Information integration in multi-dimensional agri-food supply chain networks: a service-oriented approach in the KodA program

Sjaak Wolfert[1], Cor Verdouw[1] Adrie Beulens[2]

1 LEI, Wageningen UR, P.O. Box 29703, Den Haag, 2502 LS, The Netherlands, Tel: +31 70 3358330, Fax: +31 70 3615624, sjaak.wolfert@wur.nl, cor.verdouw@wur.nl

2 Information Technology Group, Wageningen University, P.O. Box 8130, Wageningen, 6700 EW, The Netherlands, Tel: +31 317 484154, Fax: + 31 317 485646, adrie.beulens@wur.nl

Abstract. Agri-food companies increasingly participate as networked enterprises in multi-dimensional, dynamic and knowledge-based networks. They have to make new connections rapidly and employ 'up-to-the-minute' information smoothly in business operations. Appropriate exchange and integration of information should enable this. As part of the Dutch co-innovation program 'KodA', an in-depth study investigated the role of information integration in multi-dimensional networks, described the current situation in agri-food supply chain networks (particularly arable farming) and provided a vision for the future. This paper presents the results of this study. It concludes that the level of standardization for data, application and process integration in arable farming is poor. A service-oriented approach that supports companies to concentrate on their business processes is proposed as a solution direction. Developments should focus on industry-specific elements, adopting worldwide cross-industry standards and building upon existing industry standards. A step-by-step approach in which business partners themselves are responsible, organizational embedding and involvement of all relevant stakeholders are important success factors.

Keywords. service-oriented architecture (SOA), business process management (BPM), information integration, data standardization, interoperability, arable farming

Introduction

The business environment of agri-food production is changing rapidly, driven by various and changing needs of consumers and society. Production is becoming more demand-driven, has to be transparent and must meet quality and environmental standards. Several incidents in the last decades (e.g. foot and mouth disease, swine fever, dioxin scandals) have made food safety one of the major issues. Meeting these requirements gives actors in the supply chain a 'licence to produce'. Besides, agricultural markets in Western Europe are under pressure because of high land and labour prices in combination with intensified competition due to globalisation. One main answer to this development is to innovate towards a more demand-driven and knowledge-based production, producing high-grade products. This requires application of 'state-of-the-art' knowledge and involvement of research and technology institutes in innovation. In such context, agri-food supply chains are not simple linear chains, but are characterized by multiple network dimensions (see Fig. 1):

- Vertical chain dimension: combination of actors that together develop, produce and distribute products to fulfill customer needs;
- Horizontal fulfillment dimension: combination of producers who complement each other providing a complete assortment in the required volume and delivery reliability;
- Horizontal innovation dimension: cooperation of producers in developing resources and business processes in order to exploit economies of scale and synergy due to complementary competences (including joint creativity);
- Geographic cluster dimension: regional cooperation focusing on combining logistic flows or creating a closed system that utilizes mutual inputs and outputs.

