Towards a Traceability Solution in the Canadian Forest Sector

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Abstract: *Radio Frequency Identification (RFID) is an enabling technology that promises to create value through greater visibility in the forestry wood value chain network, higher product velocity, more efficient transportation management and improved quality control. However, it is still not clear how these objectives can be fully achieved. In this paper, we propose an ICT framework called "FTrace" for implementing a traceability system in the forestry wood supply chain based on Internet of things concept. Internet of things uses RFID technology to connecting objects. In the forest sector case object is wood and any product based on wood after transformation. FTrace will help some specific partners in the value chain to track the origin of wood, control information of raw material utilization, trace production progress and track the transportation process. FTrace solution increase collaboration between the different supply chain actors through tracing the business processes execution, orchestrating different providers, integrating the different IT application used throughout the wood process and offer a scalable traceability system. The proposed architecture will also provide managers with meaningful information allowing them to track and trace wood at different process stages (cutting tree, collecting wood, production, sales, etc.) to achieve a more competitive advantage. FTrace is tested in the Canadian forestry context.*

Keywords: *Internet of things, Traceability, RFID, Forest Supply Chain.*

1 Introduction

In forestry, the wood is treated generally as raw materials and it is graded at the final stages of production. Significant savings can be achieved if the right quantity, type, and quality of wood are available for the final product that is best adapted for so that unnecessary decommissioning is minimized and the yield of the desired product is maximized. Better overall control of the information and material flows might optimize the efficiency of production in the forestry network and minimize environmental impact [1]. The key for implementing this control is the identification and traceability of the wood products through the value chain. As an example, the Chain of Custody (CoC) certification for forest and wood products ensures that the forestry and

wood products come from certified, well-managed forests and their authenticity as they travel through the supply chain from processing to the customer. According to the International Organization for Standardization (ISO), in the ISO 9000-2005 standard [2], traceability is defined as "the ability to trace the history, application or location of that which is under consideration". From product identification, we are able to trace some important data related to this product. Several technologies have been used for tracking wood. They include conventional and special paint markings smart cards, barcode tags, and Radio Frequency Identification (RFID) tags. RFID technology has a number of advantages when compared to the other marking methods in the forestry: line of sight is not needed, the reading can be done over a distance allowing highly automated identification, the transponders are not sensitive to dirt or moisture, and there are a large number of unique identification codes or memory for coded data. In addition, [3] stated that RFID could be the best tool for the identification of wood.
Although RFID is an enabling technology that promises to create value through greater visibility in the forestry wood value chain network, higher product velocity, more efficient transportation management, improved quality control, and reduced human error; it is still not clear how these objectives can be fully achieved. Moreover, there is still no consensus on how the information system should be developed to address with success the basic traceability issues in the forest sector. To better understand and validate the potential use of RFID technology in this sector, more recently some research projects have been made in relation with the use Information and Communication Technology (ICT) systems to enhance forestry traceability. The Indisputable Key project [4] is one of these initiatives. They propose an ICT system for data collection from different providers in the value chain in order to offer an efficient supply chain management [5]. However, the proposed architecture is unable to capture a dynamic process management. In fact, they don't clearly specify how adding new actors (providers) is possible in the system after the operation of the forestry supply chain. Another important initiative is the "Seamless Operation of Forest Industry Application" (SOFIA). SOFIA is a platform that optimizes contractors order logistic management and developed in the forestry sector in Finland [12]. It's an innovative proposal of ICT solution for forestry, but it remains preparatory project and there is no validation proof of this platform in industry.

In this paper we propose an extensible ICT framework called "FTrace" that offers a dynamic process management and a unified data communication for tradable information through the forestry supply chain providers that enhance traceability. FTrace support Internet of things concept by using RFID technology to collect information about wood products. This architecture helps some specific partners in the value chain to track the origin of wood, control information of raw material utilization, trace transformation and production progress and track the transportation process. The proposed architecture will also provide managers with meaningful information allowing them to track and trace wood at different process stages (cutting tree, collecting wood, production, sales, etc.) to achieve a more competitive advantage. The proposed solution is tested in the Canadian forestry context and demonstrates the additional value of creating a sustainable wood value chain. The remaining of this paper is organized as follows. In section 2, we introduce the research problem. In section 3, related works are discussed. Proposed approach and a real time tracking architecture is put forth and discussed in details in section 4. Conclusion and future works are presented in section 5.

