

Object Oriented C++ Library IsoAgLib Study and Implementation from the Remote CAN-Based Distributed Control System Workbench

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Abstract.

Contextualization (or background): *The multidisciplinary practices of Precision Agriculture (PA) which use embedded electronic and remote sensing in agricultural machinery has demanded researches of sensors and communication networks for data acquisition and control in the farm field. The CAN-Based Distributed Control System (DCS) according to ISO 11783 (or ISOBUS) standard provides the interconnection of electronic devices embedded in agricultural machinery and implements through a control network and serial data communication. The IsoAgLib is an Object Oriented C++ library that has the communication services and needed management systems according with the ISO 11783 standard. This library allows building ISOBUS compatible equipment without the protocols implementation contained in this standard. This work presents the remote access of CAN-Based DCS workbench for the IsoAgLib study and implementation to support the development of the CAN-Based DCS systems, the ISO 11783 standard parts, the Precision Agriculture (PA) and the Information and Communication Technology (ICT). The CAN-Based DCS workbench consists in two Personal Computers (PC), one desktop and one notebook. The DCS connection between two PCs is by embedded CAN hardware from Vector CANtech Inc.. The IsoAgLib library is implemented, compiled and executed on the desktop. In the notebook, there is an Electronic Control Units (ECU) called Virtual Terminal (VT) simulator of Vector CANtech Inc., which allows the visualization of the IsoAgLib executable from desktop. To remotely access this workbench, is used the web service LogMeIn Free from LogMeIn Inc. with the web browser Mozilla Firefox from Mozilla Foundation. The evaluation of the connection was done by analyzing the log messages of the remote access and the log messages thorough CAN-bus between IsoAgLib executable and the VT simulator. The remote connection of the CAN-Based DCS workbench provides free access to expensive hardware and software (Vector CANtech Inc. products). Provides distance learning for researchers and professionals of ISO 11783 extensive standard, and for the PA and ICT applications, in CAN-Based DCS automation area.*

Keywords: *Distributed Control Systems, CAN networks, Electronic Control Unit (ECU), ISO 11783, ISOBUS, CAN, IsoAgLib, embedded network communication, Precision Agriculture, communication standard, file standard.*

1. INTRODUCTION

The most common use of the embedded electronic and remote sensing in agricultural machinery demands adoption of Precision Agriculture (PA). PA is management strategy for the agricultural production and involves multidisciplinary practices (Gozdowski and Samborski, 2007). It's become necessary the researches of sensors and communication networks for data acquisition and control in the farm field works (Wei et al., 2005; Darr et al., 2007; Ni et al., 2009; Steinberger et al., 2009). The ISO 11783 (also known as ISOBUS) provides a standard for the interconnection of electronic devices, or Electronics Control Units (ECU), embedded in agricultural machinery and implements through a control network (CAN – Controller Area Network) (Iso 11898, 1993) and serial data communication (Auernhammer and Speckmann, 2006). The remote CAN-Based workbench consist in a Distributed Control System (DCS) with two Personal Computers (PC) connected in CAN-Bus. The implementation and understanding of the ISO 11783 standard is increased by the IsoAgLib (Isoaglib, 2010). The IsoAgLib is a library that has the communication services and management systems needed to be compatible with the ISO 11783 standard (Spangler, 2001; Spangler, 2008). This library allows building ISOBUS compatible equipment without the protocols implementation contained in this standard. This work presents the remote access of ISO 11783 workbench for the IsoAgLib study and implementation to support learning of ISO 11783 standard parts, PA and Information and Communication Technology (ICT) (Steinberger et al., 2009). In the next section will expose the ISO 11783 and IsoAgLib characteristics and remote access technology. In the section 3 will talk about the materials and methods. In the section 4 will present the results and discussion. And the section 5 will talk about the conclusion of this work.

2. LIBRARY FOR THE COMMUNICATION NETWORKS AND REMOTE ACCESS

2.1 ISO 11783

ISO 11783 (or ISOBUS) is the standard that specifies a communications system for agricultural equipment based on the CAN 2.0 B protocol (Bosch, 2010) and SAE J1939 documents (Sae J1939, 2010). The main task of ISO 11783 is to provide an open and interconnected system for embedded electronic systems and serial data communication in agriculture and forestry machinery, in other words, to provide the communication among the Electronic Control Units (ECU) via standardized network (Iso 11783-1, 2007).

