Alternative Data Channel for BRT Using PLC

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Abstract: - The use of communication technology system called Power Line communication (PLC), which consists of data communication through the grid network that is available in the urban center. Another feature of the STI for BRT is that the environment will exchange data packets small, so the use of narrowband technologies is possible. The goal of the intelligent transport system (ITS) for Bus Rapid Transit (BRT) is to improve the public transport in relation to security, usability, mobility, quality and productivity through the use of information and communication technologies and one of the main problems is to ensure that elements of his, such as buses, sensors, actuators, lights, among others exchanging data with them, due to the size of this environment, the communication infrastructure between the transportation management system (TMS) and its components is extremely important . This work was considered the evaluation of two narrowband PLC initiatives, PRIME and G3, which has similar physical layer and privileges of high Prime data rates in favorable conditions and G3 delivers better performance in unfavorable conditions. The project can be used as a data communication channel for communication among its elements BRT because the communication calls for a low bit rate.

Key-Words: - PLC, BRT, bandwidth, Specification, Mobility, Transportation

1 Introduction

Medium and small cities have the need to implement a fast and efficient urban transport system to meet the needs of the population and offer a low-cost and quality service. In this context several Brazilian cities have implemented a solution called Bus Rapid Transit (BRT). [1]

The BRT solution is the use of an infrastructure based on exclusive bus lanes stations with pre-payment system. To improve the performance of services, implements up systems that can perform a prioritization of traffic signal, location of the bus and through the planning system can achieve integration between modes of transport.

The implementation of a BRT system requires a lot of planning because of the various components that influence the process, such as the provision of service stations, vehicle configuration, bus interface to the system, information service to passengers and marketing, among others.

One of the BRT components is the ITS. The ITS system consists of a technological matrix intended for the operation and management of urban mobility. It consists of sets of information systems, communication, control, monitoring, sensing, acting and others. It aims to provide greater operational efficiency of transport and transit operations services, and provide comfort and safety for users of BRT services. [2] [3] [4]

An important aspect is that management systems need to communicate with the networks of sensors and actuators installed in the city, in order to obtain the actual information from each location, thus an effective communication system for exchanging data among the elements is required .

Typically, data communication technologies that are available are: pair wire dedicated line, radio frequency, cell phone and others, but the cost of maintenance and deployment often prevents their projects. This article presents an alternative solution to allow communication to their base in Power Line Communication, it is possible to use the infrastructure to get out of the power grid.

2 Smart Grid

The Smart Grid is very similar to the infrastructure needed for the ITS, because in both cases there is a centralized management system that needs to communicate bi-directionally with the elements that are on the street through a data communication line. In this context, considering that the energy service providers have their installed power distribution line in the city and also its need to receive data in its entirety, the company responsible for monitoring the transport can use the same communication infrastructure via PLC, reducing the ITS communication costs. This article focuses on the evaluation of data communications technology that is common to the Smart Grid and ITS.

3 Telecommunications Technologies

- The following communication technologies that can be used for ITS are:
- • Dedicated Line or data networks with dedicated wire can be designed to meet all requirements, however, the implementation costs depend directly on the distance between locations.
- • Radio Frequency (RF) technology is based on data communication using radio waves in the frequencies used worldwide are controlled by the ITU (International Telecommunication Union) and ANATEL (National Telecommunications Agency) in Brazil. The frequency spectrum is divided into bands where each band has a good feature set, free track frequencies are bands of 2.4 GHz and 915 MHz. The scope of an RF communication module may vary depending on the signal strength transmitter and has a low cost compared to other technologies. However, the issue of accreditation and certification of radio by the regulatory agency can be a problem. The radio may be a point-to-point or point-to-multipoint (mesh topology). Point-to-multipoint communication is possible diffusion among several residents and it is possible to achieve a large area coverage, with an emphasis on low-power operation.
- • GSM (Global System for Mobile Communications) or GPRS (General Packet Radio Service) is an alternative because of cost and installation area of coverage, however, there is a strong service operator dependent. The GSM mobile is a technology that is used in more than 200 countries, with over one billion people. In GSM, the signal and voice channels are digital, then data communication is available. The method used by GSM frequency is the administration of the combination of two technologies: TDMA (Time Division Multiple Access) and FDMA (Frequency Division Multiple Access). The GSM bit rate is about 9.6 kbit / s, so that there is limited bandwidth. GPRS is a technology that increases data throughput in the GSM infrastructure. This allows packet data transmission, so that it provides a higher throughput (56 to 114 Kbit / s) than previous technologies because it uses circuit switching. GPRS has the major advantage of huge infrastructure of telephone network operator, but has disadvantages, such as cost and small and inconsistent coverage in rural areas. [4];
- • PLC (Power Line Communication) is a communication system that uses the online distribution power cable to carry