2 Problem Description

The forestry wood supply chain considered in this paper is illustrated in Figure 1. This figure show the different stages in the wood production process, starting from the extraction of the forest raw material and finishing by sale to a consumer [6]. In addition, for simplification purposes, the proposed wood supply chain is composed of four types of providers: Harvest Units, Log Sort Yards, Sawmills and Retailers. To extract the raw material from the forest, the tree is felled and cut to logs by a "Harvester". A "Distribution agent" transfers the logs to the "Log Sort Yard" to collect wood. Thereafter, the logs are transported to the Sawmill. In the "Sawmill", logs are sawn, drying, sorted, finished and then transported to the retailer for sale to Clients.

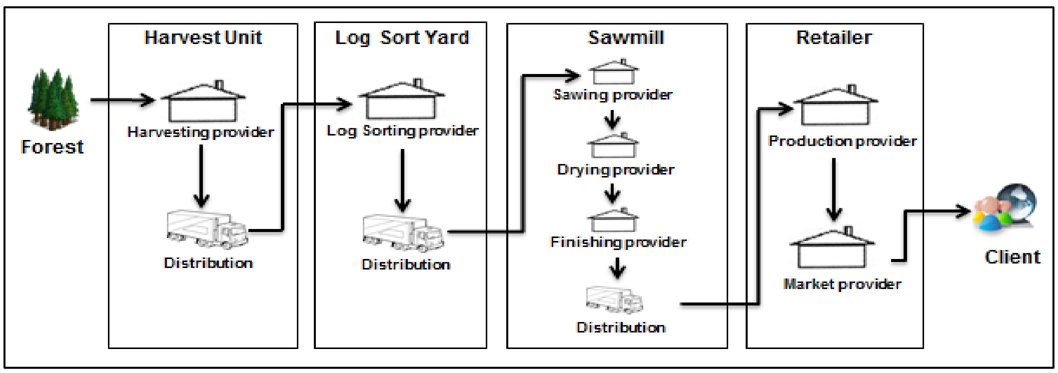


Figure 1: Forestry wood supply chain

The forestry wood supply chain is a complex process. In fact, each provider involved in the wood supply chain can take independent decisions. Moreover, wood characteristics and some specific measurements collected at each step of the wood chain process are diverse. The heterogeneity of information lead to some synchronization issues regarding the information exchanged between partners. Based on an extensive literature review, we can assume that it's a big challenge to make the connection between the information exchanged between partners and have reliable information that meets the customer's needs. Traceability and identification of assets can be a solution to this [1, 6-8]. Traceability in the supply chain presents a clear potential that might help to ensure quality control and legality of the product. It is used in different manufacturing and services applications such as Apparel, Consumer packaged goods (CPG), healthcare, logistics, Manufacturing, Defense, Pharmaceutical, etc. Different standards and norms have been developed in different areas to ensure reliable traceability systems such as the global traceability standard for healthcare used in the medical sector [9], ISO 22005 feed and food traceability standard [10] and the JIS (JISx0510) to track car components in Toyota plants [11], etc.

Although the literature about traceability based on RFID is well developed in different industrial applications [12-16], we are not able to find a clear and well-defined traceability standard or a framework for its implementation in the forest sector. This is why we should define and clarify the traceability concept in the forest sector. Indeed we have to establish the basic requirements for a traceability system in the forest sector. These requirements include wood identification, definition of traded information structure and availability of this information among forestry stages.

To achieve this objective, the challenge is to define a generic ICT traceability system to manage information exchange between partners. The new system will ensure interoperability between partners and communicate reliable information to the traceability system for a dynamic process execution. The new system should provide a dynamic and generic platform with a unified data communication between different providers involved in the traceability process. Thus, the main objective of this study is to discuss a visionary approach and develop a generic and interoperability traceability platform in order to track forest wood during its operation, transportation, processing and in its distribution chain, from the forest to the final consumer. This platform creates an information link between the final wood-based product and the forest from which the woods was collected and answer the following questions: How to exchange information? What kind of information that should be exchanged? And how we can ensure interoperability among partner's systems?

3 Related work

Traceability is essential to increase the value of supply chain operations. There are several traceability definitions in the literature. For example, in [17], the author defined traceability as the tracking of dynamic interactions between process and objects. Moreover, traceability provides means to verify the chain of custody and the origin of the timber [1]. [6] defined traceability as a process of systematic practice and information traded among different providers in the chain to be able to preserve the product identity and its origin. [7] cited that traceability is the way by which we can make information available at different stages along the forestry-wood production chain. Finally, GS1 defines traceability as the ability to trace the history, application or location of that which is under consideration [18].