The importance of electronics and Information and Communication Technology (ICT) in the agricultural sector was also recognized internationally by the development and foreign adoption of ISO 11783. The first discussions in 1988 ultimately resulted in the establishment of an appropriate subcommittee (SC 19) in 1991 under the leadership of Technical Committee 23 (ISO TC 23/SC 19) which is responsible for the agriculture and forests areas. A working group (WG 1) within 19 subcommittee deals exclusively with the application of electronics in agriculture and forestry machinery (Iso, 2010). Different from the predecessor standard DIN 9684 / LBS (Auernhammer and Frisch, 1993; Bottinger et al., 2000), the participating countries of ISO TC 23/SC 19 (Denmark, Germany, France, Britain, Holland, Canada and the U.S.) had demands the following definitions for the ISO 11783:

- Use of the CAN 2.0B protocol (Iso 11898, 1993), with an extended 29-bit identifier;
- Bus speed to 250 kbit/s;
- Adjusting according to ISO/ Open System Interconnect Basic Reference Model (ISO/ OSI Basic Reference Model);
- Definition of a standard interoperable with SAE J1939 (2010);
- Defining the tasks of the tractor (Tractor ECU) for different classes;
- Permission to proprietary message types.

Recently, the CAN protocol has been applied in agricultural automation through the ISO 11783 standard. Standardization of electronics in agricultural machinery is currently a global effort. The Table 1 shows the 14 parts and the status of ISO 11783:

Table 1 - 14 parts and the status of ISO 11783. Source: ISO (2010).

Status of ISO 11783					
PART	EDITION	STAGE	STATUS ISO/TC23/SC19/WG1 – ISO 11783	Year	
Part 1: General standard for mobile data communication	1	90.20	International Standard under periodical review	2007	
	2	30.00	Committee draft (CD) registered	2011	
Part 2: Physical layer	1	90.20	International Standard under periodical review	2002	
	2	40.99	Full report circulated: DIS approved for registration as FDIS	2011	
Part 3: Data link layer	1	95.99	Withdrawal of International Standard	2007	
	2	90.20	International Standard under periodical review	2007	
	3	30.00	Committee draft (CD) registered	2011	
Part 4: Network layer	1	90.20	International Standard under periodical review	2001	
	2	40.99	Full report circulated: DIS approved for registration as FDIS	2011	
Part 5: Network management	1	95.99	Withdrawal of International Standard	2011	
	2	60.60	International Standard published	2011	
Part 6: Virtual terminal	1	95.99	Withdrawal of International Standard	2010	
	2	60.60	International Standard published	2010	
Part 7: Implement messages application layer	1	95.99	Withdrawal of International Standard	2009	
	2	90.92	International Standard to be revised	2009	
Part 8: Power train messages	1	90.93	International Standard confirmed	2010	
Part 9: Tractor ECU	1	90.92	International Standard to be revised	2002	
	2	40.60	Close of voting	2011	
Part 10: Task controller and management information system data interchange	1	60.60	International Standard published	2009	
Part 11: Mobile data element dictionary	1	90.92	International Standard to be revised	2007	
	2	50.00	FDIS registered for formal approval	2011	
Part 12: Diagnostics services	1	90.92	International Standard to be revised	2009	
Part 13: File server	1	90.92	International Standard to be revised	2007	
	2	60.00	International Standard under publication	2011	
Part 14: Sequence control	1	50.92	FDIS referred back to TC or SC	2010	

We can check in Table 1 the firsts publications started one year after the creation of ISO TC 23/SC 19, but the most part of the standard still in development and review. However, the ISO 11783 standard is not yet widely adopted by the Brazilian companies like the foreign companies. By the global trend, it is important to initiate projects for implementation of the standard based on the information needed systematized. The investments in the agribusiness engineering in Brazil are necessary to reach the international standard. Only in this way can participate in the process of global innovation in an area so important to Brazil.

2.1.1 Relation between ISO 11783 and ISO/ OSI Basic Reference Model

The ISO / IEC 7498-1(1996) standard of ISO/ OSI Basic Reference Model provides a common basis for coordinating the development of standards for interconnection of systems, and also enables to compare existing standards with all seven layers:

- Physics;
- Data Link;
- Network;
- Transportation;
- Session;
- Presentation;
- Application.

The complete diagram and synthesized several characteristics of ISO/ OSI Basic Reference Model is shown in Figure 1.

