# ISO 11783 Standard: Procedures for Serial Data Communication between the Implement ECU with the Task Controller

[1]Robson Rogério Dutra Pereira, [1]Eduardo Paciência Godoy, [1]Rodrigo Martins Romeira Sakai, [1]Felipe Alves Cavani, [1]Rafael Vieira de Sousa, [1]Arthur José Vieira Porto, [2]Ricardo Yassushi Inamasu

[1]Department of Mechanical Engineering, Engineering School of São Carlos, University of São Paulo, Av. Trabalhador São carlense, 400, CEP 13566-590,
São Carlos, São Paulo, Brazil.
robsondutra.pereira@usp.br
[2]EMBRAPA - Brazilian Agricultural Instrumentation Research Corporation, Street XV de Novembro, 1452, CEP 13560-970, São Carlos, São Paulo, Brazil.
ricardo@cnpdia.embrapa.br

## ABSTRACT

The recent growth of the use embedded electronic and remote sensing in agricultural machinery has promoted the application of the Precision Agriculture (PA) management strategy. PA has demanded researches of sensors and communication networks for data acquisition and control in the farm field. The incompatibility between hardware, software and data formats has become a major obstacle. The global trend is to use standardized systems in accordance with ISO 11783 standard (also known as ISOBUS) on devices, or Electronics Control Units (ECU), of the agricultural production. The purpose of this work is to systemize the information necessary of the procedures for communication of the implement ECU with the tractor task management ECU, the needed standardized files and the validation tests of the devices communication via ISO 11873 network. It was established the conceptual connection among the systematized information and embedded devices on agricultural machinery. The embedded devices consist in five ECUs connected in the ISO 11783 network. Four ECUs are located in the tractor: GPS ECU, Task Controller (TC), Virtual Terminal (VT) and Tractor ECU (TECU). The GPS ECU is responsible to the Differential Global Positioning System (DGPS) positioning. The TC is responsible to manage the prescription map and to control the implement. The VT is responsible monitor the application. The TECU disposes tractor velocity of a radar sensor. The fifth device located in the implement is Working Set Master (WSM), which is responsible to interpret the commands from the tractors ECUs and integrate the mechanical-hidraulical device to do the implement application. It was presented how to develop the needed standardized files, the capabilities needed of the Implement ECU program, the validation of communication between the Implement ECU with the TC and was prove that the information systematized has facilitated and provided the communication. It is expect, this work may open opportunities for the ISO

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11783 standard can be better understood and enlarge the possibility of providing a great number of applications involving the concept of PA in Brazil.

**Keywords:** ISOBUS, embedded network communication, agricultural machinery, precision agriculture, file standard, Brazil.

## 1. INTRODUCTION

The recent growth of the use embedded electronic and remote sensing in agricultural machinery has promoted the application of the Precision Agriculture (PA) management strategy for agricultural production. PA is management strategy for the agricultural production and involves multidisciplinary practices (Gozdowsk & Samborski, 2007). PA has demanded researches of sensors and communication networks for data acquisition and control in the farm field. The incompatibility between hardware, software and data formats has become a major obstacle. The global trend is to use standardized systems in accordance with ISO 11783 standard (also known as ISOBUS) on devices, or Electronics Control Units (ECU), of the agricultural production. The practices 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 (Wei *et al.*, 2005; Darr *et al.*, 2007; Ni *et al.*, 2009; Steinberger *et al.*, 2009). The Distributed Control System (DCS) is the suitable solution for decentralization of the data acquisition system and the Controller Area Network – CAN (Bosch, 2008) is the major trend among the embedded communications protocols (Darr *et al.*, 2005; Pereira *et al.*, 2008). In Lenz *et al.* (2007) presents the performance analysis of various embedded software development projects for the DCS relating project content, project rigor and quality, in off-road vehicles. The several works confirmed the usage of CAN protocol according to ISO 11783 standard for agricultural machinery, as following citation: Du *et al.* (2008); Godoy (2007); Miettinen *et al.* (2006); Oksanen *et al.* (2005a); Oksanen *et al.* (2005b); Pereira *et al.* (2008), Suvinen and Saarilahti (2006), Zhang *et al.* (2008) and Benneweis (2005).

The soils correctives are fundamental inputs in agricultural exploration. The Brazilian soil has high acidity and this condition is unfavorable to plant. So, the correct input application assumes an important signification, in terns of soil fertility, yield and economic factors. The efficiency of the inputs in the agricultural productive process is dependent of its quality and application way at soil. Errors in one of the stages above affect directly the agricultural yield. The purpose of this work is to systemize the information necessary of the procedures for communication of the implement ECU with the tractor ECU and the validation tests of the devices communication via ISO 11873 network. This work presents the implementation and evaluation of the CAN-Based DCS via ISO 11783 network for the Variable Rate Technology (VRT) (Gao & Liu, 2005) system a soil corrective in agricultural machinery. In the next section will expose the ISO 11783 review needed parts and PA, the agricultural machinery and the CAN messages based on ISO 11783. In the section 3 will depict about results and discussion. And the section 4 will talk about the conclusion of this work.

## 2. MATERIAL AND METHODS

The requirements for the implementation of this work were divided in the review the necessary ISO 11783 standard parts, the Precision Agriculture phases and technologies, the development of the CAN-Based Distributed Control System in agricultural machinery and a creation of a set of CAN messages for the evaluation the agricultural implement to effectuate VRT application.