Traceability is important for many reasons such as wood value chain maximization [19]. It increases the end product quality by optimal use of resources when allocate the right raw material for the right final product [20]. [1, 17] state that traceability improves control during the wood processes in the supply chain by providing the accurate and complete information about the wood origin. Indeed, traceability minimizes waste and environmental impact while increasing profitability and earnings [1, 7, 20]. In [21], the use of a simulation model to analyze improvements by collecting reliable traceability data throughout all wood value chain demonstrate the importance of traceability. From the previous research, it is clear that traceability definition might be different and context dependent.

Thus, in this research we define traceability as following: "Traceability can be defined as the monitoring of traded information between processes and wood from their origin to their destination". More specifically, to locate a product, we must link information and wood movements though the forestry supply chain from origin to destination to be traced back. Implementing traceability in the forestry value chain requires that several technologies are combined and integrated to operate as a system [20]. ICT traceability system is the core of traceability concept. Movement detection of each product in different process stage requires the implementation of ICT architecture to collect reliable information. In the literature, we can find different models to implement an ICT architecture in different type of supply chain [13] such as freight transportation networks [22], food chain [23, 24], and bulk grain supply chain [25]. For example, a framework of traceability called Traceability for Complex Systems (TraCS) proposed by [26]. This approach applies heterogeneous techniques to integrate an extensible traceability framework. Nevertheless, they provide a poor integration with users because they must make these decisions themselves throughout traceability process. TraCS is tested in an example drawn from a system to control chemical reactions at a catalyst plant. In [25], the authors present a traceability system in the bulk grain supply chain. They use the Extensible Markup Language (XML) for information exchange (e-information) and a relational database for data management. By using XML and a relational database, the author simplify the traceability concept, but this is not enough to offer an extensible and interoperable traceability system.

The ICT penetration in the forest sector is still very low [5]. SOFIA is one of the platforms that optimize contractors order logistic management developed for the forestry sector in Finland [12]. It ensures a sustainable ICT infrastructure for forestry operations. The SOFIA platform integrates several technologies including Service-Oriented Architecture (SOA), agent technologies and the Semantic Web for allowing integration and interoperability. It's an innovative proposal of ICT solution for forestry, but it remains preparatory project and there is no validation proof of this platform in industry. In [6], the authors proposed a forestry traceability model and they present basic requirements to manage information of the wood supply chain from the Amazon Forest. They use SOA to manage traceability. The Indisputable Key project develop an ICT traceability system to manage forestry supply chain based on RFID identification [4]. However they don't take into consideration the dynamic and the interoperability aspects in the proposed traceability system.

To create an efficient ICT traceability system in the Canadian forest sector, we identified some basic requirements inspired from the previous projects and from collaboration with our research partner. Thus, the traceability requirements are composed of three basic elements:

- **Provider's (type) identification**: For an effective traceability system, we have to identify production process stage in forestry supply chain and type of generic actors whose product goes through. The proposed wood supply chain is composed of four types of providers: Harvest Units, Log Sort Yards, Sawmills and Retailers.
- **Product identification**: Product identification is required in traceability to make reliable information available about different process stages. Automated identification in forestry eliminates multiple measurements needs and repeated inventories of wood [1]. We can find a variety of labeling technologies for wood identification such as conventional paint

and chisel labels, hammer branding, tracer paints, barcode tags, chemical and genetic fingerprinting and RFID [27]. Many previous researches affirm that RFID is the most appropriate to be used for wood identification in forestry [1, 6, 27, 28]. Indeed [19] claimed that RFID could be a good candidate to replace marking stamps, at the same time as possibly enabling the transfer of valuable information in the logistic chain of the forest industry. So, the ICT system should be able to handle different labeling technologies.