telecommunications services mode allowing data communication over the network at low, medium and high voltage, with advantage of using existing physical resources.

3 Evaluation of PLC for ITS

The power line communication (PLC) is a technology that uses the power cord of live distribution, for communication using PLC and each user must have a PLC modem. Due to the transformer some signals are blocked, so a bridge to traverse it is required. Some applications use PLC at frequencies below 60 Hz, allowing signals to pass through transformers, but these signals transmit data at lower speeds. The factors responsible for the low data communication skills are changes in impedance, high noise levels caused by changing the signs and inductors. This degradation of communication rate caused by noise often limits the applicability of the technology. Other issues still need better solutions, such as electromagnetic compatibility, lack of standardization and better regulatory policies.

In PLC technology, to provide data communications via broadband to feed the utility stations some elements may be necessary, such locking elements being canceled interference in hubs and RF repeaters to increase problems of signal levels.

The broadband PLC is a communication system that provides broadband services (voice, data, multimedia, video, etc.) cabling using the electrical system of high tension that belongs existing electric companies. The PLC scope is the provision of broadband services using one or more power cables in the distribution network and simultaneously electricity is provided. The RF signal is modulated at the first point with the data signal and inserted in the distribution network, which serves as a communication channel. In the second phase, the RF signal is recovered from the power grid with a signal demodulator modulated to recover the original data signal. The data is sent from the second to the first point in a similar manner just by changing the frequency band. The broadband service is full-duplex communication of two simultaneous routes between two locations.

The PLC narrow bandwidth does not require changes in the distribution network and no additional equipment for the packaging distribution transformer. Communication is not affected by equipment or abnormal conditions that may exist in the electricity distribution network, such as capacitor banks, transactions for underground power lines, voltage drops and harmonics. There are no blind spots to the system, which may be caused by phenomena of standing waves generated by extension of the electricity supply or configuration.

Due to the characteristics of each system, this article analyzes the narrow bandwidth performance for ITS PLC monitoring services.

This article considers the use of narrow band PLC in Intelligent Transport System as a communication channel between its elements and OCC (Operation Control Center), as both consider the topology shown in Figure 1. To evaluate the scenario, this work considers the following initiatives:

- • PRIME (Powerline Intelligent Metering Evolution) is focused on developing an open solution for telecommunications, public and non-proprietary new supporting not only smart metering functions, but also progress toward the smart grid. PRIME specified a PLC that uses an OFDM (orthogonal frequency-division multiplexing), open and non-proprietary focusing on interoperability between equipment from different manufacturers and systems.
- • G3 PLC is focused on the definition of an open standard for the implementation of smart grid. The G3 PLC is a power line communications specification based on the promotion of interoperability standards in smart grid deployments.

Both projects use OFDM to modulate the narrowband signal PLC. Tha characterized OFDM signal is the sum of multiple orthogonal sub-carriers with the data of each sub-carrier being independently modulated using some form of PSK or QAM. This signal baseband is used to modulate a main conveyor, used for communication via radio frequency. The advantages of using OFDM are many, including spectral efficiency, high immunity against multipath and simple noise filtering.

Combining OFDM with error correction techniques, adaptive equalization and reconfigurable modulation, it has the following properties: [12]

- Resistance to optical dispersion;
- Resistance slowly changing phase distortion and fading;
- Resistance against multipath using guard interval;
- Resistance against frequency response null and frequency interference constant;
- Resistance against burst noise.

