Computers and Electronics in Agriculture 117 (2015) 141–148

Contents lists available at ScienceDirect

Computers and Electronics in Agriculture

journal homepage: www.elsevier.com/locate/compag

Remote access of ISO 11783 process data by using OPC Unified Architecture technology

Timo Oksanen *, Pyry Piirainen, Ilkka Seilonen

Department of Electrical Engineering and Automation, Aalto University, P.O. Box 15500 (Otaniementie 17), 02150 Espoo, Finland

ARTICLE INFO

Article history:
Received 1 March 2015
Received in revised form 3 August 2015
Accepted 4 August 2015
Available online 14 August 2015

Keywords:
Agricultural machines
Remote automation
Telematics
Wireless communication
OPC UA
Information models

ABSTRACT

There are various scenarios in which someone might want to remotely access the data of agricultural machinery. In this article, we concentrate on telematics applications, where the manager of a vehicle fleet has an interest in seeing both what the vehicles are doing and where they are in real time. In this article the feasibility of using OPC Unified Architecture (OPC UA) technology to transfer ISO 11783 related process data between a mobile agricultural vehicle and the Internet is studied. A device containing an ISO 11783 Data Logger, an OPC UA server and a mobile network connection was designed and installed in a vehicle. A capability for downloading and interpreting a ISO 11783 Data Dictionary Object Pool (DDOP) was designed for the OPC UA server application in order to link the ISO 11783 and OPC UA standards together. The system was evaluated by transferring a few process data variables over a 3G connection from a tractor and a connected seed drill. The latency and bandwidth usage of communication were measured and found feasible for telematics. In addition to this, the approach for converting a DDOP to an OPC UA information model was observed to be functional.

1. Introduction

There are various scenarios in which someone might want to access the data of agricultural machinery. It may be in the interest of the manufacturer of the vehicle (or a part of it) to access the data of the machine after it has left the factory, in order to provide maintenance services for instance. On the other hand, it may be in the interest of the owner of the vehicle to track its position, to prevent hijacking.

In this article, we concentrate on scenarios where the manager of a vehicle fleet (working on a single farm) has an interest to see *what* the vehicles are working on and *where* they are working in real time. This information can be used in the management system to estimate the progress of the production phase operations in the field. Common electronic controllers and connected sensors in the implements allow more information flow than basic GPS-related information (like position and velocity), also relaying the current application rate or crop yield rate. By fusing the vehicle process data and other data sources, the production process can be optimized. The other data sources may involve material storage data, vehicle/driver availability data, weather forecast data or disease forecast data, for instance.

The ISO 11783 standard and ISOBUS components based on the standard are supported by companies manufacturing tractors and implements connected to those. Therefore, in this article the focus is to access the data of ISOBUS compatible implement remotely by relying on the standard messages in the ISO 11783 network. The key concepts of ISO 11783 related to remote access of the implement variables are Process Data messages, Device Description Object Pool (DDOP) and Data Logger interface.

Fig. 1 summarizes the scenario of this study. The mobile system (the vehicle) consists of a tractor and an implement, both connected to an ISO 11783 network (known also as ISOBUS). The Tractor Electronic Controller Unit (Tractor ECU) and Virtual Terminal (VT) are other parts of ISO 11783, besides the Implement ECU and the developed *Gateway*. The Gateway consists of a Data Logger interface with an ISO 11783 network and OPC UA server to the Internet. The technology enables the remote connection from the client system to the implement; for telematics application use.

The main objective of this article is to study the feasibility of OPC UA technology being able to transfer ISO 11783 related process data between the mobile agricultural vehicle and the client system. The questions are: (a) Is it a feasible technology for the stated application? and (b) How can the ISO 11783 and OPC UA standards be linked together?

The study is limited to a one-way data flow from the mobile device to infrastructure, due to functional limitations of ISO

* Corresponding author. Tel.: +358 50 3160970.
E-mail address: timo.oksanen@aalto.fi (T. Oksanen).

http://dx.doi.org/10.1016/j.compag.2015.08.002
0168-1699/

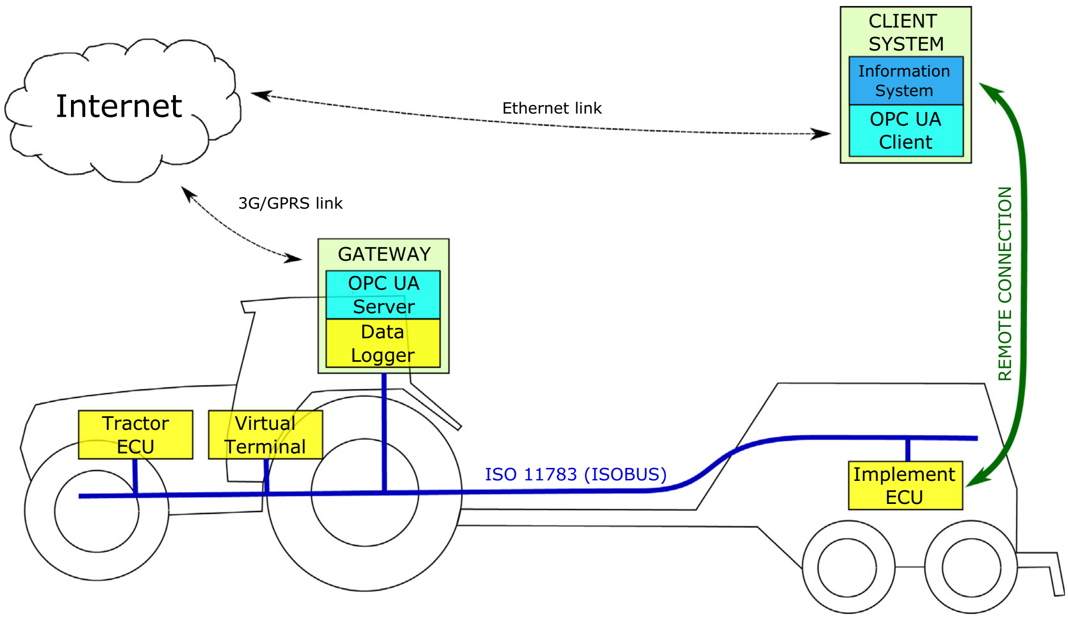

Fig. 1. The scenario under study.