- **Communication information standard**: The third traceability required is the communication standard. It is a set of standard information that specifies product information exchange with the different supply chain partners. Examples of communication standards in forestry sector are eFIDS, GS1, StanForD and Papinet. eFIDS (e-Forestry Industry Data Standards) is a metadata standard for traded information within forestry industry. It is based on no named exchanged XML documents among supply chain which leads to a conflict of documents. The GS1 provides traceable data matrix that depends on product types and contractual relationship, and it's divided in public and private information [18]. StanForD (Standard for Forest machine Data and Communication) is used to control harvesting as well as monitoring the production of harvesters and forwarders [29], and it's used in Indisputable KEY project. PapiNet standard is an open standard that anyone can contribute to [30]. It supports the forest industry business areas. StanForD and PapiNet use XML technology to represent the information. These standards will remain independent but each one could support the other. However PapiNet standard is used for exchanged information between providers or StanForD used into the forest for sending information from harvesters and forwarders to the first receiver of data. PapiNet and StanForD represent two complementary standards. In our project, we combine these standards presented in section 4 for defining a global communication standard.

4 Traceability Proposed System

4.1 Forestry information system

In this article, we propose an ICT forest traceability system called "FTrace". FTrace is developed to collect information from forestry supply chain providers, and then use it effectively in order to trace wood material throughout the supply chain. The system offers also the possibility to understand, evaluate the forest value chain and take the right decisions. This system is composed of three modules (see Figure 2):

- Module 1: Traceability business processes.
- Module 2: Business application.
- Module 3: Web portal.

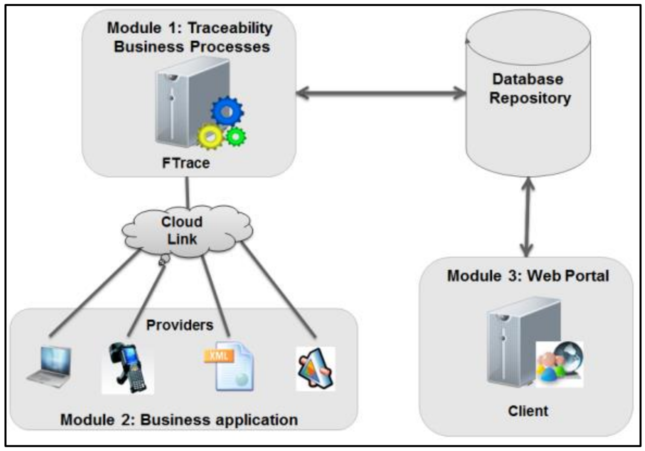


Figure 2: FTrace Information and Communication System

The “Traceability Business Processes” module includes the most important parts of the FTrace information system like the FTrace server that manage the traceability activities of the different supply chain processes. FTrace server connects with business application module through a cloud connection for recording activities and collects information from supply chain providers. Information recorded is stored in a database for finally showing traceability information needs to client in web portal. In order to allow a transparent traceability between providers, it is necessary to provide information on all internal transformations of each provider’s system. FTrace allows interoperability and integration with existing provider systems. FTrace can connect with different types of ICT provider system (web service, barcode, RFID reader, XML file…). In the following section we will describe the FTrace ICT architecture components.

4.2 FTrace ICT architecture

FTrace allow interoperability between providers and information system. It can connect different types of technologies (service, RFID, XML file, etc.). Figure 3 presents in details the FTrace architecture for the proposed solution. FTrace architecture is composed of the following components:

- Application layer: this component describes the business applications used by each provider (partner). This layer communicates with other FTrace components in order to collect traceability informations. We can define two methods for collected data: real time data extraction (using BizTalk) or Batch data extraction with ETL. Indeed FTrace can connect to provider’s business applications with different adapter’s type (web service, barcode, RFID…) for real time information extraction, or connecting to provider’s internal database for batch extraction.
- Data Extraction Layer: this layer helps the integration of each provider in FTrace architecture. FTrace offer two data integration methods, batch extraction and real time extraction:
    - ETL: Extract-Transform-Load is a process to pull data out of one source systems (files, database, etc.) and place it into another database by following data extraction logic. The role of ETL in FTrace is to extract data from internal database of each provider in supply chain into FTrace database repository.

