SOFIA: AGENT SCENARIO FOR FOREST INDUSTRY
Tailoring UBIWARE Platform Towards Industrial Agent-driven Solutions

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Abstract: Current economical situation in Finnish forest industry desperately calls for higher degree of efficiency in all stages of the production chain. The competitiveness of timber-based products directly and heavily depends on the raw material cost. At the same time, the successes of companies, that use timber, determine the volumes of the raw wood consumption and, therefore, drive forest markets. However, wood consuming companies (e.g. paper producers) can not unilaterally dictate logging and transportation prices to their contractors, because profitability of those, has already reached its reasonable margins (Vesterinen, 2005, Penttinen, 2009). Recent research conducted in 2005-2008 shows extremely high degree of inefficiency in logistic operations amongst logging and transportation companies. Some of them have already realized the need for cooperative optimization, which calls for cross-company integration of existing information and control systems; however privacy and trust issues prohibit those companies from taking the open environment solutions. Therefore, the researchers have suggested new mediator-based business models that leverage the utilization and preserve current state of affairs at the same time. New business solutions for logistic optimization can be built, when a unified view on the market players is possible. Nevertheless, with fast development of communications, RFID and sensor technologies, forest industry sector is experiencing a technological leap. The adoption of innovative technologies opens possibilities for enactment of new business scenarios driven by bleeding edge ICT tools and technologies. We introduce an application scenario of the semantic agent platform called UBIWARE to the forest industry sector of Finland.

1 INTRODUCTION

Current economical situation in Finnish forest industry desperately calls for higher degree of efficiency in all stages of the production chain. The competitiveness of timber-based products directly and heavily depends on the raw material cost. At the same time, the successes of companies, that use timber, determine the volumes of the raw wood consumption and, therefore, drive forest markets. However, wood consuming companies (e.g. paper producers) can not unilaterally dictate logging and transportation prices to their subcontractors, because profitability of those, has already reached its reasonable margins (Vesterinen, 2005, Penttinen, 2009). Recent research conducted in 2005-2008 shows extremely high degree of inefficiency in logistic operations amongst wood logging and transportation companies. Some of them have already realized the need for cooperative optimization, which calls for cross-company integration of existing information and control systems; however privacy and trust issues prohibit those companies from taking the open environment solutions. Moreover, the logistic optimization within one company is complicated due to heterogeneity of information systems used in harvesters and timber trucks. The same harvester, in order to perform logging for e.g. three different clients, needs to use three distinct systems. Those systems are not integrated, thus the logger has to learn three different interfaces still not having a composite view. Same applies to the subcontractor's office desktop systems, where, operator needs to manage e.g. 5 harvesters having different ordering systems from its

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clients. Although, an increasing number of logging and transportation subcontractors have or control two or more machines, still the logistic plan is mainly done manually or requires manual work to align the data from different systems.

The research performed in 2005-2009 (Lappalainen, 2009) has suggested new mediator-based business models that leverage the utilization and preserve current state of affairs at the same time. New business solutions for logistic optimization can be built, when a unified view on the market players is possible. Although, the companies involved in the forestry sector have a high degree of the ICT infrastructure, yet they do not utilize it to improve the situation cooperatively. The ICT solutions used in a majority of cases are developed as black box standalone applications, therefore the integration of those raises technological challenges. Traditional system integration, if applied here, would become an expensive task involving changes to the existing solutions on the companies' site or building a new system from the scratch. According to the surveys conducted in Finland, currently, forest market players are more or less satisfied with the existing ICT solutions and are neither interested, nor capable to spend resources for new information systems and technologies. The innovative ICT solution, if it takes place, should seamlessly penetrate into the existing infrastructure. The revolutionary changes would not be accepted, unless dictated by market leaders in wood consumption. Those, however, are tied by the contracts with their ICT solution providers.

In this paper we present an outcome of the preparatory project – a proposal of innovative ICT solution for forest industry. In Section 2 we explore the problem domain and define a driving use case that calls for a new ICT solution. Section 3 presents the architecture of the semantic middleware platform that can be considered as a construction tool for a new solution. The extension of the middleware platform to the forestry domain is discussed in Section 4. In Section 5 we present related work and conclude in Section 6.