11783. Based on scenario analysis, it was decided to concentrate on the scenario where the managing system of a vehicle fleet follows the vehicle's operation in real-time – or a manager follows where the drivers work. This is a typical telematics application. The fleet may be working solely within a single farm or it may be a company contracting field operations in a region.

2. Telematics application

2.1. Definitions

Process data incorporates various variables in a system that is used for production. In the context of agricultural machinery, the process data means variables like yield rate, application rate, the number of items collected, the number of items planted, fuel consumption, the mix rate of the input dose et cetera. This process data is typically labelled with a time stamp and a geographical position stamp in order to record *when*, *where* and *how much* or *how many*. Typically, the purely mechanical variables of agricultural machinery (for instance, the gear ratio of locomotion) are not considered part of process data, but it is not prohibited to include some of these variables to improve the traceability of production. In the ISO 11783 standard the process data variables are transferred from and to the implement by using Process Data message defined in ISO 11783-10, Annex B (ISO, 2014a).

Remote access allows data exchange between the *client system* and *remote device*, by using wired or wireless communication. The client system may be a standalone device like a PC or it may be an Internet service connecting a remote device. In this article, remote access refers (in most cases) to the scenarios where the mobile agricultural vehicle (the remote device) is working in the field and, by using wireless communication, two-way communication is established in order to exchange process data. Remote access incorporates various features including messaging protocols, authentication, authorization and encryption.

2.2. Telematics application and information management in agriculture

Vehicles and the other parts of the infrastructure of a farm require overall information management. When the ISO 11783 standard protocol was designed, the focus of information management was in integrating the sensors and actuators of manufacturers in a multi-brand system (Stafford, 2000). Currently, Internet technologies are involved more and more in crop farming systems. Concepts trying to cover all management duties are proposed. Nash et al. (2009) studied the actual and potential data-flows in precision agriculture in order to understand the requirements for information systems in agriculture. The analyzed data-flows concentrated on precision agriculture processes and over the operations and, the analysis reveals the potential users for the data. Nikkilä et al. (2010) studied the requirements of Farm Management Information System (known as FMIS) and proposed an architecture based on Web application. FMIS founded on Internet technologies makes it tempting to use the same technologies to interconnect the data sources from the mobile systems as well. Fountas et al. (2015) propose a Farm Machinery Management Information System to handle all information flows of a tractor or an autonomous tractor.

Öhman et al. (2004) presented a concept for the remote maintenance of ISOBUS machines. The prototype used PDA in a tractor cabin with a GPRS connection and it acquired fault indicators from an ISOBUS network. The faults of an ISOBUS implement were identified from various sensors in a seed drill. However, the system was limited on fault diagnostics and indicators, not on accessing the full process data (Miettinen et al., 2006).

Another prototype implementation of a system for transferring process-data from ISOBUS to an external user was proposed by Steinberger et al. (2009). The system does not only cover the data transfer from ISOBUS but also covers analysis and aggregation, which are available for external systems as a web service. In the prototype system, a PDA was used to sync the collected data to a PC, but the authors write that the architecture is not limited to that.

Rusch et al. (2014) presented a telematics system, compatible with ISOBUS. The main idea was to utilize a database of CAN messages to configure the mobile end, to interconnect the vehicle data to the server. The database was converted to program code automatically.

Commercial systems providing telematics services (a.k.a. telemetry) for their vehicles are: AGCO (with AgCommand), John Deer (with JDLink), Claas Telematics, Raven Slingshot and Trimble Connected Farm. These are closed systems for telematics applications. Support for the implements is typically limited to products by the same brand or to commercial partners, like in the Claas Telematics on Implements (TONI) concept.

3. The ISO 11783 standard series

Communication standards to enable data exchange between a tractor and connected implements have been developed since the 1980s (Stone et al., 1999). The current workhorse is the ISO 11783 standard series, which is based on a plug-and-play 250 kbps CAN bus (ISO, 2002). The standard series defines the protocol and the messages as well as the physical layer, but it does not provide good guidelines for applications or devices. The protocol is widely accepted by the industry; the manufacturers using the protocol have established a foundation, AEF, which markets the compatible products with the name ISOBUS. AEF has prepared guidelines to help manufacturers make a common interpretation of the standard series – Task Controller Basic being an example of this (AEF, 2012). The standard has proven its functionality for in-vehicle communication in a modular multi-brand system consisting of a tractor and one or more implements, including auxiliary devices like position based recording, variable rate application and/or section control. Later in this article, ISOBUS and the ISO 11783 network are used as synonyms.

Therefore, the protocol is well established on in-vehicle communication, but vehicle-to-vehicle or vehicle-to-infrastructure communication requirements are not covered by the standard series (except for the XML data file format used for offline data exchange between a farm information system and a vehicle) (ISO, 2014a).