### 2.1 Review of the ISO 11783 standard and Precision Agriculture

The ISO 11783, also known as ISOBUS, is standardization of the serial control and communication data among the electronic devices embedded in the tractors and the machinery for agriculture and forestry. Two groups, North American ISOBUS Implementation Task Force (NAIITF, 2008) in the United States of America and ISOBUS Implementation Group (IGI, 2008) in Europe with support of the International Organization for Standardization (ISO, 2008) have created the ISO 11783 - Tractors and machinery for agriculture and forestry - Serial control and data communication network, consisting of 14 parts, of which 11 already published (ISO, 2008). In Brazil, the ISO 11783 was divulged in international agriculture fair Agrishow 2007 (Agrishow, 2009) in Ribeirão Preto - SP, supported by Task Force ISOBUS Brazil (FTI Brasil, 2008).
The ISO 11783 standard is a set of definitions, rules and procedures that are designed to allow the connection and information exchange between control units of a tractor and an agricultural implement. In other words, it’s an attempt to apply the concept of "plug and play" between the agricultural machinery and equipment. ISO 11783 arose from the union of two other standards: LBS/ DIN 9684 (Auernhammer & Frisch, 1993; Bock, 2000) and SAE J1939 (Auernhammer & Speckmann, 2006; Lenz *et al.*, 2007; SAE J1939, 2008), both standard based on protocol Controller Area Network (CAN) (Bosch, 2008). Therefore, the communication network of ISO 11783 is based on CAN 2.0B version protocol messages. The messages are composed of fields of bits, which two are highlighted: the Parameter Group Number (PGN) and Data Field. The PGN identifies the type of message and is composed of 18 bits. The Data Field contains data from the message and can be up to 8 bytes. The basic concept of the ISO 11783 standard follows the Basic Reference Model OSI in order to meet one of the limitations of previous LBS/ DIN 9684 standard. The typical ISO 11783 network is composed of the following basic units controllers: GPS (Global Positioning System) receiver, Virtual Terminal (VT), the Tractor ECU (TECU) and the Task Controller (TC), distributed over the network or Binary Unit System (BUS).

#### 2.1.1 Physical Layer (part 2) and Network Layer (part 4)

ISO 11783 defines rules and procedures to enable the connection and exchange of information between the electronics nodes on the network ISO 11783. The Electronic Control Unit (ECU) is the electronic system which promotes the interconnection of a particular device to the network. However, a single ECU can be responsible for the connection of two or more devices to the BUS. Also a device can be connected to the BUS for more than one ECU. The electronic node consists of device and ECU. These ECUs can be located at two BUSES defined by ISO 11783, which are the tractor BUS and the implement BUS. The BUSES and the ECUs connections to the BUS must have physical and electrical characteristics in accordance with specifications of ISO 11783-2 (2002). Recently, in the meetings of the Brazilian Commission Study of the ISOBUS, [1]CE 04:15.15 – Comunicação e Eletrônica Embarcada (FTI Brasil, 2008), due the implement BUS are located at tractor and at the implement, there was a need to call the implement BUS in two names, implement BUS (located in the tractor) and BUS of the implement (located in the implement), which we adopted in this article. ISO 11783 provides for the connection of two BUSES with different network architectures, for example, the BUS A with SAE J1939 (2008) network and other BUS B with ISO 11783 network. This connection between different networks is made through an ECU used as a Network Interconnect Units (NIU) with the function of isolating the different networks, according to ISO 11783-4 (2001). In a typical ISO 11783 network can have up to 30 nodes and maximum length is 40 m. Therefore, for complex systems that are need more than 30 nodes, is necessary to use a NIU for each nodes group to not exceed the number of nodes in accordance with ISO 11783-4 (2001). A typical topology of a network ISO 11783 is shown in Figure 1.

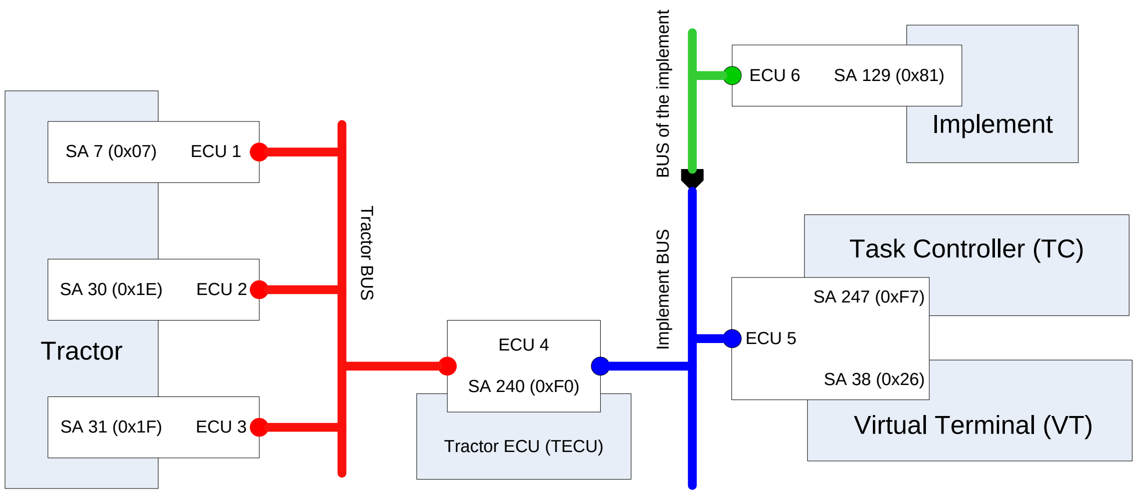



Figure 1 - Typical Network Topology of the ISO 11783. Source: adapted from ISO 11783-4 (2001).

The Figure 1 shows Tractor ECU (TECU) working as a NIU responsible for isolation and the interconnection between the tractor BUS with the implement BUSES. The tractor BUS is not necessary be ISO 11783 network and the implement BUSES is mandatory be ISO 11783 network.