2 ICT IN FORESTRY

The business environment considered in this work involves wood buyers, forest owners, forest owner associations, and forest and transportation contractors. The interactions are automated, i.e. the wood purchase and cutting orders are done via information systems.

2.1 State of the Art: Wood Purchase Scenario

A forest owner either finds a forest buyer or contacts forest owners association with the request to sell forest in a certain area on the owner's behalf. The forest counsellor (either from the association or from the forest buyer) goes to that area to estimate what will be an approximate outcome and of what quality (classified by dimensions).

Forest counsellor is equipped with the handheld device with the GPS-receiver and her/his conclusion automatically goes either to the association or to the buyer database. Upon counsellor's decision, the operator of the association or buyer enterprise makes an order to a forest contractor for harvesting service. The order includes the amount and optimized sizes of the logs to be cut. The forest contractor loads the order to the information system of the harvester and starts felling. After the felling is done, the timber is forwarded to the roadside storage place where it can be accessed by the timber truck. The operator of the association or buyer's enterprise then does next order to the transportation contractor to deliver the wood to the destination place (e.g. sawmill, pulp mill, power plant, etc.).

2.2 Contractor's Viewpoint

A large share of forest logging or transportation contractors usually own two or more harvesters or timber trucks. Furthermore, increasing number of them receives orders from two or more order makers (wood buyers, forest management associations) (see Figure 1). In order to receive these orders, the contractors have to install respective information systems. Each buyer and/or association has its own tailored solution, which is incompatible with the solutions from others. The contractor has to learn peculiarities of each system, such as different internal codes for wood types, different user interfaces and principles of functioning, etc. *The system heterogeneity makes it impossible for the contractor to integrate the data from those systems and obtain an integrated view of his/her own business.* At the moment the integration is done manually by reading and inserting data into one table, or, sometimes, calculations on the paper are used. In the following subsection we present a desired functionality of the logistics management platform for harvesting and transportation SME's in a form of a use case.

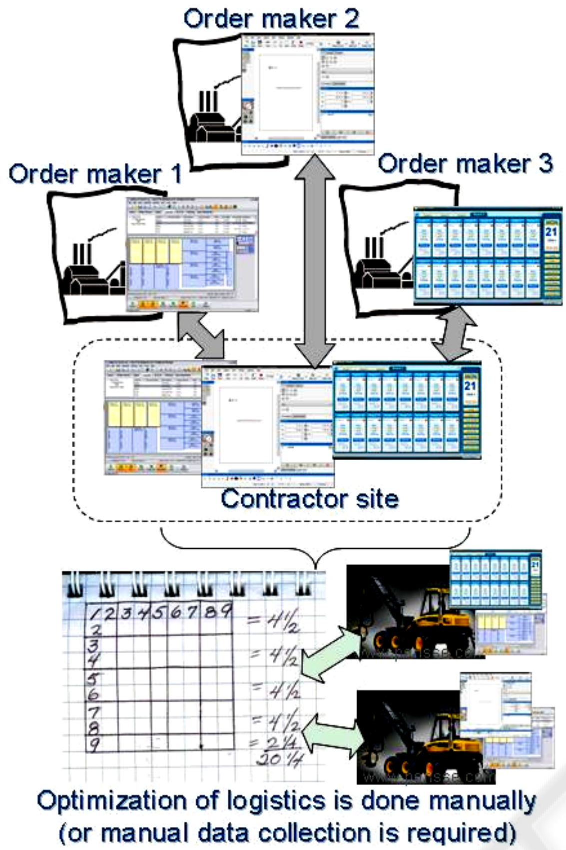

Figure 1: Contractor's view point.