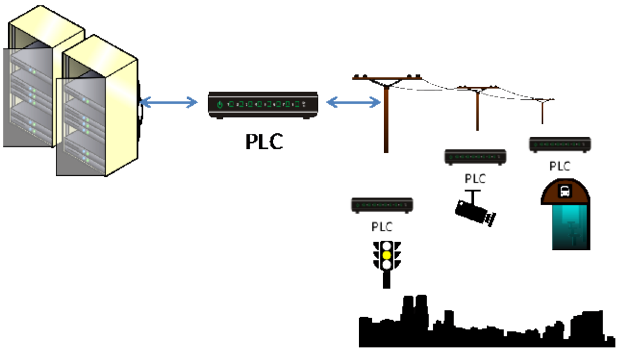

Fig. 1 Scenario for ITS and PLC

The parameters of each project are shown in Figure 2, the structure and parameters of coding options used in G3, and Prime has unique characteristics and merits can be synthesized and optimized to produce a single frame coding which can deliver high performance with low complexity in a variety of noise conditions.

PRIME provides high-speed data communications through the use of un-coded mode, since the G3 privileges the issue of robustness by supplementation of the convolutional code with Solomon Reed (RS) defined external code and uses fourth code to code convolutional repetition rate output.

Furthermore support PRIME interleaving across the physical layer packet on only one symbol in 2.048 ms. G3 makes the interleaving across the physical layer packet, taking up to 252 symbols in each 640 microseconds.

The coding parameter and structures used in G3, and Prime has unique features and advantages, and can be synthesized and optimized to produce a single coding structure that can have high performance with low complexity in a range of noise conditions.

Although the unique monitoring activities of their own, there is no communication skills and requires high bandwidth, and it is necessary that the quality of data communication services and / or allow network performance meets the real-time requirements .

The narrowband interference occurs mainly in low-voltage distribution due to communications systems narrowband, television receivers and the screen refresh rate. This article considers the use of narrow band PLC low voltage.

PRIME and G3 PLC different noise levels and impedances on the same network can create a good level of communication in one direction and a poor level of communication in the opposite direction, so it is necessary to evaluate each separate direction.

Parameter	PRIME	G3
Nominal sample Frequency	250 KHz	400 KHz
FFT Length	512	256
Modulation	Frequency-Differential	Time-Differential
Type of Modulation	DBPSK DQPSK D8PSK	DBPSK DQPSK
Channel Interleaving	One symbol (2,048 ms)	Across symbols over the whole packet up to 256 symbols, each with 640 ms.

Fig. 2: Specification of PLC

The magnitude of transfer function could be verified through the transmission of block with constant magnitude on neighboring frequency bands, so the receiver detects these like OFDM symbols and performs a FFT (fast Fourier transform). [6]

The SNR (signal-noise relation) is an important criteria for evaluation of data communication, so it is necessary to analyses the signal in frequency and time domain intensive communications tests on different frequencies, considering several bandwidths and type of modulation are performed in each situation.

The results permit to compare PRIME and G3, considering: [6]

- Number of received synchronization;
- Number of correct packets;
- Maximum and average value of the gain selected by AGC (Automatic Gain Control) during the synchronization.

The power distribution environment is extremely complex because it depends on several elements that are serving as resistance network wiring, transformers, repeaters, among others.

So it is difficult to predict the behavior of the data transmission via the PLC, which can be aggravated by the number of nodes that exist in the distribution line.

This study evaluates the narrow PLC as a means of data transmission between the sensors and the ITS systems in medium voltage lines (13.8 kV), which concludes that the transmission is feasible because the means of interference voltage lines and noise is low furthermore, as the monitoring application does not require sustained high throughput, this allows the PLC to operate with greater simplicity.

Therefore, this work considered the evaluation of PRIME and G3 PLC, which has similar physical layer and privileges of PRIME high data rates in favorable conditions and G3 PLC providing better performance under adverse conditions. Both designs may be used as a data transmission channel for communication between sensors and systems, due to the low bit rate required.

Initial tests began with two modems composed of F28069 controller board and board AFE031 PLC wire, both from Texas Instruments. These modems been provided with PRIME as the communication protocol between the PLCs, with the following characteristics:

- Operating frequency in the range 40-90 kHz (CENELEC A)
- Data rates from 21 kbps to 128 kbps
- Transmission made with OFDM (Orthogonal frequency-division multiplexing) and FEC (forward error correction)
- Modulation phase shift (DBPSK/DQPSK/D8PSK)
- Automatic Gain Control (AGC)
- Support for layers PRIME PHY, MAC, and IEC61334 -4-32 LLC
- Ports with USB and RS-232 for control and as host for data transmission

The initial tests performed in the laboratory analyzed the behavior of different scenarios in modem connection settings for the equipment and modulation, gain and different packet size.

