elements: stations and cameras. It's hierarchically organized so that stations own one or more cameras.

We have worked with 3 types of cameras. Each one has special features, which have made us take different approaches to manage each camera type.

First, network cameras, which do not include internal storage systems, need an external system to store their video. The network camera we have chosen, AXIS 230, uses MJPEG codec, which is no more than a sequence of JPEG images. MJPEG is not an efficient video codec as it only performs spatial compression (based on Discrete Cosine Transformation), as opposed to MPEG-4 that performs both spatial and inter-frame compression.

As it needs an external FTP server with enough storage space to stock the video, this can make for an excessive use of network bandwidth.

Webcams and analog cameras need dedicated PCs to performing the needed compression and streaming. We have chosen Windows Media software platform to deal with these processes, which allows full control over nearly all aspects regarding the previously mentioned procedures.

- Windows Media Encoder is a software component that takes video and audio from USB cameras and frame grabbers and compresses them with Windows Media codecs, variants of MPEG-4 codec in the case of video and MP3 in the case of audio. It also allows for storing of compressed content in the fly on both local and remote storage.
- Although WME also allows streaming using HTTP/TCP protocols, Windows Media Services is a specialized component that takes data compressed with WME and pushes it to the network using RTSP/UDP protocols. Apart from using more efficient network protocols for streaming, WMS is the needed solution for allowing external stations to receive multimedia content from WME encoders, in case IP addresses of encoder stations are inside the local scope.

3.3 Multimedia Synoptics

Synoptics are the common way that HMI systems use to show, in a single screen, all representative data about SCADA elements. The IDOLO system takes this approach and adapts it to the multimedia field (Figure 2) by:

- Showing video windows and audio coming from cameras located at a given station.
- Having graphics of all representative elements in a station, which, when clicked, command PTZ cameras to move to a preset position so it focuses on the selected element.
- Allowing the activation of manual control on PTZ cameras, which are able to control them using the mouse or even a joystick.

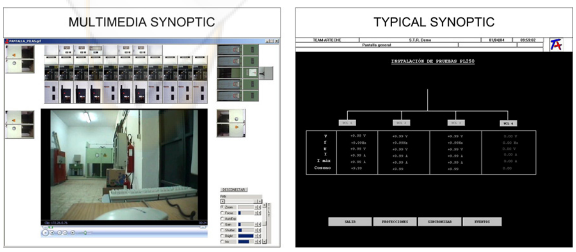

Figure 2: Screenshots comparing multimedia synoptics and classic synoptics.

The concept of multimedia synoptics is also a solution to the inherent delay introduced by MPEG-family codecs, which makes manual control of PTZ devices a bit confusing as images run late in respect to camera movements.

4 DEPLOYMENT ON AN ELECTRICAL FACILITY

The final goal of the IDOLO project has been the integration of our system into a real, working SCADA system. For this reason, we have garnered the cooperation of the Medina Garvey electrical facility, a regional electrical provider located in Seville.

The existing facilities owned by Medina Garvey have been controlled and supervised using SCADA hardware and software developed by Team Arteche. An example of those SCADA components has been the Multitrans device we have used in our integration tests.

As we have not wanted to compromise the integrity of existing system, we have decided to use separate links for sending multimedia and SCADA information, from remote stations to the supervision station. The modern facilities in Medina Garvey were equipped with fiber optic links to communicate with supervision station, so we have used spare fiber cabling for our purposes. These fiber optic links are more than adequate for transmitting high-quality multimedia streams.

There are some older facilities that do not use such high-speed links. In such cases, they have used serial radio links to transmit SCADA status information, which do not have enough bandwidth to send multimedia information over them. But these facilities had also been equipped with telephonic lines, so we have used ADSL technology for sending our multimedia streams. However, using ADSL limited the transmission to fewer, and lower-quality streams; we have tested the transmission of one 512 Kbps stream, and alternatively, two 256 Kbps streams, successfully.

In respect to the SCADA/HMI system used by Medina Garvey, SIPCON HMI system, it's a proprietary, MS-DOS based system, which does not allow the integration of external components. Therefore, IDOLO software has been deployed separately, by using a PC with a Internet Information Services web-server to provide web content to the intranet.

5 WHY USE EMBEDDED TECHNOLOGY?

When our system has been installed in that real-life environment, we have interviewed operators in order to find out their degree of satisfaction. One of the improvements that they have proposed has been that the IDOLO system is like a black box for them. That is a system which is easy to maintain and configure without needing any experience with computers (just by pressing a button). That have made us think about the possibility of developing the system by using embedded technology.

Embedded systems shouldn't be thought of as PCs with general characteristics. Although, more and more, they could be replaced in some application fields thanks to the development of microprocessors and microcontrollers.

They could be considered as hard – soft applications which are more interesting in the immediate future of the Information and Communications Technology sector. The main idea is to use systems which are practically invisible and made up of microprocessors and software in very small systems. These systems allow us to obtain information and accomplish its processing everywhere, in a quick and easy way (ubiquitous computation). If we are able to create a network composed of these embedded systems, which are almost invisible, and we provide them with communication and action abilities, we can create a spatially distributed hardware structure that is available at all times. It makes user anticipate (pervasive computation) (Marwedel, 2003) (Sutter, 2003). All of this can be accomplished in a more secure and reliable way and with a quick and easy maintenance with an economic costs and electric consumption lower than those of traditional PCs.

By introducing these systems in some hierarchical schemes of "surveillance" distributed in substations or transformation centers, we can accomplish an automatic surveillance which allows preventive maintenance operations. In this way we can anticipate possible anomalies that could produce blackouts, which are quite problematic for the end users and, as a result, have significant economic impact for the electric utilities.