2.3 Driving Use Case: A Platform for Integrated Logistics Optimization

A logging contractor company called KORJUUBEST Oy has 5 harvesters and three different order makers (customers). Timo Saarinen is a company owner and CEO. Timo likes to keep things controlled in his own hands; therefore, he also does the operator job when he is free from traveling and meetings. Timo has double backup, if he is busy, then another operator in the office can substitute him, or Timo can turn on the automatic mode in his new logistics control platform called SOFIA. Every morning Timo comes to his office and after a morning coffee he starts his laptop and logs into the SOFIA platform. The system shows current situation of Timo's harvesters and their status (e.g. *working*, *stopped*, *short maintenance break*, or *out of order*). Timo chooses the harvester icon and browses the tasks assigned and planned. He can also browse the history. After a short look on the harvesters' status Timo opens the bookmark called *orders*. He sees the integrated currently pending order list as well as the orders already planned, based on the long term contracts. The system proposes the optimized order assignment table for the next week, where Timo can reassign tasks to other harvesters if he thinks it is needed and press "Approve" button. The system will send new (not yet sent) logging tasks to the harvesters and the operators will immediately see the new task information in the operator's web-based view. The operators can download order files attached to the task and load them to the harvester's native system. In the evening, upon the completion of the work, the operators can send progress reports or, if the task was completed, a closing report.

SOFIA platform can be configured so, that it automatically sends closing reports to the order maker, or, it may wait for an approval and manual submission from Timo or the operator in charge.

After a half a year of successful operation and optimized utility, Timo has realized that his company can serve at least one more order maker (customer) and luckily, he has met a potential client from big company called Metsänhoitajat Oy last week in sauna. They have agreed to meet in more formal way as soon as they clarify how much work would be needed to integrate their information and ordering systems. Timo has called to the SOFIA maintenance center and has received a surprisingly good answer. With the minimum cost a new customer's ordering system can be connected to Timo's platform with no need to stop it. Luckily, Metsänhoitajat Oy company has already worked with other contractor, who is using SOFIA platform, therefore the system adapter is already available, it only needs to be configured for Timo's platform. Even, though, the adapter wasn't ready, it would not take longer than one month to plug a new ordering system to SOFIA.

In the evening, after a successful meeting with Metsänhoitajat Oy where a new contract was signed, Timo has made an order to SOFIA maintenance center for a platform configuration. Next day Timo could already see a new partner in his system and in short time, new orders have started to come.

In the following section we present a middleware platform called UBIWARE – a convenient tool for the implementation of SOFIA platform.

3 UBIWARE PLATFORM

UBIWARE is a generic domain independent middleware platform (Katasonov et al., 2008) that is meant to provide support for integration, interoperability, adaptation, communication, proactivity, self-awareness and planning for different kinds of resources, systems and components (e.g. data information and knowledge, software and services, humans, hardware and processes). The UBIWARE platform is developed inline with the fundamental vision towards GUN - Global Understanding Environment (Terziyan, 2003, 2005; Kaykova *et al.*, 2005). In GUN various resources can be linked to the Semantic Web-based environment via adapters (or interfaces), which include (if necessary) sensors with digital output, data structuring (e.g. XML) and semantic adapter components (XML to Semantic Web). Software agents are to be assigned to each resource and are assumed to be able to monitor data coming from the adapter about the state of the resource, make decisions on behalf of the resource, and to discover, request and utilize external help if needed. Agent technologies within GUN allow mobility of service components between various platforms, decentralized service discovery, utilization of FIPA communication protocols, and multi-agent integration/composition of services.

When applying the GUN vision, each traditional system component becomes an agent-driven “smart resource”, i.e. proactive and self-managing. This can also be recursive. For example, an interface of a system component can become a smart resource itself, i.e. it can have its own responsible agent, semantically adapted sensors and actuators, history, commitments with other resources, and self-monitoring, self-diagnostics and self-maintenance activities.

At the same time, UBIWARE naturally integrates such domains as Semantic Web, Proactive Computing, Ubiquitous Computing, Autonomous Computing, Human-Centric Computing, Distributed AI, Service-Oriented Architecture and Enterprise Application Integration.

3.1 UBIWARE Platform Architecture

UBIWARE has two main elements: an agent engine, and S-APL – a Semantic Agent Programming Language (Katasonov and Terziyan, 2008) for programming of software agents within the platform.