The scenarios analyzed in this report are:

- Direct cable 100m: Both modems were connected to each other via a cable of 100 meters and were not connected to any power network, and the only electrical signal through the wire is the signal generated by the PLC.
- Connection through the electrical grid of laboratory: this scenario the communication between the modems was made linking them in electrical grid of 110 volts present in the laboratory. They were ligated in two places near the same phase.

In order to verify and analyze the operation of the modem to the different situations was used PLC application Quality Monitor, used to change the modem settings when using PRIME. The settings are varied to check the behavior of the PLC are:

- Modulation: There are 3 different modulations to the modem using PRIME: DBPSK, DQPSK, D8PSK
- FEC (Forward Error Correction): FEC adds redundancy to the transmitted signal to reduce errors in transmission.
- Transmitter Gain: the gain of transmission can changed and there are 8 different levels ranging from 3db gain among themselves.
- Receiver Gain and AGC (Automatic Gain Control): The receiver can be set to use automatic gain control that adjusts the gain of the receiver to present less variation and better output signal. Furthermore it is possible to adjust the receiver gain manually to choosing among eight levels ranging from 6dB to each other.
- Curve Data: The program allows you to pass three different kinds of data packet, and they fixed a byte, a ramp that ranges from 0 to 255 and the standard of certification data PRIME consisting of two sentences (PRIME IS A WONDERFUL IS TECHNOLOGYPRIME A WONDERFUL TECHNOLOGY) with no space between them.
- Size PPDU (Physical Layer Protocol Data Unit): This size varies from 1 to 765 bytes when the FEC is disabled and 1 to 377 bytes when the FEC is enabled.

In both scenarios, the modems are configured to transmit data at a slope of 125 bytes and PPDU with AGC on. The reason for PPDU Size was chosen due to the behavior of the BER PPDU curve X indicated only for very small values PPDU that effectively changed rate. As in actual cases streaming value, the PPDU tends to be close to the maximum value and a small value is used not presenting the same values for BER PPDU that in cases of great.

For direct connection 100 meters of cable initially modem's operation was analyzed the scenario conditions 1 above, where the modems were connected directly to each other with a 100m cable between them just where he passed the signal generated by the PLC . In this situation was expected at any chosen modulation, even without activating the FE signal data transmission errors would not be present and also the SNR would be low, as there is no external interference, the impedance of the wire was too low to affect the transmitted signal.

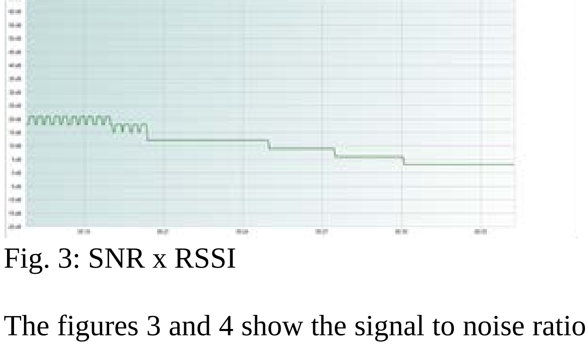

Fig. 3: SNR x RSSI

The figures 3 and 4 show the signal to noise ratio and the error rate for the six variations of modulation.