ISO/ OSI Basic Reference Model

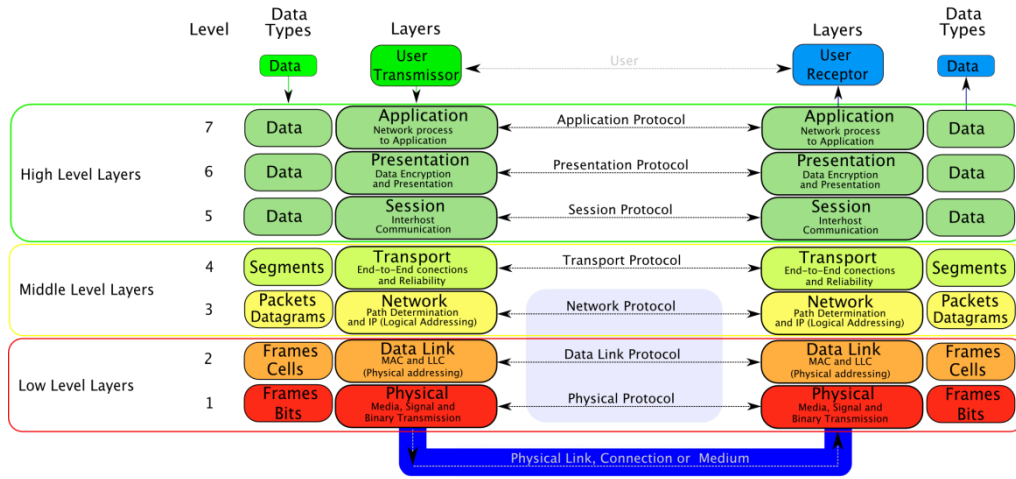


Figure 1 - ISO/ OSI Basic Reference Model. Source: ISO/IEC 7498-1 (1996).

It is observed in Figure 4, according to InfoCellar (2010) and ISO/IEC 7498-1 (1996), the seven layers can be grouped into three levels:

- Low Level Protocols (Layers 1 and 2) - how the data are converted into electrical impulses 1 and 0 (bits) and sent through cables or the physical environment and in other way, how the electrical impulses are received from the cable and converted to 1 and 0;
- Middle Level Protocols (Layers 3 and 4) - how the data are converted into packets and frames, and is implemented as error checking and flow control, and in other way, how the packets and frames received are converted into structures;
- High-Level Protocols (Layers 5, 6 and 7) – how the data are presented, summarized and displayed to the user, and in other way, how data are prepared by the user to assembled into data structures.

A diagram adapted from ISO 11783 Part 3 shows an essential application according with ISO/ OSI Basic Reference Model, see in Figure 2 with Figure 1.

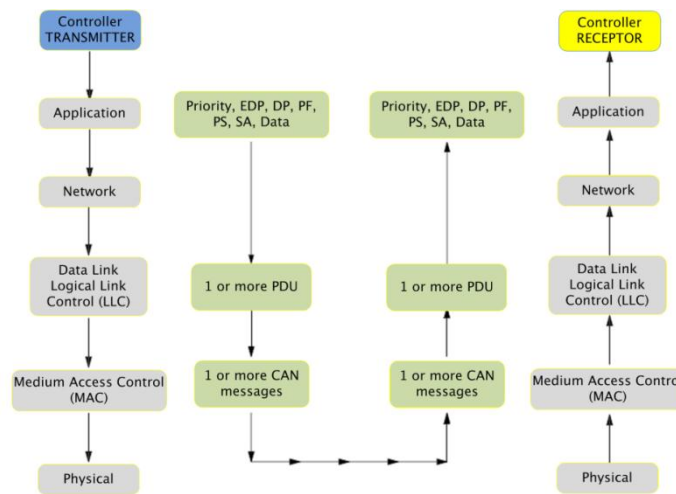


Figure 2 - Implementation of the ISO/ OSI Basic Reference Model according to ISO 11783. Source: Adapted from ISO 11783-3(2007).

The Figure 2 a data transmission via 5 layers between Transmitter and Receptor. The Transmitter sends data by the application layer to the physical layer with their corresponding data types. After that, the data arrives at the physical layer of the Receptor to Application layer with correspond types of files to use check the data.

The ISO 11783 is based on CAN/ ISO 11898, SAE J1939 and DIN 9685(Auernhammer and Frisch, 1993; Iso 11898, 1993; Bosch, 2010; Sae J1939, 2010). Due the works (Pereira et al., 2008; Pereira et al., 2009a; Pereira et al., 2009b) related whit those standards, a relationship diagram of parts of ISO 11898 and ISO 11783 with Basic Reference Model ISO/ OSI shows in Figure 3.

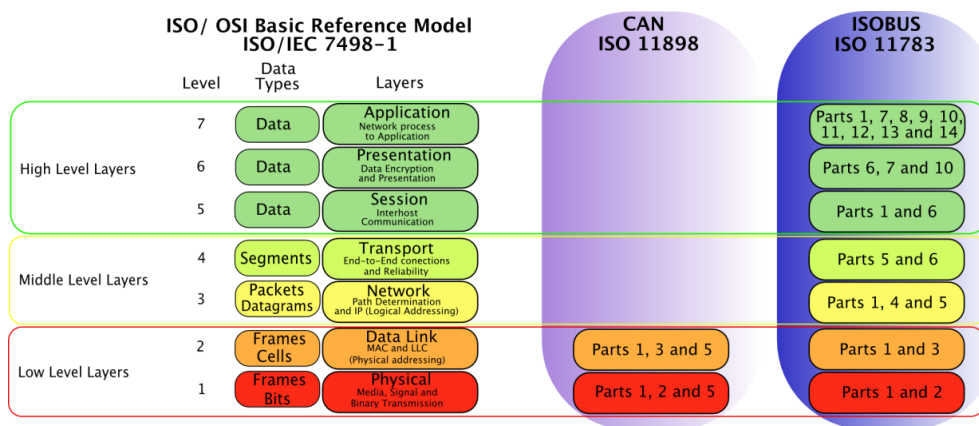


Figure 3 - Relationship of parts of ISO 11898 and ISO 11783 with Basic Reference Model ISO/ OSI.