The architecture of UBIWARE agent (Figure 2) consists of a *Live* behavior engine implemented in Java, a declarative middle layer, and a set of Java components – *Reusable Atomic Behaviors* (RABs).

RABs can be considered as sensors and actuators, i.e. components sensing or affecting the agent’s environment, but are not restricted to these. A RAB can also be a reasoner (data processor) if some of the logic needed is not efficient or possible to realize with the S-APL means, or if one wants to enable an agent to do some other kind of reasoning beyond the rule-based one.

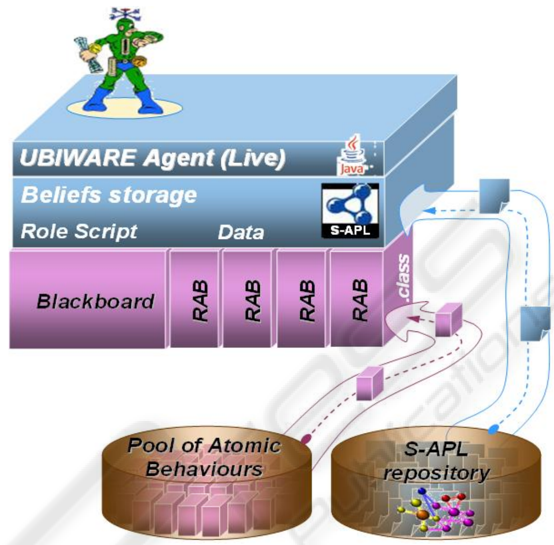

Figure 2: UBIWARE Agent.

UBIWARE agent architecture implies that a particular UBIWARE-based software application will consist of a set of S-APL documents (data and behavior models) and a set of specific atomic behaviors needed for this particular application. Since reusability is an important UBIWARE concern, it is reasonable that the UBIWARE platform provides some of those ready-made.

Therefore, logically the UBIWARE platform, consists of the following three elements:

- The Live behavior engine
- A set of “standard” S-APL models
- A set of “standard” RABs

The extensions to the platform are exactly some sets of such “standard” S-APL models and RABs that can be used by the developers to embed into their applications certain UBIWARE features.

As Figure 2 shows, an S-APL agent can obtain the needed data and rules not only from local or network documents, but also through querying S-APL repositories. Such a repository, for example, can be maintained by some organization and include prescriptions (lists of duties) corresponding to the organizational roles that the agents are supposed to play.

Technically, the implementation is built on top of the JADE – Java Agent Development Framework (Bellifemine et al. 2007), which is a Java implementation of IEEE FIPA specifications.

4 UBIWARE MEETS FORESTRY

The business models that were thoroughly studied in the recent research (Lappalainen, 2009), stumbled in the technological challenges that are being tackled in the UBIWARE. At the same time, UBIWARE platform should be tailored to the industrial domains, in order to attract businesses. Therefore a SOFIA platform (SOFIA stands for Seamless Operation of Forest Industry Applications) described in Section 2.3, when developed on top of the UBIWARE, will benefit from inherent flexibility and extensibility and ensure sustainable ICT infrastructure for logging and transportation SMEs.

4.1 Tailoring UBIWARE to Forestry

The logistics optimization drives the main direction of platform development. However, in order to solve optimization tasks, the platform requires adaptation and connectivity problems to be resolved first. Those, in turn, call for a unified domain model (domain ontology).

As soon as SOFIA platform will serve as an integrator of information systems provided from different order makers (wood buyers and forest owner associations), the orders coming from different systems will be gathered to one integrated view allowing the contractor to apply logistics optimization tool and decrease useless overheads in operation (see Figure 3).