Both the SNR as BER varies due to the gain variation of transmission is done during transmission, where the moments in which it can be noticed varies by more abrupt variations in curves

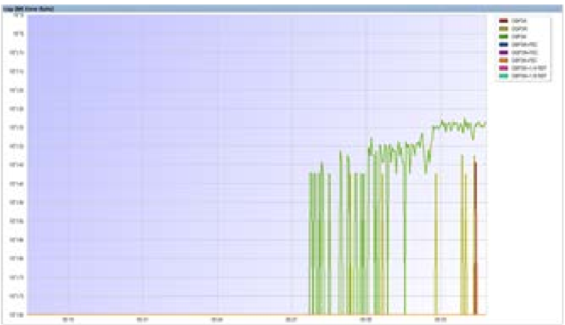

Fig. 4: Bit error Rate with Several Modifications

As expected, the above values show that even for values slightly below the maximum gain of the PLC, the transmission showed a high reliability even with a zero error rate for the three modulations even without FEC. It can only observe different values of zero bit error rate, with lower gains MOL (Maximum Output Level) 15dB when the FEC is not enabled, and when using the FEC transmission shows no error, even for low SNR. Then using a transmission gain to 9 dB below the maximum reliability can be guaranteed at a maximum transmission rate of 128 kbps with D8PSK modulation without using FEC.

4 Conclusions

The use of PLC narrowband and data transmission means for BRT ITS is feasible, since interference with power distribution lines is low and the need for data transfer rate as well, which allows the PLC operate in the minimum configuration. The study evaluated the PRIME and G3 projects that have similar physical layer and PRIME is more favorable for data transfer, the G3 delivers better performance in terms of interference and noise, but both projects can be used as a communication solution for ITS BRT. In the laboratory, PRIME has been successfully evaluated, now, the next step is to evaluate the performance by installing equipment in the field. In field tests will evaluate the quality of services and the PLC technology performance parameters in real conditions of use.

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References:

[1] D. Falcão, “Integração das Tecnologias para Viabilização da Smart Grid”. Available at www.labplan.ufsc.br.

[2] C. Cecatti at Al, “An overview on the smart grid concept”. Presented at IECON 2010 - 36th Annual Conference on IEEE Industrial Electronics Society, pp. 3322–3327, Dec. 2010.

[3] ANEEL. “Resolução No. 394”. ANEEL. Dez 2008.

[4] R. Benato, R. Caldon. “Application of PLC for the control and the Protection of Future Distribution Network”. IEEE. 2007.

[5] Kim, B. Varadarajam, A. Dabak. “Performance Analysis and Enhancement of Narrowband OFDM Powerline Communications Systems”. IEEE 2010.

[6] G. Bumiller. “Automated Channel and Performance Measurements for Narrowband MV and LV Power Lines. IEEE. 2007.

[7] T. Sauter and M. Lobashov, “End-to-end Communication Architecture for Smart Grids” IEEE Transactions on Industrial Electronics”, vol 58, no. 4, Apr. 2011.

[8] M.Duarte, et al.,“Sistema de Leitura Automática de Medidores Eletrônicos de Energia Elétrica para o Meio Rural”, presented at SENDI 2010- XIX Seminário Nacional de Distribuição de Energia Elétrica, Nov. 2010.

[9] K.Razazian et al., “G3-PLC Specification for Powerline Communication: Overview, System Simulation and Field Trial Results”, presented at IEEE ISPLC 2010: 14th IEEE International Symposium on Power Line Communications and its Applications, Mar. 2010.

[10] D.W.Rieken and M. R. Walker II, “Distance Effects in Low-Frequency Power Line Communications”, presented at IEEE ISPLC 2010: 14th IEEE International Symposium on Power Line Communications and its Applications, Mar. 2010.

[11] Lasciandare et al., “STarGRID ™: the first industrial system on chip platform full PRIME compliant”, presented at IEEE ISPLC 2010: 14th IEEE International Symposium on Power Line Communications and its Applications, Mar. 2010.

[12] A.Haidine et al., “High-Speed Narrowband PLC in Smart Grid Landscape – State-of-the-art” , presented at IEEE ISPLC 2011: 15th