### 2.1.2 Management Network (part 5) and Data Link (part 3)

The ISO 11783-5 (2001) contain rules that define the administration of the Source Address (SA) of the ECU and the association of addresses with the identity of the functional device connected

[1] CE 04:15.15 - Code of the ISO 11783 Brazilian commission studies

to the network by the ECU. It defines the connection and initialization process of the ECU on the network. The three types of particular ECU are defined in this part: Standard ECU which has no special functions; Diagnostic or Development ECU connected to the BUS with respect to track and analyze the network that is connected; and Interconnection Network ECU (NIU, as described before) with special functions that allow communication different networks. Are specified four distinct forms of address configuration in an ECU, which are: non-configurable-address ECU, service-configurable-address ECU, command-configurable-address ECU and self-configurable-address ECU.
The ISO 11783-5 (2001) defines a structure of the Data Field on the message called NAME. This structure is composed of 64 bits and has the function of providing a functional description of an ECU for other ECU connected on the network. The NAME provides a SA numerical value for the SA dispute process for the ECU get access to a network. The NAME structure contains the fundamental information for the connection and initialization process of ECU on the network. This structure allows an ECU to connect in a network, to identify by its function and to obtain an SA. In the startup process in which the SA of messages is negotiated through the BUS, this structure is even more important. For the negotiation and administration for the network are defined four specific messages: Request for Address Claim, Address Claim, Commanded Address and Cannot Claim Source Address. Rules are defined for the startup process of the ECU, which uses the messages depicts before, to setting the SA with message exchange between the ECU already initialized with the ECU in the boot process. This part of the standard describes the rules and illustrates the communication of messages through diagrams. The development of the self-configurable-address ECU requires understanding of this process.
The ISO 11783-3 (1998) Data Link layer defines the adoption CAN 2.0B protocol version (Extended CAN). The Data Field size message is from 0 up to 8 bytes (64 bits) and the Identifier size is 29 bits, as you can see in Figure 2.

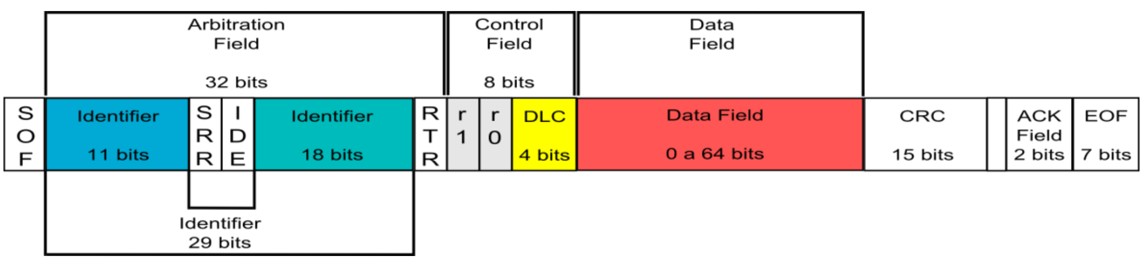


Figure 2 - Frame of CAN 2.0B (Extended CAN). Source: adapted from ISO 11783-3 (1998).

The Identifier field allows messages exchange with different priorities independent of the node source. The ISO 11783-3 (1998) defines ways to use the bits of the Identifier and the Data Field in frame of CAN message, as depicted in Figure 2. There is a schema of the Identifier bits use, called Protocol Data Unit (PDU), which could be, according to ISO 11783-3 (1998), PDU1 and PDU2. These PDUs are message structures that allow for different types of addressing for a message. A structure called PDU1 allows ECU sends a message directly to another ECU. The structure called PDU2 allows identifying the data type of the message, but does not address the message to a specific ECU, providing for any ECU connected on BUS evaluate the content of the message by its identifier and decide whether or not receiving this message. Figure 3 shows the two types of PDUs specified by standard ISO 11783-3 (1998).

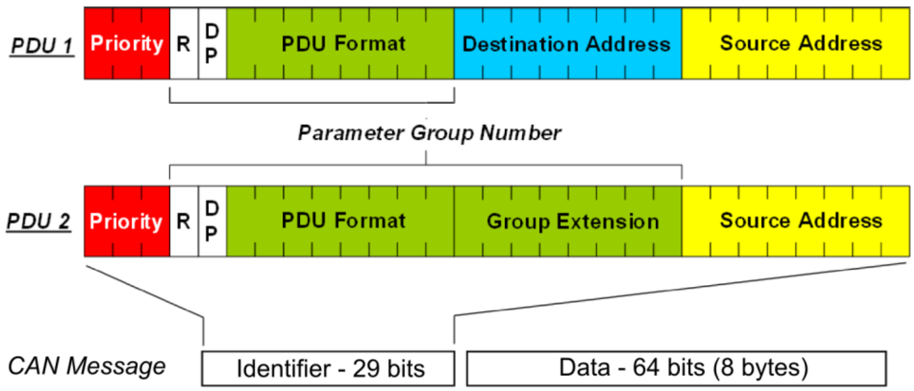


Figure 3 – PDU Types. Source: adapted from ISO 11783-3 (1998).

There are 256 (0 to 255 - 8 bits) possibilities of SA available on a network for the two possible Identifier structures (PDU1 and PDU2), as can see verifying the size of the fields Source Address (SA) and Destination Address (DA) in Figure 3. The address 255 is the destination address and global address 254 is an invalid address used for administration of the network.

The field PDU Format (PF) of the identifier, see Figure 3, allows the ECU connected to the BUS to identify the type of PDU, PDU1 or PDU2, which is being used to communicate a message from particular node. If the PF field (8 bits) has decimal value equal to or greater than 240 is PDU2, if else will be PDU1. The other function of PF field, when it is associated with Data Page (DP) and Reserved (R) fields, is the formation of Parameter Group Number (PGN). If the message is PDU1 the PGN has 10 bits, if else the PGN has 18 bits for PDU2 because the addition the Group Extension (GE – 8 bits) field.

The standard classifies the data transmitted in data measured because of state or because of command, and specify parameters to characterize these data, for example, for a given continuous variables measured, it specifies the unit of measurement, precision and resolution. The sets of parameters that have similar characteristics are grouped together to compose a message on a particular theme, such as message with the engine parameters or parameters with the navigation message. This group of parameters is called Parameter Group (PG) and is a defined message format for each PG. The PGN implements a way to indicate the contents of a data message, or is associated with PG. There are 8,672 PG possibilities and allows implementing different sets of messages to meet the needs of data communication between ECU in agricultural machinery and implements.