The ISO 11783 consists in fourteen following parts (presented in Table 1):

- Part 1: General standard for mobile data communication
- Part 2: Physical Layer
- Part 3: Data Link Layer
- Part 4: Network Layer
- Part 5: Network Management
- Part 6: Virtual Terminal
- Part 7: Implement Messages Application Layer
- Part 8: Power Train Messages, reference of SAE J1939
- Part 9: Tractor ECU
- Part 10: Task Controller and Management Information System Data Interchange
- Part 11: Mobile Data Element Dictionary
- Part 12: Diagnostics Services
- Part 13: File Server
- Part 14: Automatic Functions

The Part 1: General standard for mobile data communication defines lot devices, terms and messages witch are necessary in others parts. It's possible to check in Figure 3, the Part 1 is in various levels of the standard.

2.2 IsoAgLib

The IsoAgLib is a C++ library to development of ISO 11783 standard applications in an Object Oriented way (Spangler, 2008; Isoaglib, 2010). The library provides resources to program and to simulate the software of implement ECU or of another client device of the Virtual Terminal (VT), Task Controller (TC) and File Server (FS). The author of IsoAgLib library, Dipl.-Inform. Achim Spangler, licensed with exceptions under the terms of the GNU General Public License (GPL). The GPL grants users of the library the right to use, to modify and to distribute it. This library allows building ISOBUS compatible equipment without the protocols implementation contained in this standard. Nowadays, hosting and maintaining IsoAgLib are carried out by OSB (2011). The business model IsoAgLib contains engineering services, tools, support and maintenance contracts. The IsoAgLib software is open source and thus source code open to every user. Using IsoAgLib is generally free; there are available two different types of licenses:

- GNU General Public License (GPL), Version 2, with Exceptions;
- Commercial (OEM) License.

In case of using the open source license GPL, the implementation of IsoAgLib in your products can be protected by support and maintenance contracts with OSB, however it is not mandatory. The commercial licensing is particularly suitable for implementations of IsoAgLib within complex software architectures and along with specific enhancements (Os, 2011).

The IsoAgLib has a modular design according to the different functional components of the standard ISO 11783. The library has modular design to ensure the minimal use of IsoAgLib in program memory of Implement ECU. The IsoAgLib presents the layered design to be easily adapted to new hardware platforms. Most of the software can be used without modification on all platforms. The layered structure is described by the diagram in Figure 4.

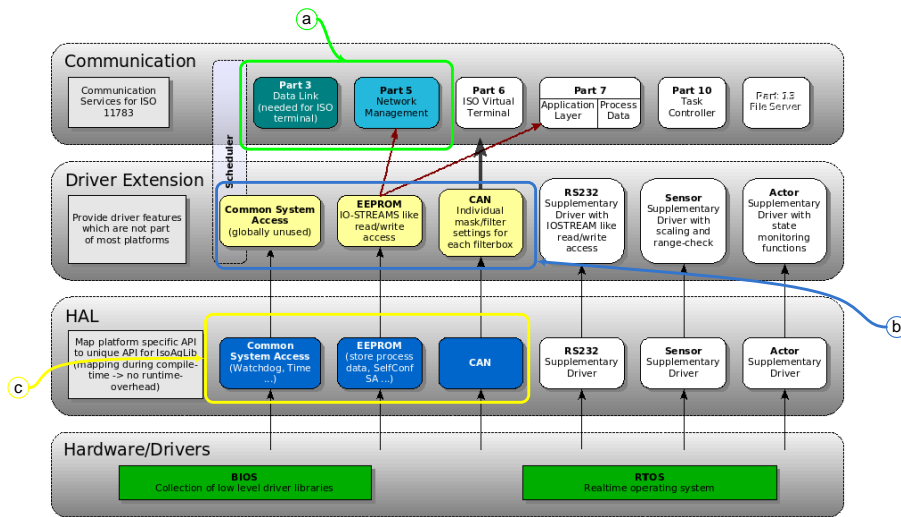


Figure 4 – Structure view of IsoAgLib modular design. Source: IsoAgLib (2010).

In the Figure 4 are listed all the elements needed by layers for all projects:

- HAL (Hardware Abstraction Layer) - Figure 4 (c);
- Extensions - Figure 4 (b);
- Communication - Figure 4 (a).

The other elements listed in the Figure 4 are not necessary for all projects. For example, drivers in the HAL layer as RS232 input sensors and control actuators (mainly PWM) were developed for a research project at the Technische Universität München (TUM - Technical University of Munich).