IEEE International Symposium on Power Line Communications and its Applications, Apr. 2011.
[13] A.Sendin et al., "Strategies for PLC Signal Injection in Electricity Distribution Grid Transformers", presented at IEEE ISPLC 2011: 15th IEEE International Symposium on Power Line Communications and its Applications, Apr. 2011.
[14] L. Yang and C. Feng, "Design of Traffic Lights Controlling System Based on PLC and Configuration Technology", presented at MINES 09 International conference on multimedia information networking and security, Nov, 2009.
[15] A. Haidine et al, "High-speed narrowband PLC in Smart Grid Landscape – State of the Art", presented at IEEE International conference on power line communications and its applications, Apr. 2011.
[16] P. MLynek, M. Koutny, J. Misurec. Power line modelling for creating PLC communication system. International Journal of Communication. Issue 1, Volume 4. 2010.
[17] H. Hou, G. Li. Cross-layer Packet Dependent OFDM Scheduling Based on Proportional Fairness. WSEAS Transactions on Communications., Volume 11. Issue 1. 2012.
[18] Y. Huang et Al. Performance of Partial Parallel Interference Cancellation With MCCDMA Transmission Techniques for Power Line Communication Systems. WSEAS Transactions on Communications., Volume 7. Issue 1. 2008.
[19] Turucu, C. Turucu C. Gaitan, V. Integrating Robots into the Internet of Things. International Journal of Circuits, Systems and Signal Processing. Issue 6. Volume 6. 2012. p430-437
[20] Surinwarangkoon, T. Nitsuwat, S. Moore, E.J. A Traffic Sign Detection and Recognition System. International Journal of Circuits, Systems and Signal Processing. Issue 1. Volume 7. 2013. p58-65
[21] Matysek, M. Kubalcik, M. Mihok, M. Monitoring of Computer Networks Resources.. International Journal of Circuits, Systems and Signal Processing. . Issue 1. Volume 7. 2013. p75-82.
[22] Wessels, A. Jedermann, R. Lang, W. Transport Supervision of Perishable Goods by Embedded Context Aware Objects. International Journal of Circuits, Systems and Signal Processing. . Issue 3. Volume 4. 2010. p102-111.
[23] SECRETARIA NACIONAL DE TRANSPORTE E DA MOBILIDADE URBANA. Manual de BRT: Guia de Planejamento. 2008.
[24] APTA STANDARDS DEVELOPMENT PROGRAM. Implementing BRT Intelligent Transportation Systems. 2010.
[25] INTERNATIONAL ORGANIZATION FOR STANDARDIZATION. ISO 14813-1:2007 – Intelligent transport systems – reference model architecture(s) for the ITS sector – part 1: ITS service domains, service groups and services. 2007.
[26] US Department of Transportation. National ITS Architecture 7.1. Available on: http://www.iteris.com/itsarch/index.htm. Accessed on October 2015.
[27] NTU – Associação Nacional das Empresas de Transportes Urbanos (National Association of Urban Transportation Companies). Avaliação comparativa das modalidades de transporte público urbano (Comparative evaluation of public transportation modes). Prepared by Jaime Lerner Associated Architects. Brasília, 2009.
[28] NTU – Associação Nacional das Empresas de Transportes Urbanos (National Association of Urban Transportation Companies)]. Conceitos e Elementos de Custos de Sistemas BRT (Cost concepts and elements of BRT systems). Prepared by Logit. Brasília, 2010. 72 p.
[29] AUSTRALIA. AUSTROADS. Defining Applicability of International Standards for Intelligent Transport Systems (ITS).AP-R338/10. 2010. 111 p.
[30] BRASIL. Ministério das Cidades (Ministry of Cities), Secretaria Nacional de Transporte e da Mobilidade Urbana (National Secretary on Urban Transportation and Mobility), BRT (Bus Rapid Transit) Manual – Planning Guide. Brasília, 2008..
[31] CANADA. ITS Canadá (ITSCa). ITS Architecture (version 2.0). Available at http://www.tc.gc.ca/innovation/its/eng/architecture.htm. Accessed July 2015.
[32] RITA (Research and Innovate Technology Administration). Available at www.its.dot.gov. Acessed July 2015.
[33] B. WILLIAMS, Intelligent Transport Systems Standards. Artech House, 2008. 878 p.
[34] D. GORNI, Modelagem para Operação de Bus Rapid Transit – BRT (Operational Modelling for BRT). Mestrado (Master Thesis) - Escola Politécnica (Politechnical School), Universidade de São Paulo (USP), São Paulo, 2010.
[35] C. L. MARTE, Sistemas Computacionais

Distribuídos aplicados em Automação dos Transportes (Automated Transportation Distributed Computational Systems). Tese Doutorado (Doctor Thesis) - Escola Politécnica (Polytechnic School), Universidade de São Paulo (USP), São Paulo, 2000.