### 2.1.3 Virtual Terminal (part 6) and Extended Transport Protocol (part 3)

To perform the data transfer larger than 8 bytes, there are two protocols defined by ISO 11783, which are the Transport Protocol (TP) and Extended Transport Protocol (ETP). The specifications of those protocols allow the point-to-point communication (ECU sends messages to another ECU specific) and the broadcast communication (ECU sends messages and any other ECU may receive or not the message). The TP is used for data transfer larger than 8 bytes and up to 1785 bytes. The timings, packaging and re-packing of data, messages (PGNs) and following transfer of the TP are defined in the annexes of ISO 11783-3 (1998). The ETP is used for transferring data over 1785 bytes and up to 117,440,512 bytes. Respectively, the timings, packaging and re-packaging of data, messages (PGNs) and following transfer of the TP are defined in one of the annexes of ISO 11783-6 (2004).

To eliminate various Human-Machine Interfaces (HMI) dedicated to each device connected to the implement or tractor, the ISO 11783-6 (2004) defines a single HMI called Terminal Virtual (VT). This part of the standard provides definitions, physical characteristics and dynamic behavior of the device for the startup procedures, procedures for updating data, processing and handling of alarms of different types of objects (which will be displayed on your TV). For each device or implement that is a control and/ or monitoring of the operator of the tractor shall send a set of objects (Object Pool - OP) through the protocols TP or ETP (depending on file size). The OP contains information that is interpreted by VT to present graphically the implement or device on VT screen, establishing the HMI between the operator and the device connected on the network or put from/ to implement.

### 2.1.4 Precision Agriculture and Task Controller (part 10)

The basic principle of Precision Agriculture (PA) is handling the variability of soil and crops in space and time. This variability are of the soil, the climate, the diversity of cultures, the performance of agricultural machinery and natural or synthetic inputs used in agricultural production. Based on these principles are given some definitions of the term PA:

• "A management strategy that uses Information Technology (IT) to collect data from multiple sources to support decision making system of the agricultural production." (National Research Council: Board on Agriculture, 1997);

• "A set of techniques that allows the management of localized cultures." (Balastreire *et al.*, 1998);

• "Precision agriculture is the application of principles and technologies to manage the spatial and temporal variability, associated with all aspects of agricultural production to increase agricultural productivity and environmental quality." (Pierce & Nowak, 1999);

• "A set of techniques and crop management actions taking into account the variability of soil parameters and the behavior of the crop in the plot." (Menegatti & Molin, 2004);

• "PA is defined as a holistic strategy and protective of the environment in which agricultural producers may change the use of materials and methods of cultivation to match the variation of soil and cultural conditions across the country. There are still other definitions and all these suggest that there are at least three critical elements to the success of PA: information, technology and management." (Srinivasan, 2006).

A PA system should have the ability to relate the measures of the field and interpretation of spatial and temporal variability, generating information for the management of variability by the application of inputs. These applications should be located and made by machines and devices for the correct application of different inputs in a specific location. The PA system should be able to register the data of the applications for review by a specialist team, and after examination, should be generated action plans for future management of the variability. The following process "field data acquisition" → "data analysis" → "planning of the management field" →

“management of the field” of the PA is cyclical, and this feature is called cycle of PA or PA phases, and Figure 4 show according to Molin (2003).

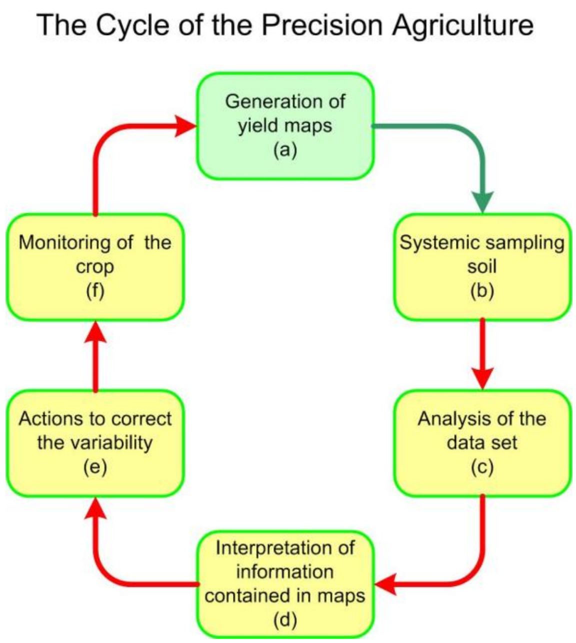
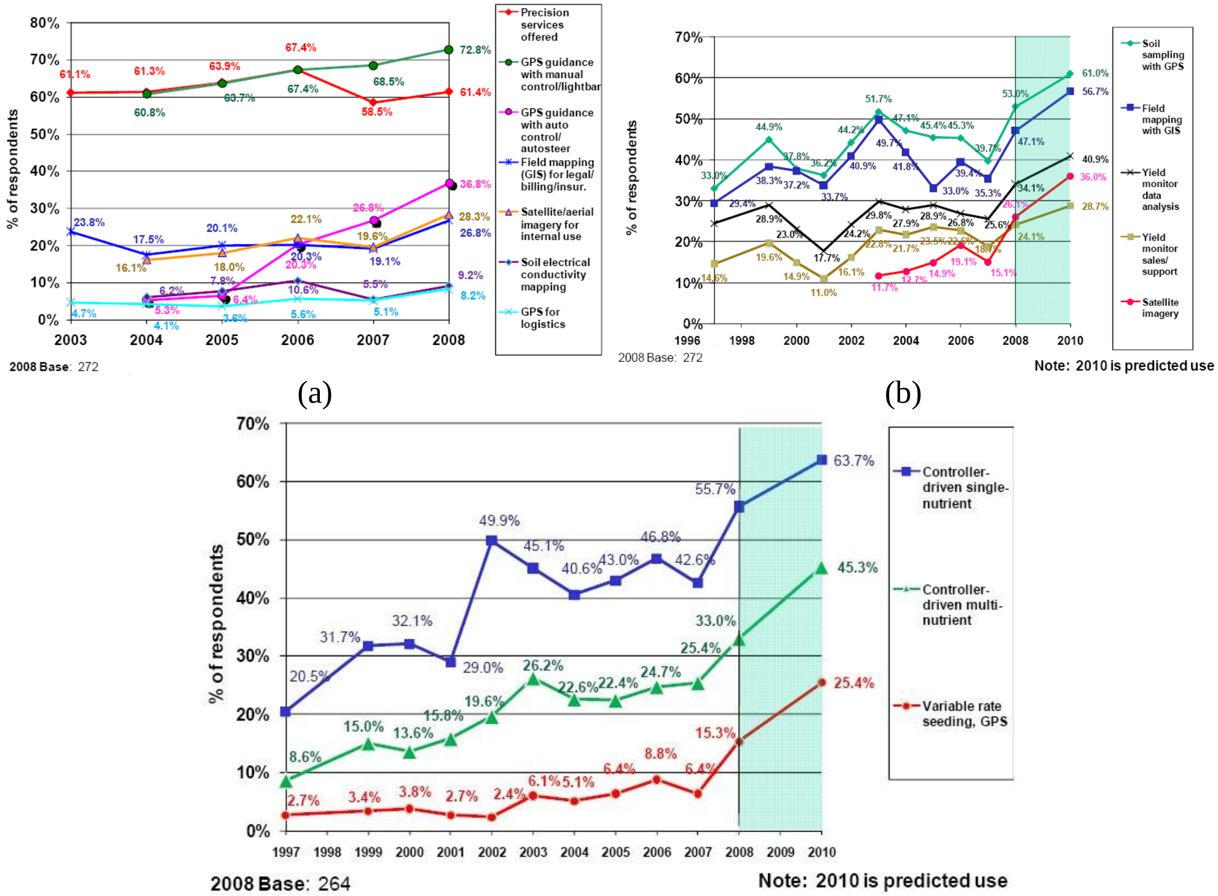