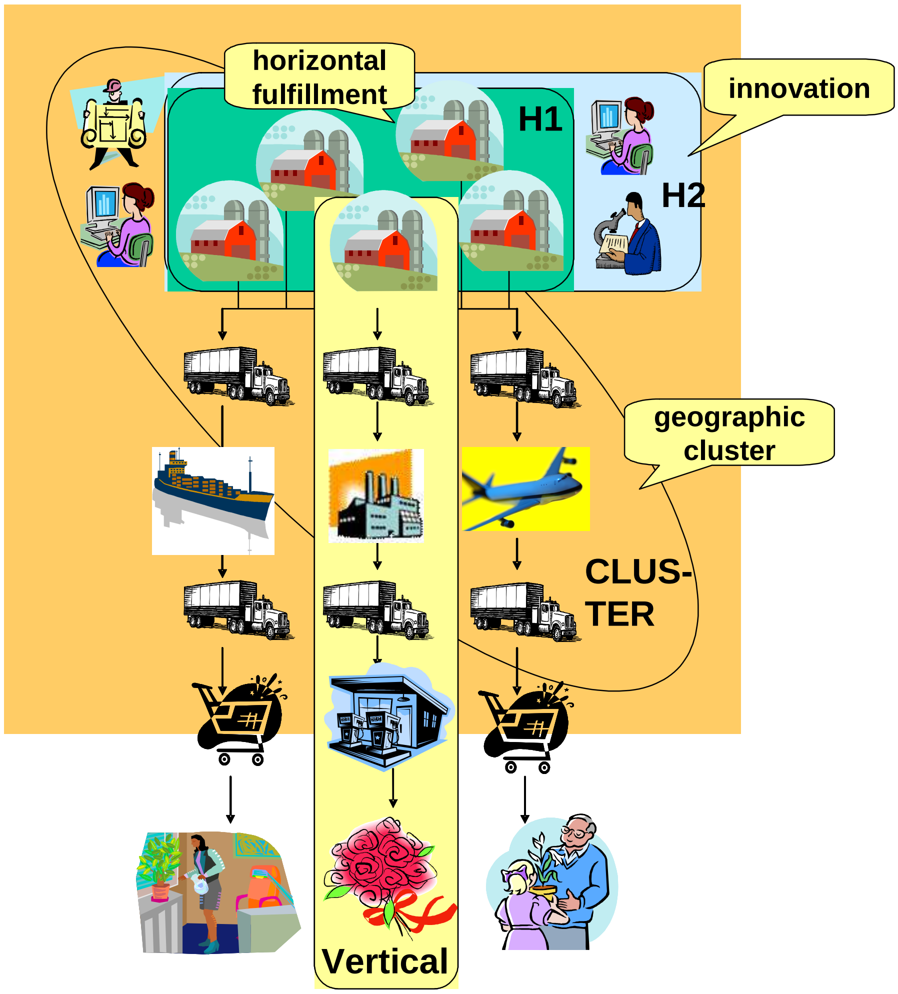

Figure 1. Multiple dimensions of Agri-Food Supply Chain Networks

Therefore, we prefer to speak of agri-food supply chain networks (further abbreviated as AFSCN). Three basic forms of network governance can be distinguished in AFSCNs (Lazzarini et al., 2001):

- Managerial Discretion (plan): discretionary actions by a coordinating agent, who centrally plans the flow of products and information;
- Standardization: standardized rules and shared mechanisms to orchestrate transactions;
- Mutual Adjustment: alignment of plans through mutual feedback processes and joint problem solving and decision making.

Multi-dimensional networks put the emphasis on standardization and mutual adjustment, requiring a high flexibility of processes and enterprises.

The requirements of licence to produce, knowledge-based production and flexibility require in their turn appropriate communication between and steering of all processes in the complete AFSCN. Related to this, appropriate information integration is important.

An in-depth study was conducted to investigate what appropriate information integration means for AFSCNs, to describe the current situation and to provide a vision for the future. This paper presents the results of this study that was carried out as part of the KodA program (see text box). In KodA, we consider the farm as the focal company in the AFSCN, which is a networked enterprise where several network dimensions come together.

In the remainder of this paper we will first elaborate on the problem statement and its context using a wider conceptual framework, related to general concepts derived from literature. The next section will reflect the current situation for AFSCNs to this framework, resulting in a list of problem areas. A vision for the future is then provided as a guide for working on these problems. Next, we will briefly describe the work in progress and finally draw conclusions and set an agenda of future challenges for research and development.

General information about the RTD program 'KodA'

KodA is a Dutch acronym for 'Kennis op de Akker', which can be best translated in English as: 'From knowledge to practice in the field of arable farming'. In KodA, about 60 arable farmers, their suppliers and processors (about 12 large companies), work together to improve quality and efficiency of arable crop production. This co-operation takes place in interactive learning networks in which predefined tasks for innovation are gradually implemented. KodA has a total budget of 8 MEuro for 4 years, in a private-public partnership with the Ministry of Agriculture.

ICT is seen as a key enabler to achieve the program's objectives. ICT enables the farmer to use and deploy knowledge, information and data efficiently. Development of integrated management support systems in which actual, state-of-the-art knowledge and farm-specific data are combined, is considered as a major condition for further development of sustainable practices (Wolfert et al., 2005; Wolfert et al., 2007).

Conceptual framework for information-integration

Integration of information for the farm as a networked enterprise in multi-dimensional AFSCNs is complex. Therefore, the study started with defining a conceptual framework (among others based on Giachetti, 2004) that is visualized in Fig. 2 and distinguishes between:

- Different integration levels:
  - Intra-enterprise: *within* enterprises to overcome fragmentation between organizational units (functional silos) and systems;
  - Inter-enterprise: *between* enterprises to move from operating as an isolated company towards a virtual enterprise that is integrated in multi-dimensional networks.
- Different integration types:
  - Process Integration: alignment of tasks by coordination mechanisms;
  - Application Integration: alignment of software systems so that one system online can use data generated by another one (interoperability);
  - Data Integration: alignment of data definitions in order to be able to share data;
  - Physical Integration: technical infrastructure to enable communication between hardware components (connectivity).