Task Controller (TC) is a communication interface defined in ISO 11783-10 (ISO, 2014a). Task Controller is an standalone device, usually installed in the cabin of the tractor and it is capable of communicating with any ISO 11783 implement, to record and command process data of that. Task Controller is the key component to realize precision agriculture tasks, to command process data site specifically. Recently, ISO 11783 was extended by another interface, known as Data Logger, to supplement the Task Controller interface. In practice, Data Logger is a light version of Task Controller, designed only to record the process data without ability to command anything. Data Logger and Task Controller share the same messaging protocol. Therefore, in the current standard the number of Data Loggers and Task Controllers on the bus is limited to one each. The standard defines only the interface a Data Logger has to realize, not all the functional requirements. Typical applications mentioned in the standard are "telemetry data logger" and "non-task-related data logging" (ISO, 2014a).

One of the concepts related to the protocol is *Device Description Object Pool* (DDOP), that contains a full hierarchical list of the process data available in the implement. This list contains both identifiers to access the data in the network and metadata like text based description. DDOP is transferred in binary representation from the implement to Task Controller or Data Logger in the handshaking phase of communication protocol.

4. OPC Unified Architecture

4.1. Open Platform Communications (OPC)

In industrial automation the need to access production machine data was made possible once digital systems were established. The classical process control works in a way that the process is controlled by Programmable Logic Controllers (PLCs), which are controlling sensors and actuators directly or over a dedicated field bus network. At this level, hard real-time requirements apply as the stability of the process is crucial. On the other hand, the PLCs do not know anything about the production process or material flows at a plant level, not to mention business functions, like production planning. In the 1990s, many of the latter functions were programmed in PCs; it became a de facto standard to make OPC Server – OPC Client communication between these two systems. OLE for Process Control (OPC Classic) uses COM and DCOM data exchange services, and therefore it does not meet all the current requirements of the industry and industrial automation. Currently OPC stands for Open Platform Communications and it is maintained by the OPC Foundation (OPC, 2013).

As the OPC Classic technology is no longer sufficient, the OPC Foundation has prepared the next generation technology to meet the new requirements. The new technology is called *OPC UA*, which now stands for *OPC Unified Architecture*. The core features are: (a) information modeling that enables rich semantics, (b) service oriented architecture that is based on open protocols and (c) a security model which enables secure point-to-point communication. Like OPC Classic, OPC UA relies on client–server architecture.

As OPC Classic was only able to work within the same network segment, and without too much security, it was not designed for true remote access. As OPC UA supports standard Internet protocols and secure communication channels, it is tempting to try to use it beyond the classic industrial automation applications.

For data access, OPC UA provides three means: read, write or subscribe. Both *Read* and *Write* are single operations while *Subscribe* enables data streaming from the server to the client with a requested refresh rate.

4.2. Remote access with OPC UA technology

The research related to OPC UA has mainly focused on the design and evaluation of the applications of OPC UA in different application domains, while the development of the standard itself (IEC, 2010a) has taken place as an industry lead activity. Until now the most studied application area for OPC UA may have been industrial automation. However, other branches of automation have also gained attention, for example, building automation and so-called Smart Grid. Regardless of the application domain a common objective in the research has been to utilize OPC UA for connecting devices to information systems in a way that increases the performance of applications (Girbea et al., 2014) and is adaptive to the configuration changes of devices (Durkop et al., 2013). In order to achieve this objective, particular attention has been paid to the development of OPC UA server applications. For example, servers have been implemented to different hardware, including hardware with very limited resources (Imtiaz and Jasperneite, 2013). Information models that expose necessary information from the underlying automation systems to clients has been designed by applying previously existing standards (Melik-Merkumians et al., 2012; Claassen et al., 2011; Fernbach et al., 2011; FDI, 2014). A few of these were built as extensions to a generic Device Information Model defined by the OPC Foundation (OPC Foundation, 2013). Furthermore, information models derived from *OPC UA for Devices* exist, for instance models for PLCs or Analyser Devices.

5. Requirements for remote access of ISO 11783 implement

Requirements are set by the application (by telematics), the in-vehicle communication standard (ISO 11783 series) and practical aspects.

For remote access, the first requirement is that the remote device needs to be accessible anywhere within operational range. For a single farm this range may be in the range of tens of kilometres but for contracting operations the region may extend to hundreds of kilometres. This requirement rules out local wireless communication links.

In mobile networks, the data plan typically consists of the maximum cumulative data in a month and an additional maximum momentary data rate. Which plan is affordable depends on region and time. In Finland, currently, an affordable 3G data plan is considered to be 5 GB/month. By estimating that the total operational time of a single vehicle in a month is calculated at 8 h/day and assuming that there are 20 operational days in a month (resulting in 160 operational hours a month), this leads to maximum constant allowed gross data rate of 8 kbps. This calculation shows that broadcasting all CAN bus traffic is not an option.

In a real-time application, as in telematics (a.k.a. telemetry), the requirement of the maximum time delay, or latency, is raised. Latency is related to the data refresh rate, or the information update frequency, and a design where latency exceeds the data refresh rate should be avoided (unless the link is exceptionally long). The real requirement of the refresh rate and latency depend heavily on management functionality, but in this study we select relatively strict values to show the potential. Nielsen (1994) defines up to three levels of response time limits for responsive user interfaces: 0.1 s is the limit for the user to feel like there is an instantaneous reaction, 1.0 s is the limit for uninterrupted thought and 10 s is the limit for when the user will want to start doing other things. In agricultural telematics, AGCO Corporation (2014) reports the maximum frequency of the data recording rate to be once every 10 s, but the data is not transmitted more often than once every 10 min. From this data, we set the requirement for a data refresh every 10 s for mobile communication.