Figure 4: PA phases. Source: Molin (2003).

Those phases enabling a large number of technologies, for example, the Global Positioning System (GPS) guidance, field mapping by Geographic Information System (GIS), satellite or aerial imagery, soil electrical conductivity mapping, remote sensing, soil sampling techniques, Variable Rate Technology (VRT) and others. The adoption of PA along of ten years ago is demonstrated in the Crop Life Report: 2008 Precision Agricultures Services from Center for Food and Agricultural Business of Department of Agricultural Economics of Purdue University (Whipker & Akridge, 2008). The Figure 5 (a) shows the graph of the usage of PA technologies between 2003 to 2008 years, Figure 5 (b) show the graphs of the usage of PA services between 1996 to 2008 years with predicted use for 2010 year, and Figure 5 (c) show the growth of variable rate application using VRT between 1997 to 2008 years with predicted use for 2010 year.




(c)

Figure 5. (a)Use of enabling technologies of PA over time (b)Use of PA services over time. (c)Use of the variable rate seeding + GPS, controller driver for a single nutrient and for multi nutrient. Source: Whipker and Akridge (2008).

According to the Figure 5 (a), Figure 5 (b) and Figure 5 (c), it notices since 2007 year the use of technologies and services increased linearly, showing the acceptance of PA. The relationship between the cycle of PA (Figure 4) with the technologies and services is shown in Table 1.

Table 1. Relationship between the Figure 4 with the Figure 5.

| Technologies and Services | Phases of PA |
|---|---|
| GPS guidance with manual control | (a)(b) (e)(f) |
| GPS guidance with auto control | (a)(b) (e)(f) |
| Field mapping (GIS) | (c)(d) |
| Satellite/ aerial imagery | (b)(c)(d) (f) |
| Soil electrical conductivity mapping | (b)(c)(d) |
| Soil sampling with GPS | (b)(c)(d) |
| Field mapping with GPS | (a)(b)(c)(d) (f) |
| Yield monitor | (a) (c)(d) (f) |
| Data analysis | (c)(d) (f) |
| GPS for logistics | (a)(b) (e)(f) |
| Variable rate applications (VRT) | (a)(b) (e)(f) |

Based on Table 1, in practical way, we can associate those technologies and services with the agricultural applications of the PA. To support PA, following the worldwide trend, ISO 11783-10 (2007) and ISOBUS Test Conform (2007) define the procedure for initialization and communication between the computer farm called Farm Management Information System (FMIS), Task Controller (TC) and implement the system control called Mobile Implement Control System (MICS). FMIS is that set of computational tools to analyze the variability of soil and creation of tasks to be implemented in the field, for example, application of limestone to correct the soil according to the spatial variability. The TC is responsible for interpretation, management and data acquisition tasks to be performed in the field, sending commands to the MICS. The MICS is total coupled the vehicles and implements with the network ISO 11783. The prescription maps are made by appropriated tools using the standard XML (Extensible Markup Language) and inserted (post task removed) in TC using a portable media device for transferring files. The prescription map XML file is called TaskData.xml. For the TC associate the implement to the task TaskData.xml, the implement must send a file similar to the OP, the set of objects called the Device Description Object Pool (DDOP) using the TP and ETP protocols. The DDOP could be analyzing in a XML structure file, but in the implement ECU is usually load the DDOP in bytestream format. After the transmission of DDOP, the TC must to interpret and the associate TaskData.xml with the implement. DDOP are contained in all the characteristics of each device on the implement, for exempla, all sensors and actuators, as defined by ISO 11783-11 (2007). The TC should provide options for the user control and monitoring tasks. When a task is enabled, the TC manages all the available information and commences the transmission messages of Process Data (PD), defined messages for communication between TC and the implement ECU. During a task, the TC collects and stores the data. At the end of work, the TC should format the data collected in an XML file to transfer back to the FMIS.

