Wireless Image Transmission in Electric Power Hostile Environment

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***Abstract*— This paper presents the study carried out at Universidade de São Paulo and CTEEP to apply wireless communication standards for video, voice and data transmission in Power Line high voltage environment, and provide a communication tool to help the activities of the electricians. In this context, WiFi and ZigBee standards were studied, evaluated and tested considering the specifications and environment constraints. Therefore, this paper presents the system configuration proposed considering, besides the functional specification aspects of usability (size, weight, and low power consumption), laboratory and field tests results in actual Power Transmission Line. Preliminary results show the applicability of ZigBee technology for the desired solution, but also the needed of establishing a restrictive specification, especially in image transmission in real-time, due to the interference of the Power Line environment and the narrow bandwidth of the communication channel.**

Keywords-wireless; image; voice; powerline; electromagnetic interference

I. INTRODUCTION

Many field operations performed in Power Transmission Lines, for example, installation, inspection and maintenance, require the electrician to climb towers and energized lines. Once positioned, the electrician uses his hands to move, balance and handle the tools and devices of the running process. In several steps of these operations, communications between the electrician and his support staff, located at ground, may be necessary to transmit any information or request support.

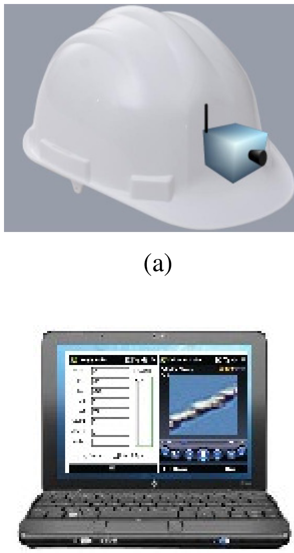
As a natural procedure, the electrician tends to use his voice for communication, and in some cases, it is necessary to shout for effective communication. In noisy environments, the communication becomes impossible. Fig. 1 shows an example of the typical working environment.

To try to solve that problem, several intercoms were tested using radio-frequency. However, this solution proved to be unfeasible due to the size of the devices and the need to handle it to activate [1].

Figure 1. Field work environment.

To envision an alternative solution to intercommunication problem between electricians, and the lack of communication to the Utility Control Center, the VICEL project was proposed to intend the use of digital wireless communication technology (WiFi, WiMax and Zigbee, among others) and provide an effective communication channel that integrates voice, data and image. Those technologies were selected due to their capability of providing digital communication services also ad-hoc and mesh features [2][3].

The communication device developed is tailored to the helmet and the electrician has a camera capable of capturing images in picture and video modes, a microphone and a headset for intercommunication and sensors to monitor the electrician health. Besides the device in the helmet, the system is composed by a main terminal that interfaces the communication with the electricians and the Utility Control Center. The terminal is implemented in a portable computer (notebook) or PDA. Fig. 2 shows the sketch of the devices.



(a)

(b)

Figure 2. (a) device on the helmet, (b) terminal.

The communication channel can be used to transmit the image captured by the camera to other electricians in order to improve the process quality and analysis of possible failures. This system will benefit the electrician activity providing an ubiquitous communication device (without interfering the activity) and that will provide better conditions and safety, due to operational support from other electricians and technical support from experts in decision-making situations. Another benefit is the ability to logging operational events and occurrences in the Transmission Line so that information can be registered for future analysis and improves quality and productivity of the services on the Power Line. Moreover, with the possibility of remote analysis and decision-making (with the transmission of data and images to specialists) rework activities in the Line may be reduced.

Based on those requirements and objectives, the methodology adopted for VICEL research and development considered the analysis of available technologies of wireless communication. As results, the Zigbee technology was chosen. In the second step, performance tests of the Zigbee communication in different environmental conditions were conducted. In addition, this paper presents the preliminary results of performance tests of Zigbee for image transmission.

II. System Architecture

The system for data, image and voice transmitting between electricians in the field operation (VICEL) is composed by devices adapted to the electrician helmet and a communication and interfacing terminal. (Fig. 3)

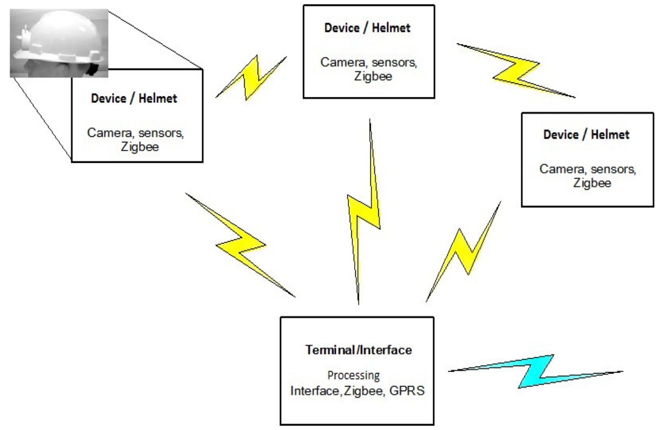


Figure 3. Communication System Diagram.