The IsoAgLib was developed to be compatible with various systems, and these systems can be composed of processor, memory, Human Machine Interface (HMI) and interface with the CAN bus. Because of this, the IsoAgLib is divided into two parts: the library itself and HAL. The HAL is responsible for communicating with the operating system (OS) or BIOS device that is running the application, as can be seen in Figure 4.

The library provides the Address Claim negotiation of an ECU to the CAN bus ISO 11783. It also implements the transport protocols that are used in the initialization with VT and TC. Due to the object orientation code design, the IsoAgLib was implemented in C++ language, and the library makes use of templates and namespaces. It also uses some objects on the STD (Standard Template Library), for example, lists, queues, vectors, etc. (Sakai, 2008). You can use the IsoAgLib in embedded devices that use Linux OS (Linux, 2011) or Microsoft Window OS (Microsoft, 2010). In addition, you can use the library in the Personal Computer (PC) running Linux or Microsoft Windows with CAN interfaces which have the HAL of the IsoAgLib.

An ISO 11783 tractor must have a VT, a TC, a FS and a Diagnostics Service Tool as shows in the Figure 5 “Server ECUs”.

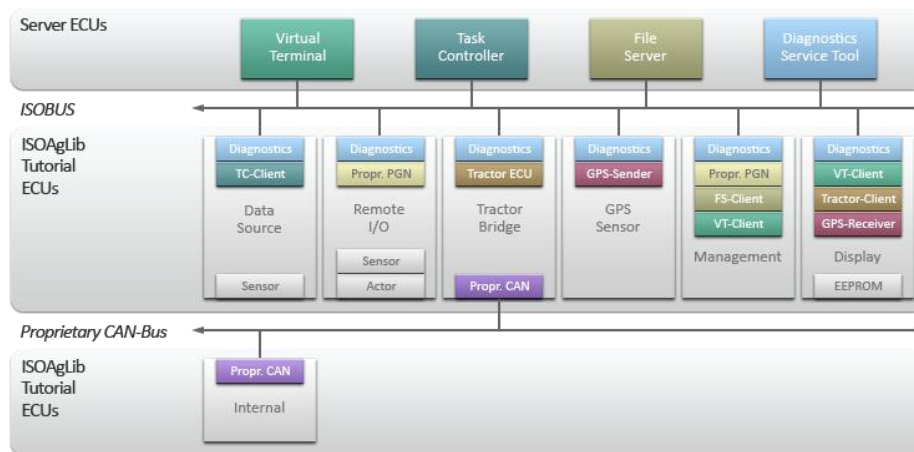


Figure 5 – ISO 11783 Network with IsoAgLib. Source: IsoAgLib (2010).

The Figure 5 presents an ISO 11783 network which the “IsoAgLib Tutorial ECUs” are the ECUs that are implemented using necessary elements in the Figure 4.

2.3 Remote Access

The advanced of the internet bandwidth and speed provides the development of a large amount of remote access services. Remote access is the practice to use a computer remotely via internet. The most common free services are the Remote Access of Microsoft Windows (Microsoft, 2010), the UltraVNC (Ultravnc, 2011) connection and the LogMeIn Free (Logmein, 2011) connection. The Table 2 presents the use of those 3 services with or without internet link and Internet Protocol address fixed or random:

Table 2 – Relation among the Remote Access of Microsoft Windows, UltraVNC and LogMeIn Free.

Remote Access Service	OS	Price	With No Internet	With Internet	IP address
Remote Access of Microsoft Windows	Only MS Windows	\$ 0 only MS Windows	Doesn't work	Work	Fix
UltraVNC	MS Windows and Linux	\$ 0	Work	Work	Fix and Random
LogMeIn Free	Via Web browser in MS Windows and Linux	\$ 0 the free version	Doesn't work	Work	Fix and Random

According to the Table 2, we can select the service which better attend the requirements of the link connection among the Local PCs and Remote PCs.

3. MATERIAL AND METHODS

This section will describe the hardware and software used to provide remote ISO 11783 workbench.

3.1 Vector CANoe and CAN Interfaces

The environment of testing and monitoring is used Vector Canoe (Figure 6 (a)), which can be used with two types of interfaces CAN: CANCardXL and CANBoardXL (Vector, 2008). The difference between these interfaces is that the CANCardXL (Figure 6 (b)) is a PCMCIA card, ideal for use in notebooks. And CANBoardXL (Figure 6 (c)) is a PCI card ideal for desktop computers.