## 2.2 Agricultural Machinery for VRT application and The ISO 11783 Distributed Control System

Most tractors are manufactured in Brazil haven’t CAN based ISO 11783 network. But there is a demand for tractors with ISO 11783 network due to the recent growth of the ISOBUS protocol implementation in agricultural machinery. It was found that the company Valtra (Valtra, 2008) had a prototype tractor BM125i (Figure 6) with a CAN-BUS. The principal types of soil correctives and fertilizers machinery applicators are defined by its functionality. There are applicators which work with gravity and with centrifuge force. The gravity machinery has the inputs distribution continuous fillets. The gravity machinery presents major potential of uniform distribution transversal and longitudinal than the centrifuge forces machinery. We adopted the gravity machinery implement DMP 7500 (Figure 6) from Baldan (Baldan, 2008) used in Pereira *et al.* (2007) that which capable to apply the specific rate at specific location. The distributed system consists in five ECUs responsible for the control and the management for the VRT application, data acquisition and communication between the devices in the ISO 11783 network, depicts in the Figure 6.

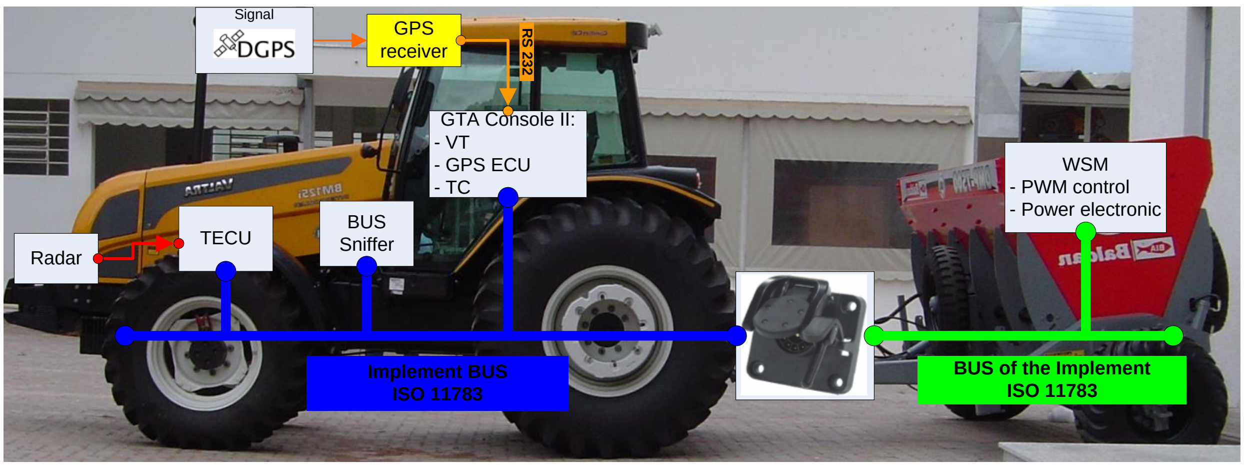



Figure 6. Schematics of the ISO 11783 embedded network for Distributed Control System developed for agricultural machinery.

Four ECUs are located in the tractor: GPS ECU, Task Controller (TC), Virtual Terminal (VT) and Tractor ECU (TECU). The GTA Console II, from AGCO Corporation (AGCO, 2009), is a commercial terminal with Human-Machine Interface (HMI) and constituted of GPS ECU, VT and TC. The GPS ECU is responsible to the Differential Global Positioning System (DGPS) positioning and dispose the coordinates in the CAN network. The VT is responsible monitor the application graphically. The TC is responsible to manage the prescription map, to store the application data and to control the implement by sending the desired rates of inputs via ISO 11783 network. The TECU disposes tractor velocity of a radar sensor in the ISO 11783 network. To analyze the communication procedures, the Sniffer was embedded. The Sniffer is PCMCIA CAN-BUS sniffer from Vector (Vector, 2008) installed in a laptop computer, witch is responsible to monitor and analyzing the application by the data messages exchange via ISO 11783 network. The fifth device, Working Set Master (WSM), is located in the implement and was developed based in Pereira *et al.* (2007) for this work. The WSM has a microcontroller PIC18f258 of Microchip (Microchip, 2008); a CAN Transreceptor to make the interface among the microcontroller and ISO 11783 BUS; a RS232 Transreceptor. WSM is responsible to interpret the commands from the tractor ECUs via ISO 11783 network and integrate the mechanical-hidraulical device to do the variable application according to the prescription map.

## 2.3 The set of CAN messages

Based on ISO 11783 part 1 standard (ISO 11783-1, 2007), rules are defined for the startup process of the ECU in a CAN network, using the definition of the Source Address (SA) messages, the exchange of information between the ECU already initialized and operating normally with the ECU in the boot process. The sets of parameters that have similar characteristics are grouped together to compose a message on a specific type, such as messages with the engine or navigate parameters. This group of parameters is called Parameter Group (PG) and is defined message format for each PG. The PGN joint with the PG, implements a way to indicate the contents of a data message for the 8672 possibilities of PG. Table 2 shows a set of the initialization and process data messages used among the TC and WSM, the message of speed and the message of de GPS coordinates.

Table 2. Process messages. Based on ISO 11783-10 (2007).