The basic requirement of ISO 11783 is that the components of the vehicle may be produced by different manufacturers and the end user must be able to act as an integrator of the system – the plug-and-play requirements come from this. In our scenario, the vehicle is a multi-brand system, where the tractor, implement, virtual terminal, task controller and our prototype data logger are all made against to the standard alone, not against to each other.

6. System architecture

As indicated above, in the system design two main communication channels drive the system design: (a) ISO 11783 is the in-vehicle network and only the standard functions may be utilized and (b) OPC UA defines the communication protocol but leaves the information model open. However, ISO 11783-10 (ISO, 2014a) is defining a DDOP model for implementing process data, so on that side the structure is fixed but highly dynamic (each implement is different but the structure of the implement is reachable).

As required, the system must work in a plug-and-play manner in an ISO 11783 network. The only option for doing this is by utilizing the new Data Logger connection.

The nature of the telematics application is to access the device remotely. Therefore, we set the OPC UA Server in the vehicle (the remote device) and the OPC UA Client is located on the host side.

Hence, in order to support the remote access of the ISO 11783 implement process data using OPC UA, the device needs to be installed in a vehicle which contains: (a) ISO 11783 Data Logger functionality, (b) OPC UA Server functionality and (c) a mobile network connection.

From the communication point of view, this device is a gateway, relying on standards and standard interfaces. The system architecture is presented in Fig. 1.

7. The information model

In OPC UA, the information which is communicated in an OPC UA connection is defined by the Address Space Model (IEC, 2010b). This model consists of Nodes that have Attributes. Furthermore, the Nodes have relations that are called References. The Nodes may also be categorized to groups, e.g. Objects, Variables or their respective types.

The purpose of the OPC UA information model is to present the data of the process in a structured way. The information models use Nodes to present the hierarchy of a specific system, as well as the connections in the network. Some OPC UA information models are prepared for specific needs, for instance *OPC UA for Devices* is an information model for devices used in industrial automation systems, defining protocol busses, topologies and version management. The information model enables easier interchangeability of the device in installation and maintenance.

The ISO 11783-7 (ISO, 2007) defines basic messages for tractor–implement communication. These messages are not dynamic, or the same signal on the bus always represents the same process variable and unit. Examples of such are rear hitch level or ground based speed of the tractor measured with a radar. The same applies to GPS signals, originating from a GPS receiver and transmitted in the ISO 11783 network. These signals are taken into account in our information model. As in every vehicle and in every power-up the signals on the bus are the same, it is relatively easy task to add these variables to the Gateway.

The ISO 11783-10 (2014) DDOP defines a hierarchical data model for the process data in a particular implement controller. There are no standardized DDOP profiles for any type of implement class, but a manufacturer of the implement may design the hierarchy. AEF guidelines cover a few common implement types by giving examples how a DDOP may be constructed but they are more like samples instead of a pattern or schema. In comparison with the basic messages discussed above, DDOP represents a dynamic part of ISOBUS messaging, as the structure is not known before plug-in.

A DDOP contains up to five element types: (a) Device, having at least one Device Element containing e.g. a version of the software and a designator for the implement; (b) A Device Element, representing a functional or physical element of the device (e.g. a bin or a section or a connector); (c) Device Process Data, representing the process data of the Device Element, e.g. the application rate (including e.g. the unit and designator); (d) Device Property, similar to Device Process Data but it is a constant value, e.g. the working width; (e) The Device Value Presentation, provides offset and scaling, and the unit in conversion (from raw data to the scaled value) that is to be used in an HMI device. Their relations are presented in Fig. 2.

The conversion from a DDOP to an OPC UA information model is a transformation between two different approaches to modeling data. The target is an OPC UA information model for ISO 11783 devices, which not only conforms to the data modeling approach of OPC UA but also contains a useful structure and harmonized data types. It was decided to use the OPC UA for Devices information model as a basis, because it is intended as a generic base information model for devices and provides object types useful for this application. Due to this design decision the transformation is not only about representing a DDOP in terms of the OPC UA address space but also in terms of the definitions of OPC UA for Devices.

Two object types derived from the OPC UA for Devices for modeling ISO 11783 devices are particularly important: ISOBUS Device Type and ISOBUS Device Element Type (see Fig. 3). The data is included in objects of these types as Data Variables (with type of BaseDataVariable) in Parameter Set. Hence, the device is converted into an object with the type of ISOBUS Device Type. Device Elements in a DDOP are converted to objects with the type ISOBUS Device Element Type and the References are used to create references to other Device Elements, as defined in the DDOP. The Device Process Data and Device Property of the DDOP are encoded

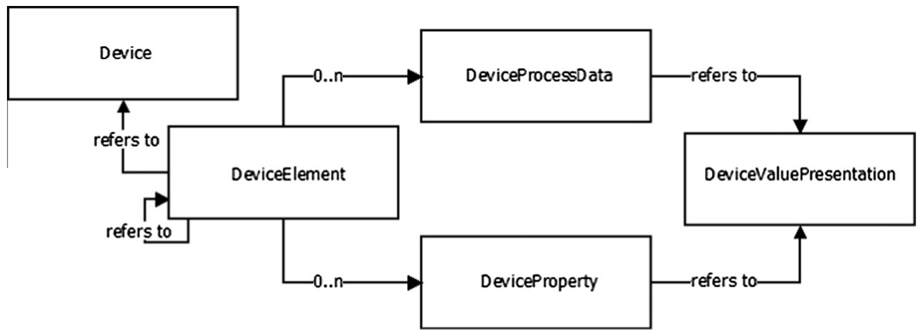

Fig. 2. DDOP object hierarchy in ISO 11783 (adapted from ISO 11783-10, 2014).

into Data Variables. The Device Value Presentation is not utilized in conversion as the same information is available in the ISOBUS Data Dictionary or ISO 11783-11 (ISO, 2014b).