The diagram of Fig. 3 shows the architecture of the proposed system. In the figure, the Mesh communication is represented between devices, in which, three devices/helmet are shown that can communicate each other. In accordance to the Zigbee specification, there is no logical limit to the number of devices that can enter to the local area network [5].

A. *VICEL Experimental Setup*

The implementation of VICEL prototype for developing and testing makes use of the Crossbow processing platform Imote2, consisting of the IPR2400 module and IMB400 images and audio acquisition module [7]. The module has the CC2400 radio frequency transceiver that implements the Physical and Medium Access Layer based on IEEE 802.15.4. Table I shows the main features of the Physical Layer of IEEE 802.15.4 for WPAN's (Wireless Personal Area Network) used in the CC2400.

The IM400 multimedia board provides multimedia processing resources to Imote2 platform and is composed by components shown in Table II.

TABLE I. Physical Layer of IEEE 802.15.4

Frequency Band	2400.0 to 2483.5 MHz
Modulation Type	QPSK
Data Transmission Rate	250 kbits/s
Number of Channels	16
Transmission Power	1 mW

TABLE II. IMB400 board resources

COMPONENT	MANUFACTURER
Image Sensor	Omni Vision
Audio Codec	Wolfson
Movement Sensor	Panasonic

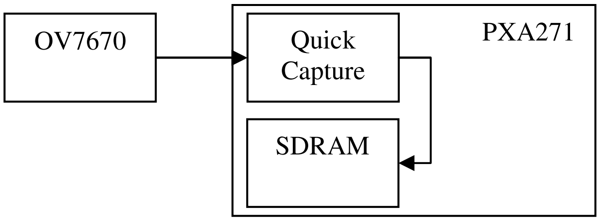


Figure 4. Simplified image acquisition process diagram

The OV7670 image sensor performs image acquisition, which will be automatically sent to Imote2 platform (PXA271 processor) via Quick Capture Interface. Imote2 receives the data bytes of the image sensor and store them automatically in the internal SDRAM memory, saving processing resources. The diagram of Fig. 4 shows the image data acquisition process.

The output image of OV7670 sensor has a VGA standard resolution and uses the YUV 4:2:2 format, i.e. two bytes per pixel. However, it is possible to configure other formats such as RGB 5:5:6, by Serial Control Camera Bus (SCCB).

III. TESTS

A. *Performance Evaluation of Communication in Laboratory*

To evaluate the communication performance of VICEL, configurations and tests were conducted in laboratory and in actual work field. The first test aims to evaluate the interference of the transmitted power in the quality and intensity of the received signal, since it is desirable to use the lowest possible power for energy saving. Two ZigBee modules were used, separated by a distance of 1.35 m and in two conditions, with and without the interposition of an obstacle (Fig. 5). Table III presents the transmission results.

The curves in Fig. 6 show variation of received signal strength due to the variation of the power of the transmitted signal. It may be noted that the distance and power range (up to -86.5 dBm) adopted in the experiment results in significant change in the received signal.

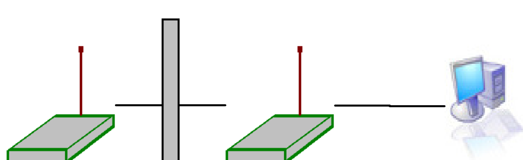


Figure 5. Test configuration – with and without obstacle.

TABLE III. EXPERIMENTAL TRANSMISSION RESULTS

Power RF (dB)	Without Obstacles		With Obstacles	
	Percentage of transmission error	*Intensity of the received radio signal (dBm)*	*Percentage of transmission error*	*Intensity of the received radio signal (dBm)*
-25,0	0,48%	-86,4	0,95%	-86,5
-15,0	0,00%	-77,3	0,47%	-76,6
-10,0	0,00%	-72,2	0,00%	-71,1
-7,5	0,00%	-67,9	0,00%	-68,0
-5,2	0,00%	-66,0	0,00%	-65,8
-3,4	0,00%	-63,7	0,00%	-63,7
-1,7	0,00%	-61,2	0,00%	-62,0
0,0	0,00%	-60,8	0,00%	-61,2

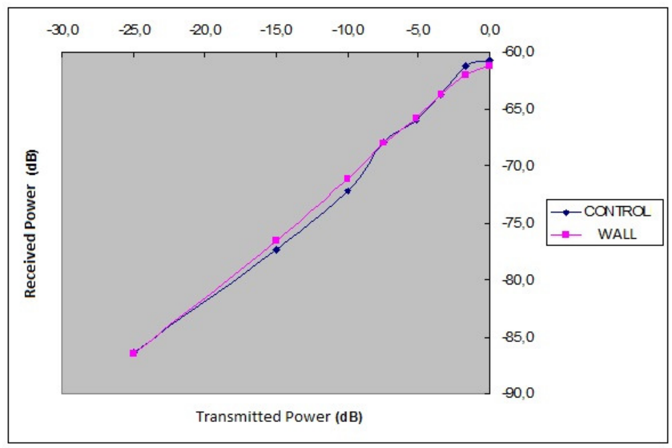


Figure 6. Transmitted and received power.