| PGN | Control Byte Data field - BYTE 00 | Message | Data field BYTES 01 – 07 |
|---|---|---|---|
| DP=0<br>PDUF = 203<br>(0xCB)<br>PDUS = DA<br>Priority = 3<br>PGN = 51968<br>(0x00CB00) | 0x0E | *Task-controller status message* | 04 to 07 indicate TC status |
| | 0x0F | *Working-set task message* | 04 to 07 indicate WSM status |
| | 0x0D | *Negative acknowledge (NACK) message* | 04 indicate the error type. If is 0x01 means there isn't activated DDOP |
| | 0x00 | *Request version message* | All reserved (0xFF) |
| | 0x10 | *Version message* | 02 indicate the version |
| | 0x01 | *Request structure label message* | All reserved (0xFF) |
| | 0x11 | *Structure label message* | 01 to 07 are the 7 characters of the DDOP structure label |
| | 0x21 | *Request localization label message* | All reserved (0xFF) |
| | 0x31 | *Localization label message* | 01 to 06 are the 6 characters of the DDOP localization label |
| | 0x41 | *Request object-pool transfer message* | 01 to 04 indicate the size of the transferred file |
| | 0x51 | *Request object-pool transfer response message* | 01 indicate if the TC has enough store file space |
| | 0x61 | *Object-pool transfer message* | 01 to n, the number n varies depending on the size of DDOP |
| | 0x71 | *Object-pool transfer response message* | 01 indicates if the file transfer was successful. 02 to 05 indicate the size of DDOP |
| | 0x81 | *Object-pool activate message* | 01 to 07 reserved (0xFF) |
| | 0x91 | *Object-pool activate response message* | 01 to 06 indicate if there is an error in DDOP |
| | 0x13 | *PDValue* | 02 to 03 indicate the DDI = 6. 04 to 07 indicate the variable value of the process (desired rate) |
| DP = 0<br>PDUF = 254<br>(0xFE)<br>PDUS = 73<br>Priority = 3<br>PGN = 65097<br>(0x00FE49) | *[2] | *Ground-Based Speed And Distance* | **BYTES 00 – 07**<br>00 to 01 indicate the ground based speed |
| DP = 1<br>Priority = 3<br>PGN = 129025<br>(0x1F801) | * | *GNSS Position Rapid Update* | 00 to 03 indicate the latitude and the 04 to 07 indicate the longitude. |

[2] Hasn't control byte.

From the group PGN = 0x00CB00 (Table 2), the messages with control bytes 0x0E and 0x0F indicates the status of TC and WSM respectively. The messages with control bytes 0x0D to 0x91 are for the initialization and configuration among TC and WSM. And the last one of this PGN group, with control byte 0x13, indicates the process value variable, in this work means the desired rate according to the prescription map. The message with PGN = 0x1F801 is for the GPS coordinates and the PGN = 0x00FE49 is for the tractor speed based on the ground.

## 3. RESULTS AND DISCUSSION

An experiment was done to check the results of the CAN-Based Distributed Control System. In this experiment, the ECUs communication test was done with a tractor and the VRT implement for application of soil corrective, both with an ISO 11783 network, at Laboratory of Simulation and Control (Simulation and Control, 2009) of the Department of Mechanical Engineering of School of Engineering of São Carlos – University of São Paulo (EESC-USP). But, before to do the test, a prescription map was generated based on Cycle of PA (Figure 4) using the PA technologies (Figure 5). The map generation started in phase (b) using an active chlorophyll crop sensor with GPS receptor to measure the spatial variability geographically. Next were the phases (c) and (d) using the GIS software GTA suite software (AGCO, 2009) for analysis and build the prescription map archive and satellite imagery from Google Earth (Google Earth, 2009) to notice the visual variability. The Figure 7 (a) presents the route of the sampling soil with the region 2 is more shaded than the region 1, i.e., the region 1 receives more sunlight than the region 2. And the Figure 7 (b) shows the georeferenced prescription map of soccer field of the EESC-USP of the interpreted variability with respective legend of the desired rates to treat the soil on phase (e). The phase (e) consist the VRT application according to prescription map.

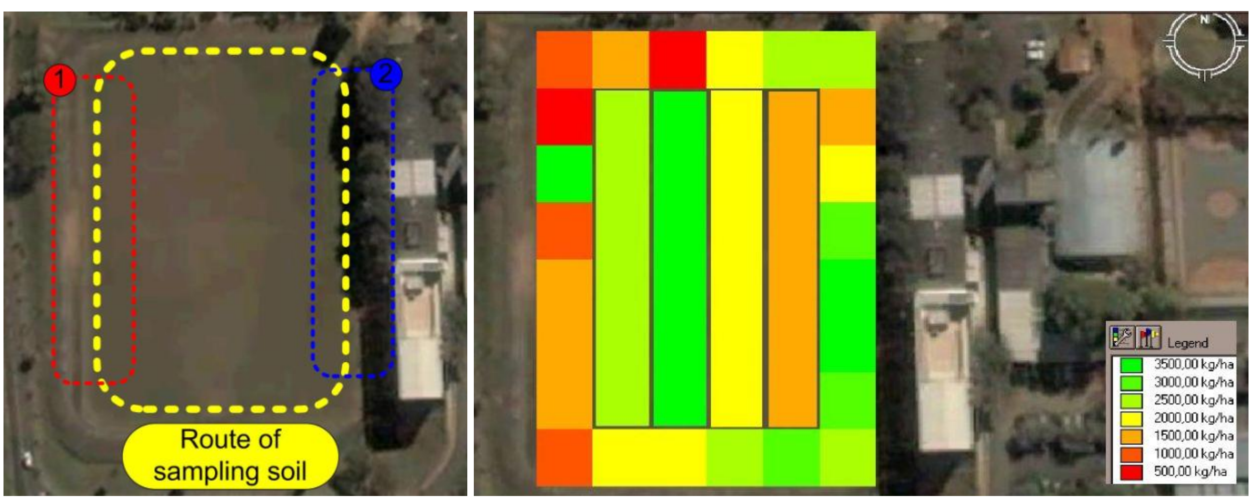



Figure 7. The EESC-USP soccer field of the prescription map. Source: Google Earth (2009) and GTA Suite Software (AGCO, 2009).

After the generation, it setup to go to the phase (e) using the Agricultural Machinery for VRT application and The CAN-Based Distributed Control System. All the communication and command process is done by exchange messages through CAN-BUS network and the BUS Sniffer was used to monitor and collect the messages exchange during the process. The prescription map was inserted on TC and the initialization among TC and WSM was started, as we can see the logged messages exchanged in the Figure 8.