An additional designed feature besides the hierarchy received from the DDOP is Functional Group Type, which is adopted from the OPC UA for Devices information model and derives its content from the ISOBUS Data Dictionary. The Functional Group Type defines whether the variable is controlled, minimum set, maximum set, default value or measured value. The purpose of the Functional Group Type is to provide a useful structure to the representation of the devices and thus help the developers of the OPC UA Client applications to find the appropriate variables easily.

The harmonization of data types in the information model is achieved through the data types used in the Data Variables (see Fig. 4). These data types are used in the OPC UA information model regardless of the original types in the DDOP. The ISOBUS Data Dictionary is used to convert the raw value received from the ISO 11783 network to the harmonized values, thus the developer of OPC UA Client does not have to know or care about the raw values.

Fig. 5 presents the workflow in the communication as a sequence diagram. The OPC UA Server is instantiated after ISO 11783 communication is established completely. The object and data types applicable to all ISO 11783 devices are stored at the OPC UA server in advance. The objects representing the connected device are created during the instantiation process. Data transfer from the OPC UA server starts only after a read or subscription request from a client.

8. Results

8.1. The test setup for performance

The system was evaluated with a Valtra T163eV tractor, a Junkkari Maestro 4000 seed drill and Garmin 19x NMEA2000 GPS receiver. The tractor was equipped with an AGCO C1000 Virtual Terminal, which was used to control the seed drill functions during drive time. In benchmarking the OPC UA link performance, only the process data of the tractor and GPS receiver on the bus were recorded. The test was done in southern Finland, in the summer of 2014. The test revealed the performance of the data transfer of the OPC UA Server application, as well as cumulative data.

In the test, up to 14 process data variables were set to be transferred over the OPC UA connection. The original update rate of those variables on an ISO 11783 network was from 100 ms to 1000 ms. Eight of the process variables were originating from GPS receiver (latitude, longitude, course, speed and quality indicators) and six from TECU (ground and wheel based speed, ground and wheel based distance, direction and hitch).

The server was running on an Intel NUC DCCP847DYE mini-PC with Win7 and the mobile network connection was established with 3G HSPA + USB-dongle equipped with an external antenna that was placed outside the tractor. The client system (a laptop running Win7) was connected to the Internet by an ADSL connection, accessed through an IEEE 802.11n wireless network.

8.2. The latency experiment

Response time is defined as the delay between when a process data variable value changes and when the change is detected by a client, over the system. The upper limit for the response time was identified by the following setup: the latency of the OPC UA connection is identified by the OPC UA Read service call, which uses a request–response pattern, so the latency is present in both directions. This was repeated 100 times by using UaExpert Performance View tool in a host computer. Table 1 shows the measured times, in various configurations. In the *localhost* test, the client system and the remote device were the same, so only the latency caused by the software is present. In the *LAN* test, the client system and

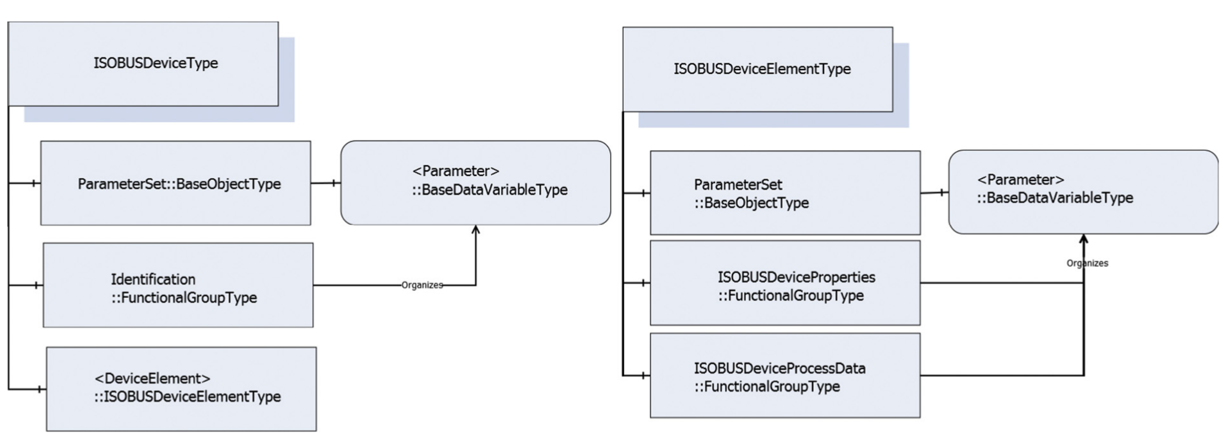

Fig. 3. Essential object types of the information model: the ISOBUS Device Type and the ISOBUS Device Element Type.