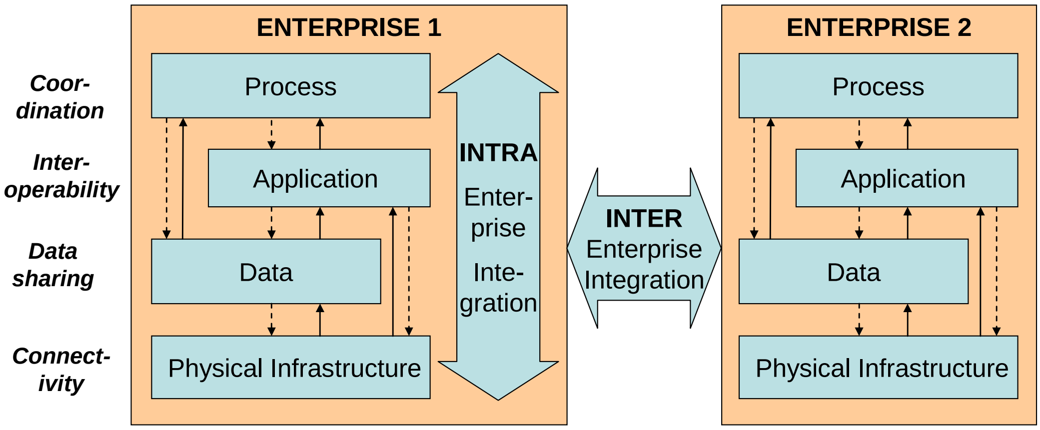

Figure 2: Integration Framework (adapted from Giachetti, 2004)

The different integration types are interdependent in two ways:

1. *Conditional* (solid lines in Fig. 2): to share data and couple applications, the physical infrastructure must be connected; to integrate applications, there must be common data definitions; for effective process coordination it must be possible to share data or to integrate applications;
2. *Requiring* (dotted lines in Fig. 2): starting point is the need for integrated processes which defines the requirements for data exchange and application integration; application integration implies specific requirements for data to be exchanged; data exchange and application integration both require a supporting technical infrastructure;

At all defined levels and types of integration, one can distinguish three basic approaches (adapted from Lee et al., 2003):

1. Implementing *one standard system* that provides all required functionality (requires managerial discretion governance);
2. Developing customized *point-to-point* interfaces (costly, complexity is growing exponentially if the number of interfaces is growing);
3. Adoption of integration *standards* that make it possible to plug different systems via standard connectors into a common platform.

Next sections elaborate the conceptual framework by describing generic standards for all defined types and levels of integration.

Physical Integration Standardization

Standardization of the physical communication infrastructure makes it technically possible to connect products, hardware, machines, devices and their operating systems. There are two groups of supporting standards:

- Interface standards: to make physical systems accessible by information systems, e.g. PLC interfaces for machine control and product identification standards (particularly barcode scanning and Radio Frequency Identification, RFID);
- Communication standards: network protocols (e.g. TCP/IP & PPP), transport protocols (e.g. HTTP, FTP, SMTP, SOAP).

In general, standardization at this level is very mature, although new technologies are emerging, requiring new standards (e.g. RFID).

Data Integration Standardization

Standardization for data exchange focuses on the format of messages and data definitions. XML has succeeded EDI as leading standard for message specification. It is applied both at intra- and inter-enterprise level. Examples of data definition standards at enterprise level are the article coding standard (EAN) and the international Standard for The Exchange of Product data (STEP). At inter-enterprise level standardization focuses on eCommerce information exchange. EDI-based standards are widely implemented (e.g. EDIFACT, ANSI X 12), but at the moment ebXML is emerging as its successor. EbXML provides a catalogue of information elements in XML format ('core components') that have to be exchanged in eBusiness processes. It consists of several sub-standards including MSS (Message Service Specification: aligned with SOA), BPSS (Business Process Specification Schema), CCP/A (Collaboration Protocol Profile/Agreement) and ebXML Registry.

Application Integration Standardization

The successive phase is integration of applications: one application calls another and receives direct, on-line response. Different software applications within one organisation or from different organisations are considered as components of one aligned system.

From 1990s on, at intra-enterprise level the focus has shifted from customized point-to-point interfaces to implementation of standard Enterprise Resource Planning (ERP) systems. Nowadays, web service based application integration is emerging. Web services are autonomous reusable software components that are based on XML message technology that can be described, published and invoked over the network (typically Internet) using open standards (adapted from Leymann, 2003; Tan and Lee, 2004). Comparable to ebXML, it consists of several sub-standards including WSDL (Web Services Description Language), BPML (Business Process Modelling Language) and BPEL (Business Process Execution Language), WSCI (Web Services Choreography Interface), UDDI (Universal Description, Discovery, and Integration).