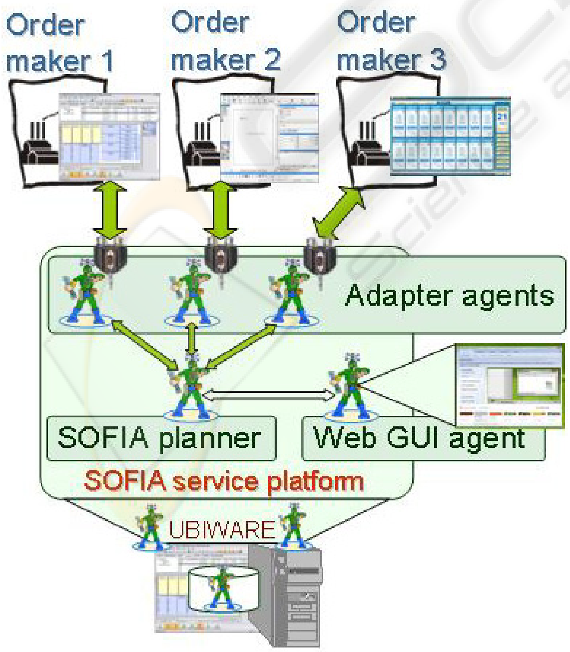

Figure 3: SOFIA platform.

To perform integration, we define a set of target information systems (based on the case studies) and make deep analysis of the connectivity options and internal data models used. The integration will result in construction of adapters to the respective systems. The configuration on the order maker site may still be required to redirect data flow from order maker to SOFIA platform.

The order makers, however, may not be flexible in changing some settings or opening access to their data and systems. Therefore, we have a requirement to minimize changes on the order maker side if not to avoid at all.

4.2 Handling Connectivity Challenges

The main implementation challenge of the platform is connectivity. Figure 4 shows a generic data exchange scenario between order maker and contractor.

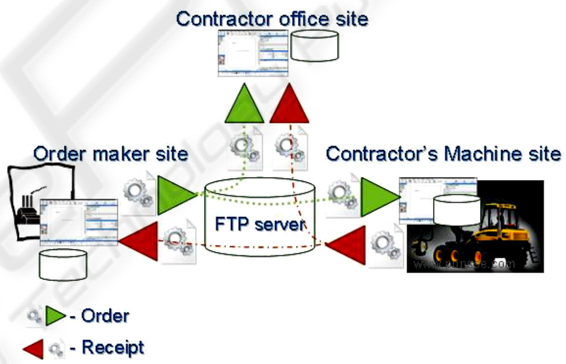

Figure 4: Data flow between order maker and contractor.

The flow is mostly organized via FTP server, which is checked by the client software installed on the contractor's machine site and, sometimes, at the office. The order flow goes directly from the order maker to the machine. In such situation a contractor is unable to decide, which order goes to which machine, i.e. the machine is rather directly controlled by the order maker (preceded by a generic contract of course). The software for data exchange is proprietary and, therefore, does not provide any API. The intermediate files, though, appear on the FTP-site as well as in temporary folders on local machines.

In such scenario even data collection may put platform development to the tight corner. We propose virtualization approach (see next subsections) to handle the issue and introduce two possible workaround scenarios.

4.2.1 Contractor Site as a Firewall

In case when an FTP server can be accessed by our platform software (only username and password are required and known), we can fully emulate the behaviour of a harvester or a truck. No changes on the order maker site are needed.

In case, when an FTP server can only be accessed by the proprietary client software (the password and username may be hardcoded and not known to the contractor), we can move the client from the machine to the contractor site and access FTP server from it. Temporary files, stored by the client, then can be sensed by the platform and passed to the responsible agent.

4.2.2 Machine Agent

In neither case, when no FTP access can be arranged, nor client software can be moved from the machine site (e.g. proprietary restrictions), we can establish our listener software on the machine site to catch the data from the client and send the data to the contractor site. In this case, we have extra delay time because of additional data transfer step from the machine to the contractor site and back. This approach may change the architecture of the whole system drastically and may require a lot more efforts. Nevertheless it is still possible.

4.3 Virtualization of Forestry Market

The requirement to preserve systems of order makers untouched can be accomplished by introducing the know-how of the SOFIA platform – a concept of virtual machine applied to harvesters and timber trucks. The contractor creates an interface-like view to his/her harvesting and transportation facilities by means of virtual machines (see Figure 5).