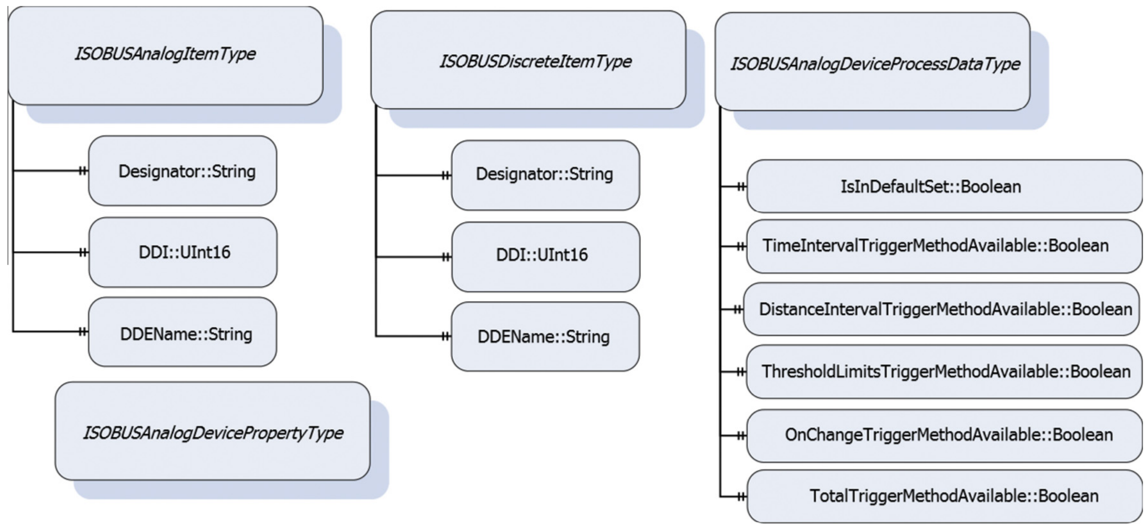

Fig. 4. Essential variable types of the information model.

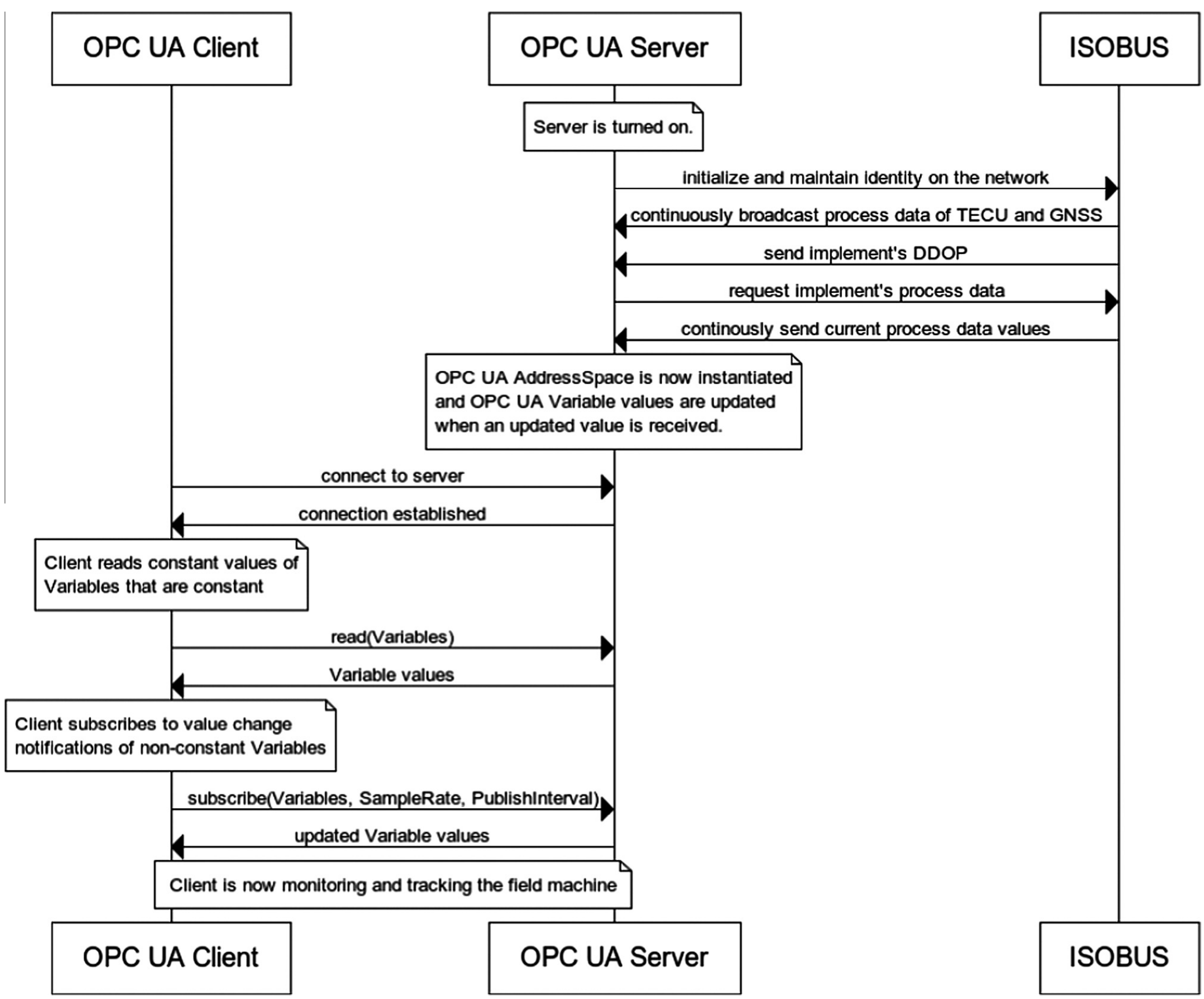

Fig. 5. Sequence diagram presenting the main interactions for remote access.