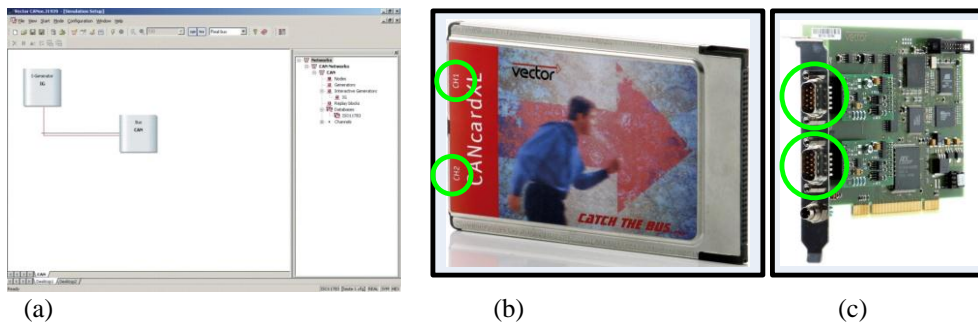
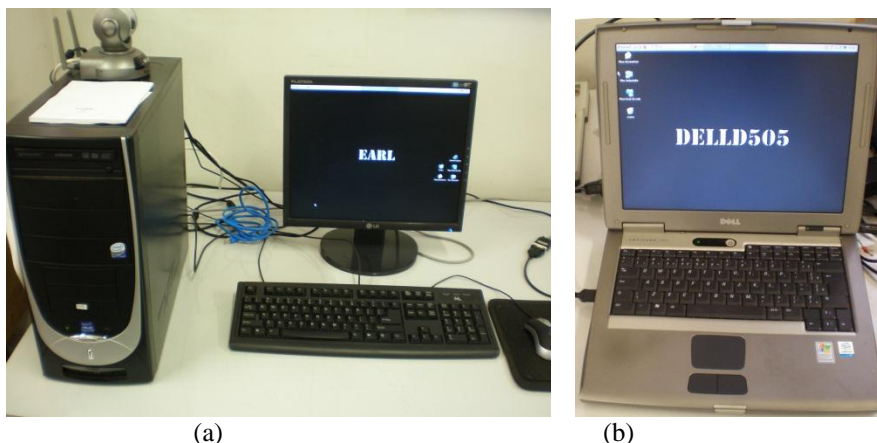


Figure 6- (a) Software Vector Canoe (b) Interface CANCardXL (c) Interface CANBoardXL (Vector, 2008).

The devices CANCardXL and CANBoardXL are interfaces between the CAN bus and the environment Vector Canoe, where the connection to the CAN bus is done via two CAN channels, CH1 and CH2 (Can observe the positions of the channels highlighted by circles in Figure 6 (b) and Figure 6 (c)). There are a large number of tools to aid the development of ISO 11783, but the most complete tool is the Vector CANoe with libraries for ISO 11783 interpretation. The general characteristics of the tool are:

- Message traffic on the bus - all messages sent on the network can be viewed in the software;
- Analysis of functionality - you can check the performance of procedures by analyzing the messages and the proper functionality of a controller;
- Performance analysis - verifying that the times and delays of messages on the bus;
- Simulation of a network layout - the software has a simulator of a VT to interact with Virtual and Real ECUs.

The requirements for the implementation of this work are present in the following sections. The ISO 11783 workbench consists in two Personal Computers (PC), one desktop called “EARL” (Figure 7 (a)) and one notebook called “DELLD505” (Figure 7 (b)). The ISO 11783 connection between two PCs is by CAN hardware CANCardXL from Vector CANTech Inc. (Vector, 2008) embedded on notebook and CANBoardXL embedded on desktop.



(a) (b)
Figure 7 – ISO 11783 Network whit IsoAgLib.

The IsoAgLib library is implemented, compiled and executed on the desktop. In the notebook, there is Virtual Terminal (VT) simulator of Vector CANtech Inc. software CANoe 5.2 (Vector, 2008), which allows the visualization of the IsoAgLib executable from desktop.

4. RESULTS

The main task of this work is to establish remote access of a CAN bus/ ISO 11783 workbench via internet to share the expensive resources like software CANoe and interfaces CANCardXL and CANBoardXL, which nowadays approximately costs \$ 27000,00.

To remotely access this workbench, is used the web service LogMeIn Free from website <https://secure.logmein.com/> with the web browser Mozilla Firefox from Mozilla Foundation (Firefox, 2011). The PC that accesses the workbench, called “PCA”, must have the internet connection and two monitors in extended view mode to facilitate the visualization of two remote PCs shows in the Figure 8.

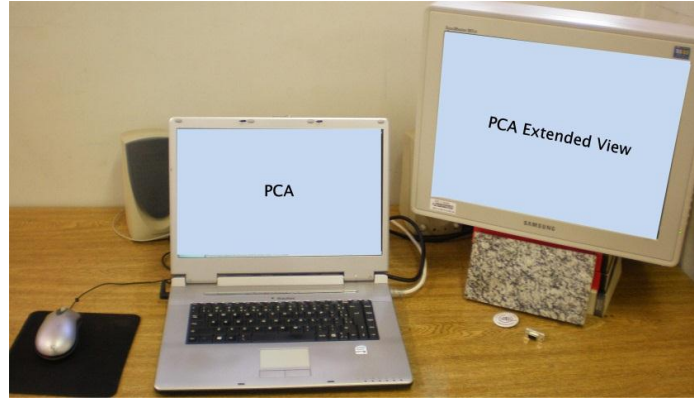


Figure 8 – PC for that accesses the CAN bus/ ISO 11783 workbench.