From the service order maker point of view the contractor looks the same, however, the real equipment of the contractor is hidden. The orders are made seamlessly, but the assembly chosen for the execution, is virtual. The service provider then has the opportunity to build an optimized operations plan and after that assign tasks to the real units.

The virtualization may go beyond the SME boundaries. Several contractors may establish virtual enterprise that works as a proxy for order makers. Such enterprise would have better optimization capacity because of wider order and equipment base. The business model, that clearly explains and guarantees the benefit to stakeholders, yet to be elaborated. The model should take into account region-specific circumstances and context.

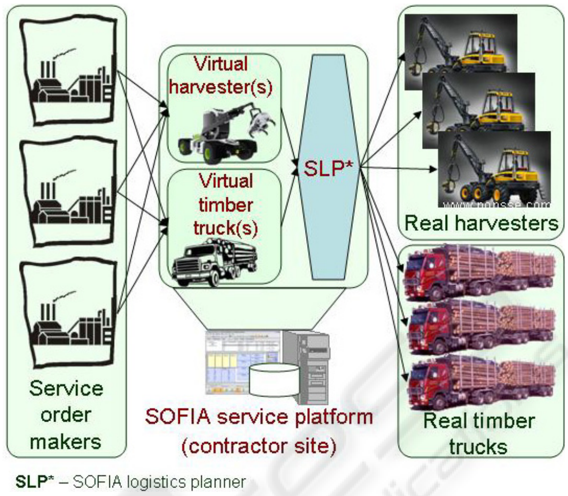

Figure 5: A virtual machine concept.

Although, physical resources virtualization (harvesters and trucks) is attractive to contractors, it may also lead to complexities in resource planning in global scale. In general, if the same resource is present in two independent planning systems (e.g. two virtual contractor SMEs have signed the contract with the same harvester owner), then both systems may build long-term plans, expecting the resource to be available. The problem may show up, only when a detailed short-term contract has to be signed and both virtual harvesting contractors are pretending to employ the same harvester. The business model should *exclude ambiguity* and guarantee the availability of the resources at the execution time. We can compare the problem to the car rental process, where we see the capacity (cars available) and know the car class (e.g. Ford Focus or analogous), but we do not know the exact car license plate id, before we come to the office and get the keys. In the simplest case, the rental company is the owner of the car, but in harvesting we may have a situation, when a harvester owner has signed contracts with two or more harvesting SMEs.

4.4 SOFIA beyond National Boundaries

The platform and the model described above fit well forestry market in global scale. We expect that a globally present enterprise can sell platform services worldwide. Although, the localization requires quite significant effort, which is not in the nature of the global service, still it is compensated by limited number of harvester manufacturers (only three key manufacturing enterprises). The small amount of manufacturers means significant reduction of software adaptation efforts. Running one nationally wide service platform would already include adapters to the systems of the key manufacturers. Next, the middleware platform we use, possesses the features for easy tailoring to local region-specific requirements. The platform architecture employs semantic technology, which can be considered as most expressive one for domain modelling. The semantic nature combined with the agent technology brings other benefits as well – adaptivity and configurability that allow the platform users to get new business models up and running with small effort. Configurability also makes the maintenance of the platform less resource-consuming for the customer.

The web-based solution on the global scale, if it takes place, can utilize cloud computing (Hayes, 2008) to ease scalability and optimize expenditures for the hardware and software infrastructure. The components of the platform (see Figure 6), when run in the cloud can be updated or configured on-the-fly.

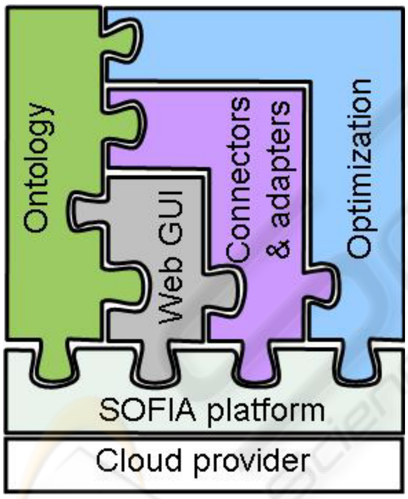

Figure 6: SOFIA component view.