6 WHY USE MULTI-AGENT TECHNOLOGY?

When we are talking about automatic surveillance we re referring to not only proactive but also reactive surveillance. This implies that the elements which carry out the surveillance have *human* capacities and are able to make decisions and act by *themselves*. This human behavior has to be programmed, and we are working to achieve this by using multi-agent system (MAS) technology.

MAS are systems composed of multiple interacting computing elements, known as agents. Agents are computer systems with two important capabilities (Wooldridge, 2002):

- They are capable of autonomous actions and can decide by themselves.
- They are capable of interacting with another agents in a social way (cooperation, coordination, negotiation…)

So, first we are modeling the different interactions among the different kinds of agents. Each defined agent is responsible for the surveillance in a specific way because each of them has a fixed intelligent level. Some of them have less processing capacity, so they can carry out a basic analysis of captured situations, whereas, others have more processing capacity, so they can accomplish an advanced analysis.

What kind of information is going to be analyzed? We are working with several types of sensors (senses in Figure 3) which capture image (visible and infrared), smoke and volumetric measurements. Depending on the kind of data, the analysis is carried out in a different way. After modeling the interactions, we are going to design the MAS. We have a main goal in mind to cover the maximum amount of elements in the electrical facility environment (surveillance targets) with the minimum agents and at the same time by keeping agents cooperating. Autonomy and learning capacities are very important for our system and both of them are great advantages of MAS.

7 ARCHITECTURE FOR THE NEW SYSTEM

We use two levels of surveillance. In the lowest hierarchical level there is a network composed by guard agents which don't need to have an excessive processing capacity. These vigilant systems are always collecting information (through sensors) and they have to control their environment by generating alarms or corrective actions (actuators) if appropriated. They have to interact with their environment in a quick and easy way, processing in real time. They have certain mobility in a limited area.

Traditionally, these reactive systems, which are in continuous interaction with the environment, execute certain steps according to that environment, and wait for events to happen. When this occurs, they carry out the process operations by generating out data and changing it to a new state. In this way, anticipation or prevision capacity is limited, since it is restricted to a series of events from a series of known states, leading the system to another waiting state.

However, if we make these guards interact, we can create a knowledge network. This network allows guards to request information by searching for the most adequate solution. If it is not possible to find a solution, our system works by acceding to the highest level, where there is a supervisor with a higher computation capacity. This can transmit the solution to the lower level, or request information from other supervisors.

The high–level architecture is shown in Figure 3.

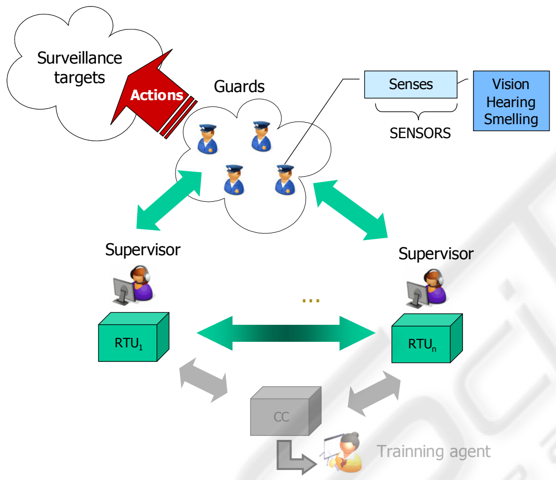

Figure 3: Scheme for the new system.

The guard agent on the lower level is implemented with an embedded system, based on an Atmel's AV32 microcontroller (Atmel Home, 2007), specifically the AT32AP7000. It includes a data memory of 32Kbytes on-chip SRAM and external memory interfaces (Secure Digital); 16 KB instructions and 16 KB data caches; and MMU and DMA controllers. Peripherals include a 16-bit stereo audio DAC, 2048x2048 pixel TFT/STN LCD controllers, 480 Mbps USB 2.0 with on chip transceivers and two 10/100 Ethernet MACs. Serial interfaces include RS232, USART, I2S, AC97, TWI/I2C, SPI, PS/2 and several synchronous serial modules which support most serial communication protocols. The board is preloaded with Linux and shipped with I/O interface drivers that can be called from your own code.

These characteristics allow for us to communicate this system with any other sensors systems, obtaining information on real time about temperature, humidity, movement and IR images from transformers centres or substations.

Supervisor agent hardware is a system based on a VIA Luke CoreFusion™ Processor (VIA Home, 2007), x86 consumer electronics platform compliant. It includes typical PC interfaces which are x86 compliant: out video signal AGP with MPEG-2 decoder/MPEG-4 Acceleration, interfaces ULTRADMA y SATA, 10 /100 Base -T Ethernet connection and two USB ports. The supervisor agent works on a preloaded Linux system, which is customized to this architecture, and always keeps the x86 compliance.

8 CONCLUSIONS

Within this paper, we have described our IDOLO system which integrates multimedia information in a HMI/SCADA system for power system telecontrol and then we have described our current work to carry out an embedded version of that system in order to improve it. This system has already been successfully deployed on a real electrical facility, and uses multimedia information in order to support the telecontrol of the power facility, so operators benefit from the advantages introduced by the displaying of video and audio signals coming from remote stations. They can get live views of maintenance works, or inspect devices located on remote facilities, from the supervision station, or even from their home though internet.

For the new improved system, we are developing an automatic surveillance function and advanced image analysis and processing techniques from IR images to improve the telecontrol tasks for operators in control centers and make them easier. We think that function can be achieved thanks to the use of the autonomous and cooperative capacities of agents in MAS technology.

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