Table 1
Latency measurements.

Latency experiment	Measured time			
	Average (ms)	Minimum (ms)	Maximum (ms)	Sample standard deviation (ms)
Read call over 3G	96.0	68.7	355.4	41.7
Read call over LAN	1.5	1.1	12.3	–
Read call from local host	1.4	1.0	6.1	–
Ping 8.8.8.8 (a public DNS server)	41.8	34.0	128.0	12.3

remote device were connected with a wired connection. The results show that most of the latency is caused by the 3G mobile network link.

8.3. The real-time telematics experiment

In this test, the motivation was to study how large a bandwidth is required in real-life. This test revealed the gross data rate of the communication in the OPC UA connection. In the test, the same set of variables was subscribed to be transported over the OPC UA connection, as above. Each test took 15 min; the vehicle was moving in a field. The test was repeated using six different sample rates and refresh rates. Two similar tests were made where the vehicle was stationary during the 15 min period.

The statistics are presented in Table 2. As expected, the cumulative data from the remote to client system exceeds the data in the other direction as we are transferring payload data from a remote direction to the client direction, but the test reveals that the outgoing data rate is significant. The nominal payload column presents the theoretical payload of the variables used in the tests; with a small refresh rate, the overhead of the protocol is relatively small, but when the refresh rate is increased, the ratio becomes worse.

From the measurements it is possible to estimate the monthly transfer rates. With 160 operational hours in a month the refresh rate of 100 ms results in 0.58 GB and the refresh rate of 5000 ms results in 0.06 GB.

9. Discussion

The performance test was carried out with the process data of the tractor and GPS receiver. The results show that OPC UA link is suitable for mobile telematics application purposes. It seems that OPC UA link does not cause remarkable additional latency or overhead for data transfer rate.

The concept of DDOP was created by ISO to support any kind of implements that contain very different process data variables, units and hierarchical structure. Dynamic behavior of DDOP sets challenges for telemetry application as the system developer cannot make any assumptions and the process data variables are not known before a farmer connects the implement to the tractor. However, OPC UA was proven to support the dynamic behavior well, which makes OPC UA a prominent choice to access dynamic ISOBUS data remotely.

Table 2
Statistics of experiments.

Experiment	Refresh rate (ms)	Vehicle moving	Total, from client (KB)	Total, from remote (KB)	Nominal payload (KB)	Average in + out rate (KB)
#1	50	yes	1592	3153	1944	5.27
#2	100	yes	958	2291	972	3.61
#3	500	yes	226	558	194.4	0.87
#4	500	no	263	410	194.4	0.75
#5	2000	yes	129	231	48.6	0.40
#6	5000	yes	102	150	19.44	0.28
#7	5000	no	122	153	19.44	0.31
#8	15000	yes	78.8	93.2	6.48	0.19

Unfortunately, ISO 11783 is an evolving standard series. New parts or new editions for the existing parts are released every year. AEF has prepared guidelines that fix certain editions of the ISO standards to form functionalities and generations of them, but this does not guarantee intercompatibility at system level if generations of every component of the system are not equal. For instance, a functional system with Task Controller and Implement ECU may lose functionality after plugging in the new Data Logger. We faced this situation in the field, as the new edition of ISO 11783-10 requires an implement to support two Task Controller connections at the same time, but the implement that was used was programmed according the previous edition and therefore parallel operation of Task Controller and Data Logger was not functional.

ISO 11783 defines a Data Logger interface to record non-task-related process data like described in the standard. The interface was founded on the Task Controller protocol which provides more functionality, to support site specific farming et cetera. Therefore, software implementation of Data Logger interface is not as simple as the functionality would suggest (listen only). Two-way communication needs to be realized even if the data flow is one-way only. On the other hand, if one is familiar with Task Controller protocol, adapting that to Data Logger is simple.

10. Conclusions

The selected system architecture was designed to: (a) rely on the ISO 11783 Data Logger function besides basic ISO 11783 messaging and (b) set up an OPC UA server in the remote device. The results show that the selected architecture was proved feasible.

The benefit of using OPC UA is to present the data for remote access in structured and harmonized way, not only as a list of raw variables. The OPC UA for Devices information model was selected as the base for the information model for ISOBUS Process Data. OPC UA information modelling was made by taking the structural model from ISO 11783 Part 10, which defines DDOP elements. However, the structure is not static, rather, it is highly dynamic; each implement manufacturer is creating a DDOP for their machine according to the physical and/or functional realization, and it is unlikely that two manufacturers would have the same hierarchy and elements, even if the machines were similar.

The designed information model is suitable for representing the information available through ISO 11783 Data Logger functionality, using a DDOP. A design to automatically generate OPC UA server object instances from the ISO 11783 implement DDOP was piloted. The approach was proven functional; it is possible to convert a DDOP to an OPC UA model.

The performance and overhead of an OPC UA protocol for remote access was measured. The cumulative data transferred reveals that the overhead of the protocol is relatively small. The small overhead is crucial to keep the data transfer cost low and the small latency supports real-time telemetry applications.

Acknowledgments

This project was part of the project CLAFIS. The research leading to these results has received funding from the European Community's Seventh Framework Programme (FP7/2007-2013) under Grant agreement no. 604659.