The platform behaviour is specified in the ontology – a backbone of both the data and the business logic. We can consider ontology as a rich configuration file that describes structure of the software components being run as well as the data. The Web GUI component may undertake minor localization changes, whereas Connectors & Adapters will differ significantly from region to region, due to a variety of local information systems at wood buyer sites that have to be connected. The optimization algorithms and methods may require region-specific settings for better efficiency, but otherwise remain untouched.

In this Section we have presented the analysis of the domain-specific features that have to be implemented on top of the existing middleware platform. The analysis shows that technical implementation is feasible in spite of the state of the market and relationships amongst market players.

5 RELATED WORK

Latest industrial ICT trends define inter-component and system interoperability as a key direction.

The interoperability is also known as one of the major future challenges in ICT. Current industrial standardization efforts aim at resolving this challenge by creating a unified vocabulary of communication, or, in other words, a standard. Forest industry is not an exception. Standardization and interoperability form a basis for competitive market, and hence, for cost-efficient production. In recent years forest industry have run a set of standardization projects, e.g. papiNet (www.papinet.org) and its initiative - WoodX, Edifact (www.unece.org/trade/untdid/welcome.htm) and StanForD (http://www.skogforsk.se/upload/6867/StanForD_MainDoc_070327.pdf).

The standards mentioned above simplify the implementation of SOFIA in order of magnitude and, therefore, we have to make thorough analysis of standards already adopted as well as those being developed. SOFIA's ontology should be built standard-compliant and allow easy standard-based document and interface generation.

The improvement of the wood production chain is also a subject of integrated EU FP7 project called "IndisputableKey" (www.indisputablekey.com). The project aims at a new methodology and advanced technologies that improve the use of wood and optimize the forest production. The project is targeting the supply chain improvement as a whole, whereas SOFIA is a contractor SME-oriented at the same time applying and developing ICT technologies far beyond those currently available.

In (Frayret et al., 2007; Forget et al., 2008) the authors state that forestry companies are facing the need to re-engineer their organizational processes and business practices taking into account other companies in forest industry. An agent-based approach is proposed to tackle the problem of dynamic planning in the supply chain. SOFIA rather approaches the same domain from the software architecture viewpoint and introduces innovative software platform model for forestry contractors.

6 CONCLUSIONS

A unified platform solution for forest industry faces the ICT challenges that were foreseen in GUN activities early in years 2002-2003. The UBIWARE platform being designed to resolve such challenges, still remains domain independent, and, therefore, has to be tailored and extended to meet domain-specific needs. Such platform customization is a first step towards GERI (Global Enterprise Resource Integration) – where various industrial domains will be taken into account. At the moment, UBIWARE-based industrial applications are naturally needed for proper platform evolution as a whole. SOFIA platform will have an extended tool set (RABs and S-APL models) on top of UBIWARE to solve forest industry sector tasks. We believe that success of SOFIA forest industry platform can bring a new breath both to the forestry and to the ICT worlds.

The results of the research published in (Lappalainen, 2009), state that utilization of business models with more than one customer for the harvesting, transportation and chipping contractors, can save approximately 50 million euro annually in the forest biomass supply chain in Finland only. A simulation study conducted within the same project has shown that annual cost savings in raw wood harvesting only would account for 21 million euro at least if business models and ICT-tools would support it (Väätäinen et al., 2008).

In addition to the cost savings mentioned above, SOFIA can be used to provide higher level harvesting and transportation services for customers at the same time serving simultaneously many of them. SOFIA would enable more efficient order handling and organization of right-time deliveries while minimizing the risk of human failures.

We have presented the results of the preparatory project. This work has been inspired by thorough analysis of business opportunities that led us to look for technological implementation challenges and workarounds. At the moment we are considering both business-oriented as well as science-oriented directions for further development of SOFIA.

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