[36] V. N. KASYANOV, Methods and Tools for Structural Information Visualization, WSEAS Transactions on Systems, Issue 7, Volume 12, 2013, pp. 349-359.

[37] T. MANTORO, A. I ABUBAKAR, M. A. AYU, 3D Graphics Visualization for Interactive Mobile Users Navigation, WSEAS Transactions on Systems, Issue 8, Volume 11, 2012, pp. 453-464.

[38] I. IVAN, M. DOINEA, C. CIUREA, C. SBORA, Collaborative Informatics Security in Distributed Systems, WSEAS Transactions on Systems, Issue 11, Volume 11, 2012, pp. 628-637.

[39] S. I. NITCHI, A. MIHAILA, Collaborative Knowledge Management, WSEAS Transactions on Systems, Issue 11, Volume 11, 2012, pp. 648-658.

[40] YOSHIOKA, L. R. ; OLIVEIRA, M. C. ; MARTE, C. L. ; FONTANA, C. F. ; SAKURAI, C. A. ; YANO, E. T. . Framework for designing automotive embedded systems based on reuse approach. International Journal Systems Applications, Engineering & Development, v. 8, p. 9-17-17, 2014.

[41] SAKURAI, C. A.; MARTE, C. L. ; YOSHIOKA, L. R. ; FONTANA, C. F. . Integrating Intelligent Transportation Systems Devices Using Power Line Communication. international journal of energy, v. 8, p. 36-42, 2014.

[42] FONTANA, C. F. ; PAPA, F. ; MARTE, C. L. ; YOSHIOKA, L. R. ; SAKURAI, C. A. . Intelligent Transportation System as a Part of Seaport Terminal Management System. international journal of systems applications, engineering & development, v. 8, p. 41-46, 2014.

[43] YOSHIOKA, L. R. ; MARTE, C. L. ; MICOSKI, M. ; COSTA, R. D. ; FONTANA, C. F. ; SAKURAI, C. A. ; CARDOSO, J. R. . Bus Corridor Operational Improvement with Intelligent Transportation System based on Autonomous Guidance and Precision Docking. international journal of systems applications, engineering & development, v. 8, p. 116-123, 2014.

[44] FERREIRA, M. L. ; MARTE, C. L. ; MEDEIROS, J. E. L. ; SAKURAI, C. A. ; FONTANA, C. F. . RFID for Real Time Passenger Monitoring. Recent Advances in Electrical Engineering, v. 23, p. 170-175, 2013.

[45] SAKURAI, C. A.; MARTE, C. L. ; YOSHIOKA, L. R. ; FONTANA, C. F. . Optical Character Recognition Technology Applied for Truck and Goods Inspection. Recent Advances in Electrical Engineering, v. 23, p. 207-214, 2013.

[46] MARTE, C. L. ; YOSHIOKA, L. R. ; MEDEIROS, J. E. L. ; SAKURAI, C. A. ; FONTANA, C. F. . Intelligent Transportation System for Bus Rapid Transit Corridors (ITS4BRT). Recent Advances in Electrical Engineering, v. 23, p. 242-249, 2013.

[47] SAKURAI, C. A.; FONTANA, C. F. ; YOSHIOKA, L. R. ; MARTE, C. L. ; SANTOS, A. S. . License Plate Recognition as a tool for Fiscal Inspection. In: 21st World Congresso n Intelligent Transport Systems and ITS America Annual Meeting, 2014, Detroit. Reinventing Transportation in our Connected World. Red Hook, NY: Curran Associates INc., 2014. v. 1. p. 360-371.

[48] MARTE, C. L. ; FONTANA, C. F. ; SAKURAI, C. A. ; YOSHIOKA, L. R. ; PERON, L. ; FACIN, P. L. M. . Deploying ITS Sub architectures over IMS (4G NGN). In: ITS World Congress 2013, 2013, Tolyo. Proceedings of the 20th World Congress on Intelligent Transport Systems (ITS), 2013.

[49] SAKURAI, C. A.; FONTANA, C. F. ; MACCAGNAN, C. M. . Smart Grid as an infrastructures for Intelligent Transport Systems. In: 19th ITS World Congress, 2012, Viena. 19th ITS World Congress, 2012.