The LogMeIn user and password are provided by the research group NEPAS (2011) by sending an e-mail to coord@isobus.org.br with explanation and guide about run test at ISO 1783 workbench. The connection among the PCA and PC EARL – PC DELLD505 was checked analyzing the LogMeIn log according to the Figure 9:

```

2010-02-22 15:34:03.985 - Info - LogMeIn - Socket - 143.107.239.122:50345/...
2010-02-22 15:34:06.579 - Info - LogMeIn - Session - 143.107.239.122/
m039.sem.eesc.usp.br:EARL\isobus...
2010-02-22 15:34:06.829 - Info - RA_RC - Startup - - Starting up

2010-02-22 15:35:48.834 - Info - LogMeIn - Socket - 143.107.239.122:50349/...
2010-02-22 15:35:51.738 - Info - LogMeIn - Session - 143.107.239.122/
m039.sem.eesc.usp.br:DELLD505\isobus...
2010-02-22 15:35:56.665 - Info - RA_RC - Startup - - Starting up

```

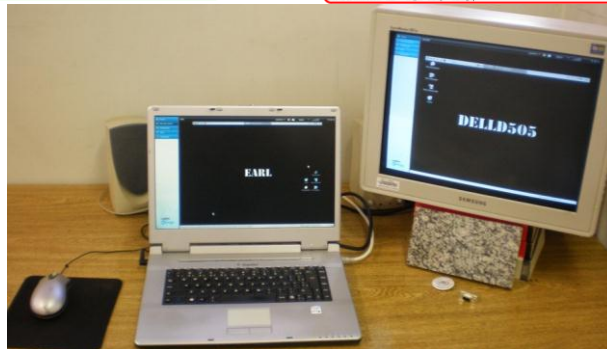
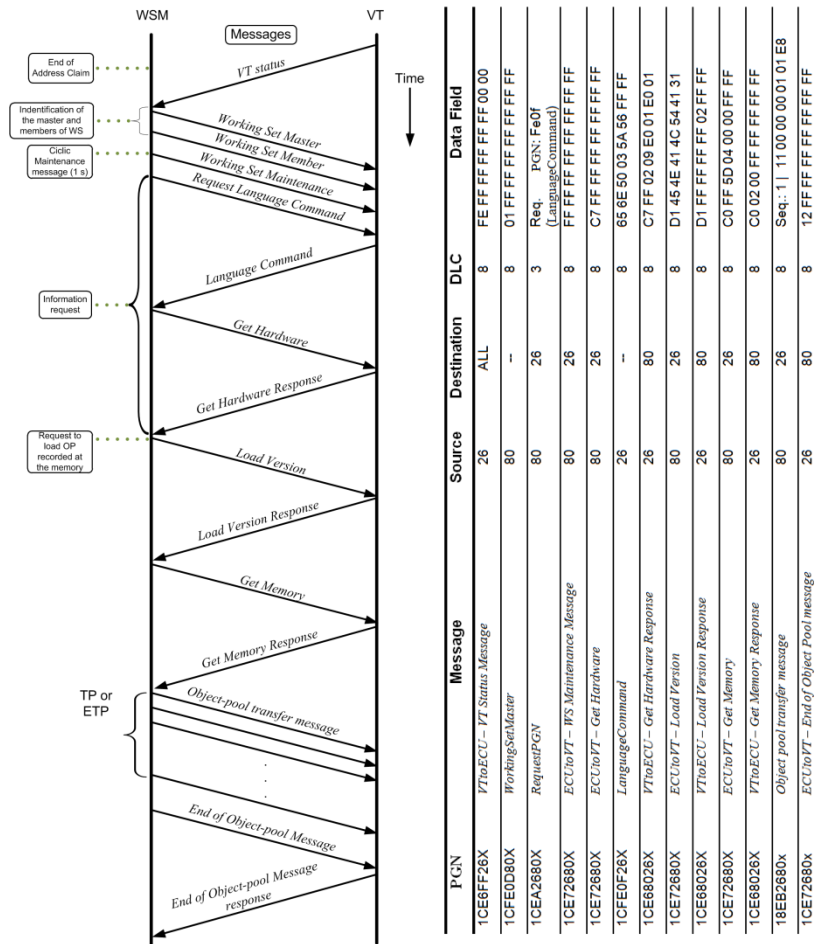
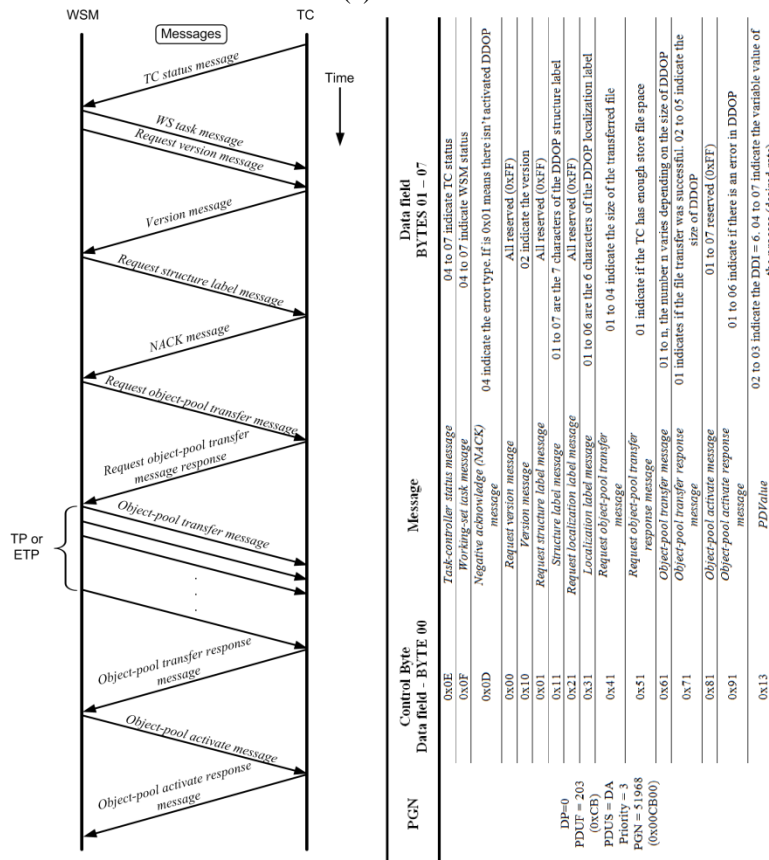