    - Orchestration Layer: this layer orchestrates and share data between providers. Indeed this layer feeds database with traceability information collected throughout forestry supply chain process. This layer enables a flexible and generic provider addition in the forestry supply chain. Each provider in the supply chain has a dependent orchestration for extract data and feeds the FTrace database by traceability information. For adding a new provider in the existing supply chain, we need just develop a new orchestration process to integrate the new provider to the existing ICT traceability system already developed.
    - Enterprise Service Bus: allows interoperability with existing applications. Enterprise Service Bus is a flexible approach to integration without writing code. For example in this layer, to extract information from RFID tags, we use BizTalk RFID that orchestrates RFID-related end-to-end processes and share RFID data. BizTalk RFID allows discovering, communicating, managing and integrating RFID devices into different existing applications on different providers.
- Middleware Layer: the Middleware layer proposes features like baseline filtering capabilities, reader integration and coordination. We should be able to intelligently filter multiple data sets resulting from multiple reading of objects that go through several antenna fields.
    - Information Management Rules (IMR): Define the client traceability information needs (implemented via XML files). The business process was defined by the IMR to offer all required traceability information.
    - Unified Data Representation: Define attributes and structuring the database using Papinet and StanForD standard. This layer defines the data format (wood properties, measurements, etc.) that will be traded by providers.
    - Filtration and data aggregation: In order to send and display needed information.
- Database Repository: Represent the data model for the whole supply chain. After extracting traceability information from each supply chain providers, all these information will be processed and stored in the database repository.
- Web Portal: Provide a global view of traceability information (list of providers, forests, products, etc.). Offer a flexible access to client: the user need just to enter the product identification in the interface and all the tractability information will be show to the user (since the product creation until today).

This architecture offers a reliable, extensible and scalable traceability solution. It provides two major benefits that are really critical to implement in the forest sector. In one hand, it offers the ability to accept and manage any devices. On the other hand, it offers scalable system that can subsequently adding or removing a provider in forestry wood supply chain. The proposed architecture is able to track product in real time, accurately in the forest and outside at different other providers and then using this information to make business decision that help improve the flexibility and speed of their supply chain.

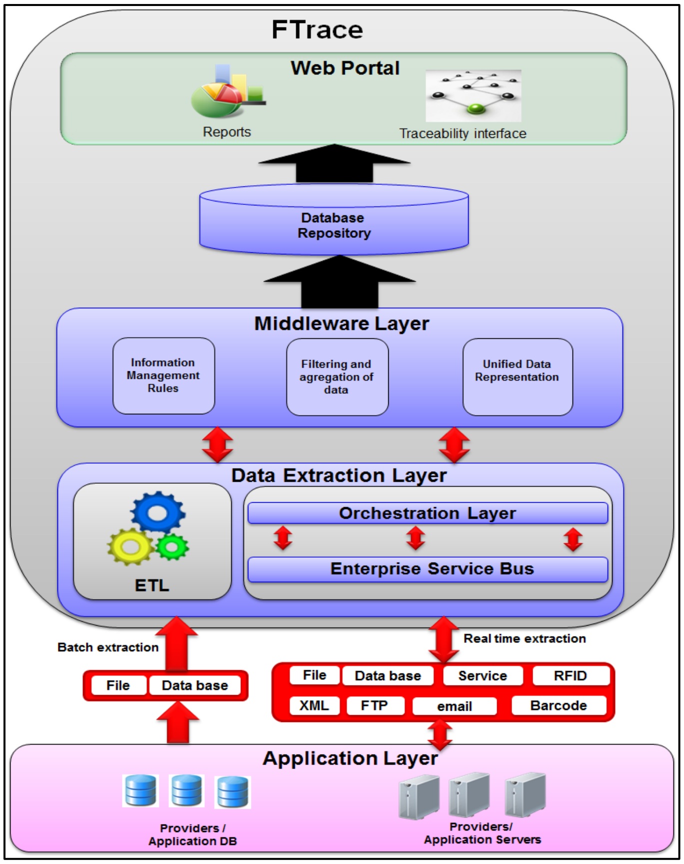


Figure 3: FTrace proposed architecture

4.3 Proof of Concept

The proposed architecture described previously was implemented and tested in a real case scenario. Figure 4 show an UML sequence diagram describing interactions done between real providers, the client and the system we propose. The client defines his traceability information needs. A set of actors types involved in the traceability business process is identified. In order to collect traceability information (for each product in inventory), providers engaged in the forestry supply chain send traceability information to FTrace system via a Cloud connection. The Web Portal displays traceability information from "FTrace" as a response to any specific request from the client.