References

AEF, 2012. AEF Guideline Implementation Specication Functionality TC-BAS, AEF Guideline TC-BAS V1.0. Agricultural Industry Electronics Foundation.

AGCO Corporation, 2014. AgCommand Standard and Standard Plus Product Guide v.1.1. <http://www.chandlersfe.co.uk/AGCOMMAND_Product_Guide.pdf> (accessed 10.08.2015).

Claassen, A., Rohjans, S., Lehnhoff, S., 2011. Application of the OPC UA for the Smart Grid. In: Proceedings of the 2nd IEEE PES International Conferenece and Exhibition of Innovative Smart Grid Technologies, ISGT Europe, Manchester, UK, pp. 1–8.

Durkop, L., Imtiaz, J., Trsek, H., Wisniewski, L., Jasperneite, J., 2013. Using OPC-UA for the Autoconfiguration of Real-time Ethernet Systems. In: Proceedings of the 11th IEEE International Conference on Industrial Informatics, INDIN, Bochum, Germany, pp. 248–253.

FDI Cooperation, 2014. FDI Technical Specification – Part 1: Overview, FDI-2021, Version 1.0.

Fernbach, A., Granzer, W., Kastner, W., 2011. Interoperability at the management level of building automation systems: a case study for BACnet and OPC UA. In: Proceedings of the 16th IEEE International Conceference on Energing Technologies and Factory Automation, ETFA, Toulouse, France, pp. 1–8.

Fountas, S., Sorensen, C.G., Tsiropoulos, Z., Cavalaris, C., Liakos, V., Gemtos, T., 2015. Farm machinery management information system. Comput. Electron. Agr. 110, 131–138.

Girbea, A., Suciu, C., Nechifor, S., Sisak, F., 2014. Design and implementation of a service-oriented architecture for the optimization of industrial applications. IEEE Trans. Industr. Inf. 10 (1), 185–196.

IEC, 2010a. OPC Unified Architecture – Part 1: Overview and Concepts, IEC/TR 62541-1 ed1.0.

IEC, 2010b. OPC Unified Architecture – Part 3: Address Space Model, IEC/TR 62541-3 ed1.0.

Imtiaz, J., Jasperneite, J., 2013. Scalability of OPC-UA down to the chip level enables "Internet of Things". In: Proceedings of the 11th IEEE International Conference on Industrial Informatics, INDIN, Bochum, Germany, pp. 500–505.

ISO, 2002. Tractors and Machinery for Agriculture and Forestry – Serial control and Communications Data Network – Part 2: Physical layer, ISO 11783–2:2002(E). International Organization for Standardization, Geneva, Switzerland, 2002.

ISO, 2007. Tractors and Machinery for Agriculture and Forestry – Serial control and Communications Data Network – Part 7: Implement Messages Application Layer, ISO 11783–7:2009(E), second ed. International Organization for Standardization, Geneva, Switzerland, 2007.

ISO, 2014a. Tractors and machinery for agriculture and forestry – serial control and communications data network – Part 10: Task controller and management information system data interchange, ISO/FDIS 11783-10:2014, International Organization for Standardization, Geneva, Switzerland, 2014. 207p.

ISO, 2014b. Snap-shot of the iso 11783-11 online data base, ISO 11783-11, International Organization for Standardization, Geneva, Switzerland, 2014.

Melik-Merkumians, M., Baier, T., Steinegger, M., Lepuschitz, W., Hegny, I., Zoitl, A., 2012. Towards OPC UA as portable SOA middleware between control software and external added value applications. In: Proceedings of the 17th IEEE International Conceference on Energing Technologies and Factory Automation, ETFA, Krakow, Poland, pp. 1–8.

Miettinen, M., Oksanen, T., Öhman, M., Suomi, P., Visala, A., 2006. Fault diagnostics in agricultural machines. In: Proceedings of the Automation Technology for Offroad Equipment, Bonn, Germany.

Nash, E., Dreger, F., Schwarz, J., Bill, R., Werner, A., 2009. Development of a model of data-flows for precision agriculture based on a collaborative research project. Comput. Electron. Agr. 66, 25–37.

Nielsen, J., 1994. Usability Engineering. Elsevier.

Nikkilä, R., Seilonen, R., Koskinen, K., 2010. Software architecture for farm management information systems in precision agriculture. Comput. Electron. Agr. 70, 328–336.

Öhman, M., Oksanen, T., Miettinen, M., Visala A., 2004. Remote maintenance of agricultural machines. Proceedings of the 1st IFAC Symposium on Telematics Applications in Automation and Robotics, Helsinki, Finland.

OPC Foundation, 2013. OPC Unified Architecture for Devices Companion Specification, Release 1.01.

Rusch, C., Horster, B., Grossman, U., Gansemer, S., 2014. M2M-teledesk – manufacturer independent telemetry system solution for agriculture. In: 71st International Conference on Agricultural Engineering, Hannover, Germany.

Stafford, J.V., 2000. Implementing precision agriculture in the 21st century. J. Agric. Eng. Res. 76 (3), 267–275.

Steinberger, G., Rothmund, M., Auernhammer, H., 2009. Mobile farm equipment as a data source in an agricultural service architecture. Comput. Electron. Agr. 65 (2), 238–246.

Stone, M.L., McKee, K.D., Formwalt, C., Benneweis, R., 1999. ISO 11783: An electronic communications protocol for agricultural equipment. American Society of Engineers.