Figure 9 – LogMeIn log of PCA access.

The IP address of PCA is 143.107.239.122 and we can check the connection was establish with PC EARL – PC DELLD505 by internet. Now, we can work with CAN bus/ ISO 11783 according to the Figure 10.



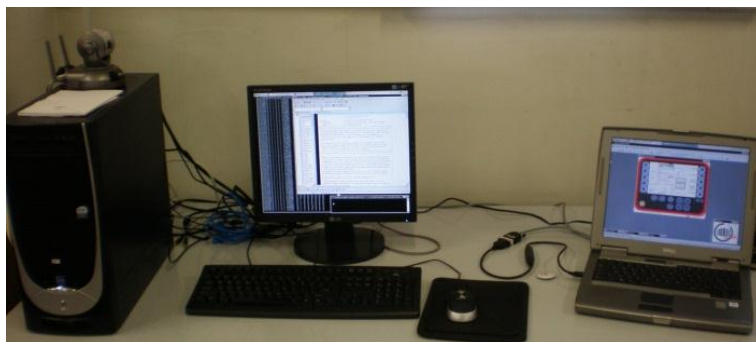
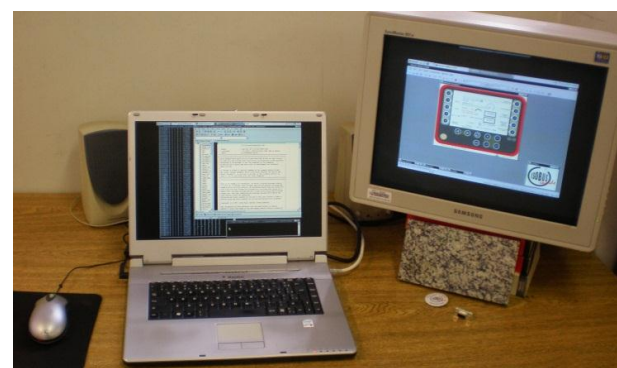
(a)



(b)

Figure 10 – Initialization of the ECU Implement with VT (a) and TC (b) with corresponding messages details.

We can see in the Figure 11 the different physical location, which the PCA is locate outside of NEPAS laboratory and PC EARL and PC DELLD505 are locate at NEPAS laboratory.



(a)

(b)

Figure 11 – (a)PCA outside of NEPAS (b)PC EARL and PC DELLD505 at NEPAS.

5. CONCLUSIONS

The remote connection of the ISO 11783 workbench provides free access to expensive hardware and software (Vector CANtech Inc. products). Provides distance learning for researchers and professionals of extensive ISO 11783 standard for the PA and ICT applications, in agricultural automation area.

Provide a real remote implementation of IsoAgLib library with the CAN interfaces which has HAL abstract protocol interface.

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