Process Integration Standardization

The final type is integration of processes (alignment of tasks) by coordination. Therefore the activities and interactions between processes must be defined in process and data models. There are several reference process models that support design of integrated intra- and inter-enterprise business processes. Some well-known integrated intra-enterprise models are CIMOSA (Open Systems Architecture for CIM-systems), GERAM (Generic Enterprise Reference Architecture and Methodology), ERP reference models of among others SAP and Baan (nowadays Infor), ISA-95 (formerly S95). Some well-known inter-enterprise models are VERA (Virtual Enterprise Reference Architecture), SCOR (Supply Chain Operations Reference-model) and the CPFR-model (Collaborative Planning, Forecasting and Replenishment) of VICS.

The next sections use this generic, conceptual model to investigate the current situation of information-integration in AFSCNs and to develop a coherent vision for the future.

Current situation in agri-food supply chain networks

Description of the situation from the farm's perspective

Using the conceptual framework, a survey for the current situation of Dutch arable AFSCNs was conducted, considering the farm as the focal company. Figure 3 provides a summarized overview of the main actors, their interactions and dependencies. Farm management can be divided into two categories: farm and field level. Inter-enterprise information-exchange mainly takes place at the farm level, while at the field level mainly intra-enterprise information-exchange takes place. However, the connection between these two levels is very important for the whole AFSCN. For example, a food processor, communicating at the farm level, wants to know what pesticides were used in the field for a specific crop product.

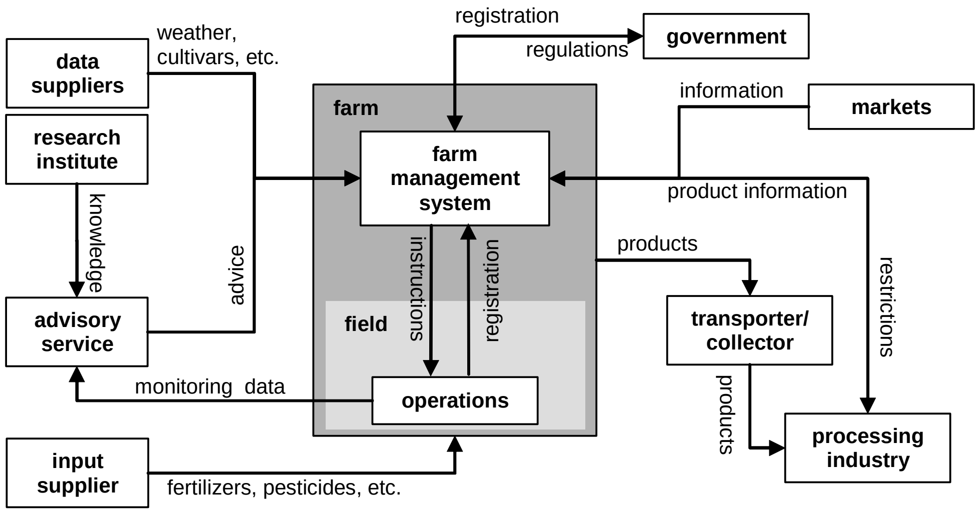

Figure 3 Simplified overview of main product and information flows in arable AFSCNs

Figure 3 shows that farms exchange information in several network dimensions. Information from several actors is combined, aggregated and used by multiple actors. Use of common standards is crucial in this process. For example, the name of a pesticide is requested by input suppliers and advisory services to provide advices on spraying. For automated exchange of pesticide information, unambiguous common definition of e.g. pesticide names, coding and properties is a basic requirement. Currently, this is hardly the case.

Sometimes the actors use electronic formats or systems, but in many cases information is still communicated by paper or verbal communication. For example, only 50% of the sugar beet farmers deliver their product information electronically. Besides, farmers use various applications (e.g. for production control, financial management and decision support), which are not or poorly integrated with each other.

Reflecting to the conceptual framework

Physical Integration, both at intra- and inter-enterprise level, is not a major problem. Network technology (e.g. internet, satellites) is commonly used, while machinery and equipment (e.g. tractors, harvesting machines) have some kind of standardized communication interfaces (plugs and contact points, board computers).