B. *Performance Evaluation in the Field*

Aiming the verification of the operation and the performance of ZigBee modules subjected to high electric and magnetic interferences, experiments were performed at the CTEEP substation in Cabreúva, SP, Brazil. ZigBee modules used were placed at different distances from Power Transmission Lines of 138 kV and 440 kV for data acquisition. Fig. 7 presents the test environment in which, (a) the module is in contact with the Line, and (b) the module is at 0.50 m far from the Power Line.

(a) (b)

Figure 7. Field test environment.

TABLE IV. FIELD TESTS RESULTS.

Cable distance (m)	138kV Power Line Signal power (dBm)	440kV Power Line Signal power (dBm)
4	-49,3	-58,4
2	-50,2	-58,1
0	-55,0	-94,5

During the experiments, electric current in the Power Lines were around 400 A and 250 A for 138 kV and 440 kV Lines, respectively. Table IV presents the results of field tests, in which the signal quality is around 100% in all tests. As shown in Table IV, the interference of energized line on the behavior of the Zigbee communication, in the sense of signal power, is very small and it can be considered negligible compared to the effect of variation of the distance.

In addition, it was observed that the disruptive discharge (Corona Effect) that occurs during the approach of the module to Power Line interferes on communication process. In testing with 440kV Line, almost in contact (~ 0 m of distance), the transmitted signal power decreases sharply and the signal quality decreases to 40%.

C. *Performance Evaluation in Image*

The module that captures the image (IMB400), allows image capturing with resolutions presented in Table V.

In Table V, the column TRANSMISSION DELAY presents the estimated time to transmit one image frame, considering that IEEE 802.15.4 allows transmission rate up to 250 kbits/s, or 31.25 kBytes/s. Thus, due to the low data rate observed in Table V, it is required the use of image data compression techniques to provide acceptable quality and delay.

The technique used for image compression is constituted by two parts, each one reduces the average size of the image frame. First, individual frames are compressed by using the discrete cosine transform in two dimensions (two-dimensional DCT) followed by the resulting quantization matrix. Then, applying the concept of similarity between consecutive frames, the algorithm sends only the changes in the image. The size of quantization matrix interfere in the compression ratio achieved by the compression of individual frames of video. A typical quantization matrix provides compression rates greater than 10 times without significantly loss in image quality. Table VI shows the size (in bytes) of each frame and the transmission delay for two compression methods tested.

TABLE V. FRAMES SIZE (2 BYTES PER PIXEL)

STANDARD	RESOLUTION (pixels)	SIZE (kBytes)	TRANSMISSION DELAY (seconds/frame)
VGA	640x480	614.400	19.66
QVGA	320x240	153.600	4.92
QQVGA	160x120	38.400	1.23

TABLE VI. SIZE AND TRANSMISSION DELAY USING IMAGE COMPRESSION

STANDARD	Bidimensional DCT		Difference Method + DCT	
	SIZE (kbytes)	*DELAY (sec/frame)*	*SIZE (kbytes)*	*DELAY (sec/frame)*
VGA	61.440	1.96	15.360	0.49
QVGA	15.360	0.49	3.840	0.12
QQVGA	3.840	0.12	0.960	0.03

IV. CONCLUSIONS

This work presented the proposal of VICEL system that enables voice, data and image transmission for electricians in the field. According to the specification, the Zigbee technology was chosen as the standard for VICEL communication, on which the designing and prototyping were conducted. The test results showed the suitability of the technology adopted for use in the Electric Power hostile environment and with respect to distance, the signal quality and electromagnetic interferences.

However, considering the limited bandwidth available in the Zigbee, it is necessary to establish adequately the compromising between image quality and transmission delay, as verified in the results of imaging performance. Due to that, VICEL will adopt two configurations for image transmission: image with high-resolution image with few frames, like pictures, and monitoring with low resolution and in real time.

Future activities include the finalization of compression algorithms, and applications embedded on the device and installation on the helmet, and new tests in the field, especially for re-evaluating the effect of the disruptive discharge on the image transmission quality.

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