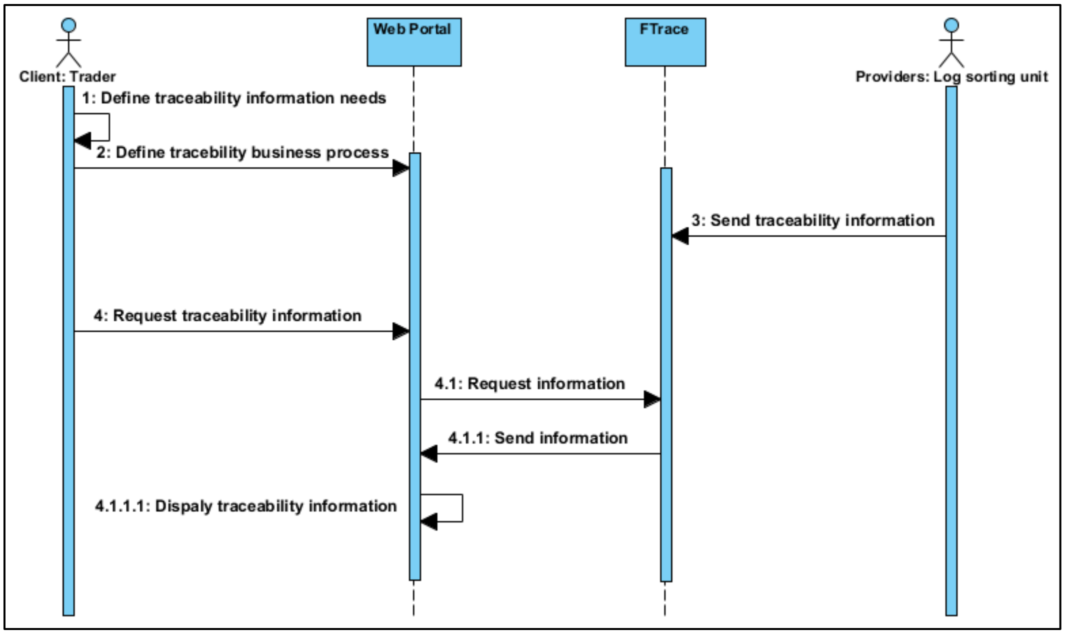


Figure 4: Traceability UML sequence diagram in the Forest Sector- Example Scenario definition

FTrace is an interoperable system; it can connect with different types of ICT provider system (web service, barcode, RFID reader, XML file…). In this prototype, we are using a provider's application developed in .Net in order to communicate with FTrace system (using XML files). These applications are implemented at different nodes of the forestry process in order to collect traceability information from providers. Figure 5 describe the log sorting provider's business application interface. By this interface, the client defines his log sorting traceability information needs. When clicking in process button, an XML file containing this information will be sent to FTrace system for processing. The processed information will be available for the client and offers the possibility to trace back some specific information from origin.

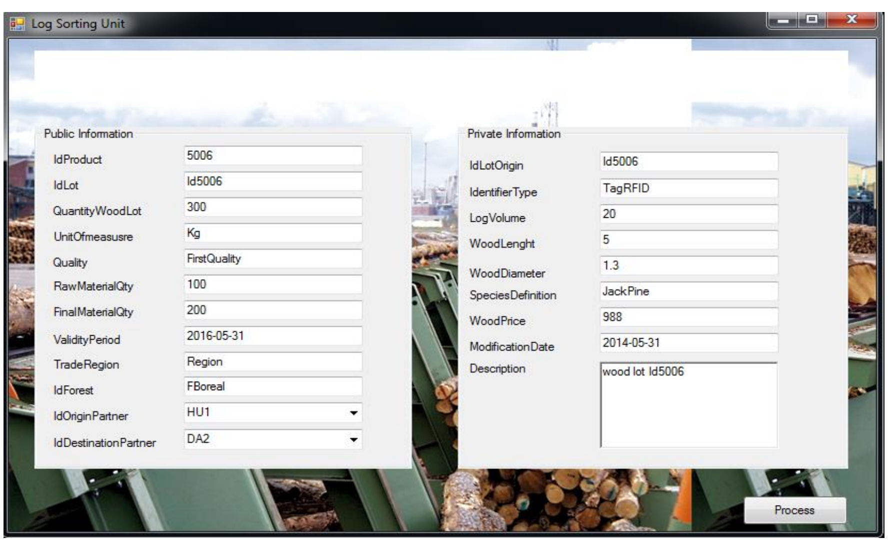


Figure 5: Providers business application

In order to exchange information between supply chain providers who are geographically distant, we propose an interoperable traceability solution equipped with internet connection. We use BizTalk as an orchestration tools to ensure the functionalities quoted previously. BizTalk provide connection between the process information and the product information. Through BizTalk usage, the system is provided automatically and in real time by reliable data. Figure 7 define an example of traceability business processes orchestration using BizTalk tools. This figure describe message exchanged between forestry supply chain provider (Log sorting provider in this case) and the FTrace system. For offering a scalable system, we can easily manage and integrate providers (adding or removing providers). For example, for adding a new provider type to the forestry wood supply chain, we must just add a new orchestration (as illustrated in figure 6) and connecting it to the existing ICT traceability system already developed.