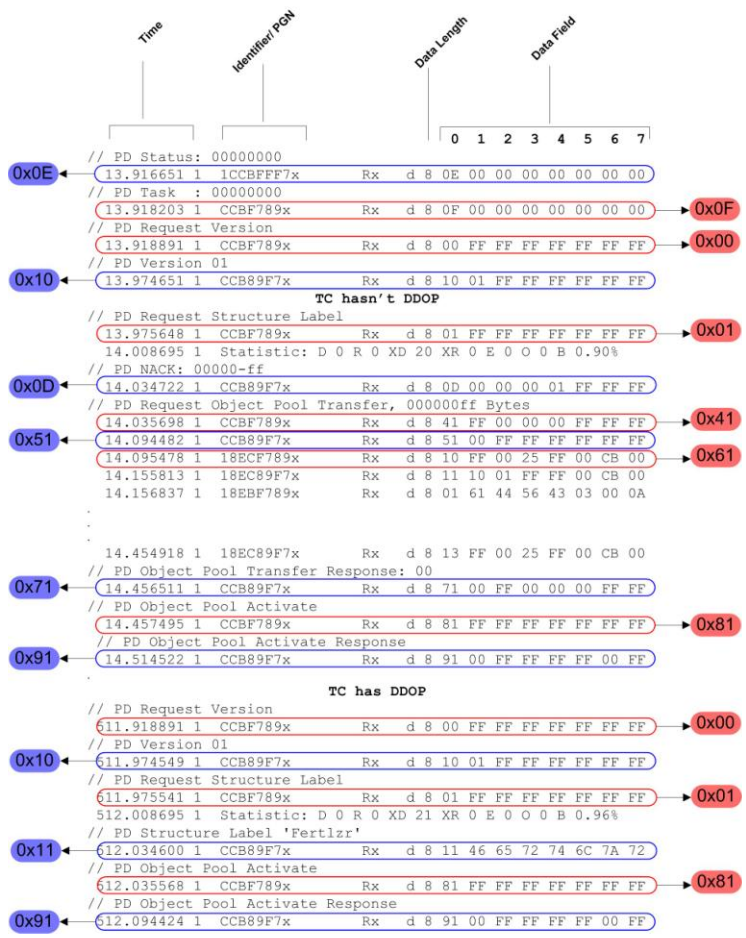



Figure 8. The CAN messages log of the initialization process among TC and WSM.

Using the Table 2, messages of Figure 8 was interpreted. A condition for the initialization start is the TC and WSM must send status message, and the condition was satisfied with the messages 0x0E of the TC and 0x0F of the WSM. The initialization and configuration began with WSM message 0x00 and finished with TC message 0x91. After that, when the tractor and implement transit over the prescription map area the VRT application commence if the TC and the WSM still send the Status message, as we can see in the Figure 9 (a.0) and the status change to 01 (Figure 9 (a.1)).

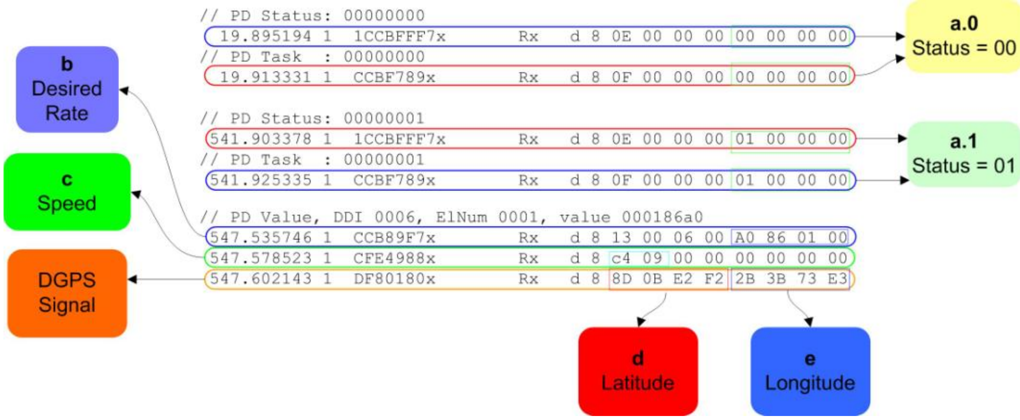



Figure 9. The CAN messages log of the VRT application using GPS ECU, TC, TECU and WSM.

The Status = 01 means the VRT application is activated. The tractor velocity is measured by the radar sensor at TECU and this information is transmitted on the implement BUS by message Speed (Figure 9 (c)) to the WSM that controls the hydraulic motor. The hydraulic motor is responsible to control the rotation of the endless spiral that changes the input application. The coordinates of the GPS was send by GPS ECU message DGPS Signal (Figure 9 (d) Latitude and (e) Longitude) and are used to by TC to check witch application rates is necessary to send to the WSM. And finally the desired rate was send by TC message Desired Rate (Figure 9 (b)). In this message sample, the desired rate was send is 1000 kg/ ha (or in the data field 0xA08601). With the desired rate, the WSM does a proportional controller (P controller) of the rotation of the VRT system shaft by power electronic. To effectuate the P controller, the WSM read the tractor velocity and desired rate to calculate the desired rotation. The desired rotation is the necessary rotation of the VRT shaft to apply the desired rate required. The VRT system developed presented a maximum error of 20%. This error could be explained due to the delays in message transmissions and in the mechanical-hydraulic actuators. The obtained error value was not critical for the type of application (soil corrective) which the system was developed.

## 4. CONCLUSION

In this work was showed the implementation of a CAN-Based Distributed Control System for Variable Rate Technology in Agricultural Machinery using an ISO 11783 network and a prescription map in automatic way. The evaluation done is about the validation of the communication and control by ISO 11783 network analyzing the collected messages. Was demonstrated how the apply PA in practical way using the enabling technologies and concepts and the acceptance of PA in last years. The implement presented acceptable results (application rate error) for the utilization in soil corrective application systems.
This work contributed with research groups about the ISO 11783 standard and making possible its development and implementation for the national industry in agreement to the news worldwide tendencies agricultural machinery area. The future works include changing the P controller to PI controller to improve the results of the VRT system.

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