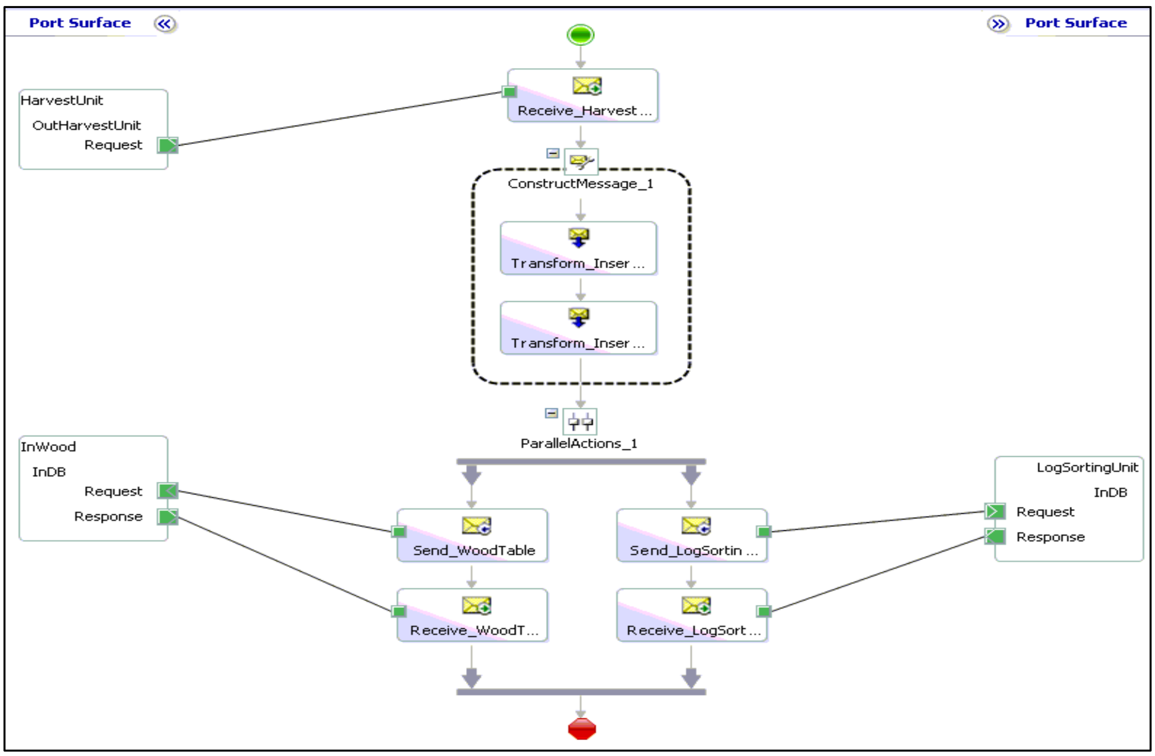
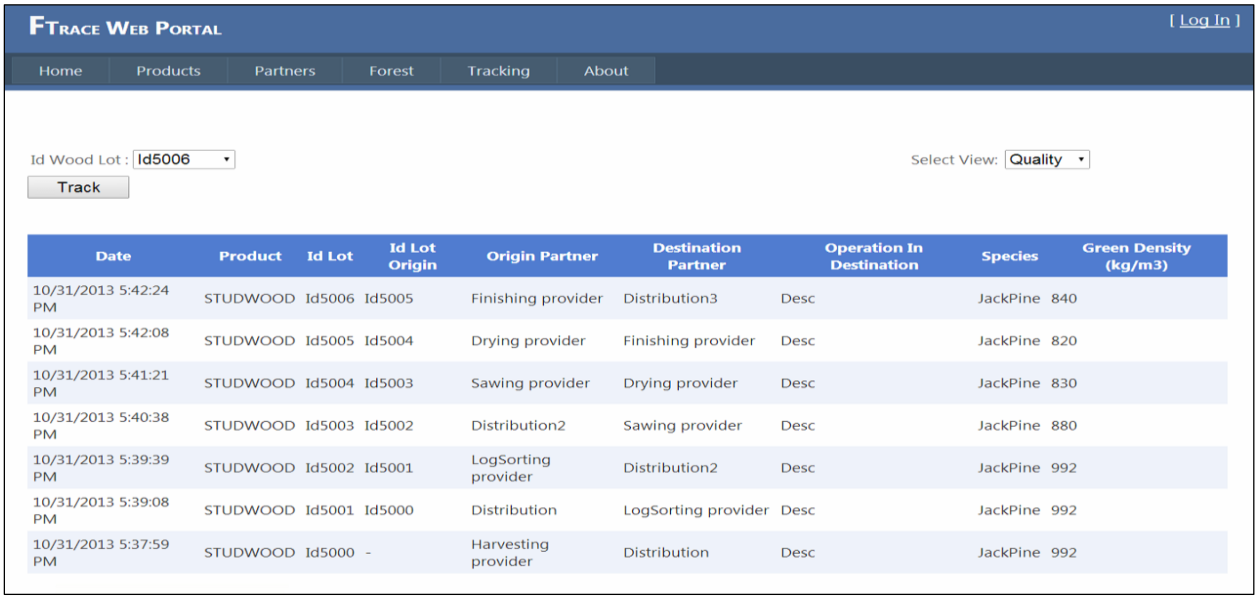


Figure 6: Traceability Business Processes – Orchestration sample

FTrace emerge Internet of Things context by: 1) using network information and 2) sharing a readable and flexible interface with end users. In order to see in a friendly manner the traceability information, the client can use a web portal. The Web portal turns requested information from FTrace system to display reliable traceability information as shown in figure 7. The Web portal is responsible to present the traceability data to the client with different views, according to the standard that has been defined in advance.



Date	Product	Id Lot	Id Lot Origin	Origin Partner	Destination Partner	Operation In Destination	Species	Green Density (kg/m3)
10/31/2013 5:42:24 PM	STUDWOOD	Id5006	Id5005	Finishing provider	Distribution3	Desc	JackPine	840
10/31/2013 5:42:08 PM	STUDWOOD	Id5005	Id5004	Drying provider	Finishing provider	Desc	JackPine	820
10/31/2013 5:41:21 PM	STUDWOOD	Id5004	Id5003	Sawing provider	Drying provider	Desc	JackPine	830
10/31/2013 5:40:38 PM	STUDWOOD	Id5003	Id5002	Distribution2	Sawing provider	Desc	JackPine	880
10/31/2013 5:39:39 PM	STUDWOOD	Id5002	Id5001	LogSorting provider	Distribution2	Desc	JackPine	992
10/31/2013 5:39:08 PM	STUDWOOD	Id5001	Id5000	Distribution	LogSorting provider	Desc	JackPine	992
10/31/2013 5:37:59 PM	STUDWOOD	Id5000	-	Harvesting provider	Distribution	Desc	JackPine	992

Figure 7: FTrace web portal

5 Conclusion

In this paper, we present a novel traceability approach based on automatic identification and data capture to trace reliable information in the forest sector. With traceability, it's possible to trace the origin of forest based products. The proposed traceability architecture will allow some companies engaging in a traceability journey to access new and traditional markets especially if customers impose the use of any kind of certification. As an example, printers are publicly committed to provide their customers with "certified paper". Thus, suppliers must provide the proof that their products are certified in the form of a chain of custody (CoC) certificate. This means that the vendor's products have been manufactured from timber sourced from "well managed forests". Another advantage from holding a traceability system is that the collected information could help companies to optimize their value chain based on better management of transportation flows of raw material and by keeping the right inventory in the best place. The proposed solution increase collaboration between the different supply chain actors through tracing the business processes execution, orchestrating different providers, integrating the different IT application used throughout the wood process and offer a scalable traceability system. In this project and regarding data extraction, we have tested two adapters to communicate with the application layer (XML file and RFID tags). As future work, we should add the other adapters such as barcode and web services. Finally, in this project, a primitive unified data representation model is proposed based on two communication standards: Papinet and StanForD. As future research, a more precise specification of data representation should be defined in order to guarantee the availability of information needed for certification purposes.

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