Data Exchange between machines at field level and management systems is supported by an extensive and widely adopted ISO standard (ISOBUS/ISO11873). However, data exchange between different systems at farm level is insufficient. Some examples of some point-to-point interfaces are found, but there are no common standards for data exchange at this level of integration. At the inter-enterprise level, the ‘EDI-teelt’ association develops standardized

XML-based messages to exchange data between farms and industry. EDI-teelt is a lightweight, virtual organisation, consisting of small workgroups of mainly software engineers that participate on a voluntary basis. However, there are serious problems in using the standard, mainly because EDI-teelt covers just one communication line in one network dimension (vertical chain dimension). Data is also dependent on actors of other network dimensions, e.g. government, advisory services and research institutes. In practice, it means that for farmers it is often difficult to deliver the right standardized information, which partly explains a low adoption rate of automated systems. Farmers also complain because the exchange is mainly one-way direction: from farm to industry. The information they receive from industry, if anything, is mostly on paper in a non-standardized data format and difficult to integrate in their management system. In response to these problems, currently the EDI-Teelt standard is being redesigned, extended and tested in some pilot projects.

Application Integration at the intra-enterprise level is mostly done in specific farm management systems, which are widely adopted. They are comparable with ERP-systems, although they are merely administrative systems for registration purposes. Integration with other systems is done by customized point-to-point interfaces. At the inter-enterprise level, there are just a few preliminary examples of point-to-point interfaces, but we cannot speak of a wide supported integration standard.

Process Integration is not supported systematically at the moment. There is no active example of a reference process model that integrates business processes neither at intra-enterprise level nor at inter-enterprise level. Two intra-enterprise examples from the past can be mentioned. First, in the 1980's several extensive reference process models were developed in the INSP-project. Although these models have been elaborated in detail, they are not used as a reference in current software applications. Some parts were used to build these applications, but then definitions further evolved internally, leading to communication mismatches between different applications. Secondly, another attempt was made during the 1990's in the context of the emergence of 'precision agriculture', in which site-specific farm management using GIS plays a central role. In a public-funded project, the IMOPA-model was developed based on the Computer Integrated Agriculture (CIA) model (ESPRIT, 1996) developed in the EU-funded ESPRIT program. Like INSP, this model has not been implemented in currently used software systems, although some parts have found their way in a completely new version of the EDI-Teelt standard that is currently being developed.

National and international developments in other sectors

Integration initiatives in other agricultural sectors (mainly horticulture and animal production) were also investigated. They are mainly focussing on standardisation of data exchange. Dutch examples are: Datatuin (horticulture, www.datatuin.nl), Frugicom (vegetables, www.frugicom.nl), Florecom (flowers, www.florecom.nl), EDI Bulb (www.edibulb.nl), EDI Agribusiness (feed, www.edi-agribusiness.nl), EDI-Cow (www.edi-cow.nl) and EDI-Pigs (www.edi-pigs.nl). Standardization initiatives for application integration are less common. One example is Plantform (www.plantform.nl), that focuses on setting standards for integrated management systems of potted plant nurseries. Many of the initiatives mentioned above started with developing data and process models.

We also identified standardization initiatives in other European countries, including PreAgro/AgroXML (Germany, www.agroxml.de), Agro-EDI (France, www.agroedi.asso.fr), GIEA (France, www.giea.fr) and EZflux (cereals & oilseeds in Belgium, France, Netherlands; www.ezflux-institute.org).

The problems and emerging solutions in other sectors and in other European countries seem to be quite comparable with Dutch arable farming. However, a thorough analysis and comparison goes beyond the scope of this paper.

Conclusions and summary of main problem areas

It can be concluded for the arable AFSCNs that the level of standardization for data, application and process integration is still quite poor, leading to the following negative effects:

- The effort for collecting, converting and exchanging necessary data is large, while the possibility for making errors is high;
- Decision-support is sub-optimal and as a consequence also decision-making;
- Transparency and accountability requirements often lead to administrative burdens.

Referring to the problem statement in the introduction, this means that reaching a desirable level of a licence to produce, knowledge-based production and flexibility is hampered by a poor level of information-integration. To overcome these problems, some major steps on the intra- and inter-enterprise level for information-integration have to be made. The next section provides a vision for the future as a roadmap for further development.

Vision for the future on information-integration

Agri-food companies increasingly participate as networked enterprises in multi-dimensional, dynamic and knowledge-based networks. They have to make new connections rapidly and employ ‘up-to-the-minute’ information smoothly in business operations. The conceptual framework showed that standardization in information integration of processes, applications, data and physical infrastructure are important to realize this.

For setting-up and changing integrations quickly, we propose a rapid (re-)configuration approach in which information integrations are set-up from standard components (‘pick, plug and play’). This requires component-based information systems, independent components, standardized interfaces between components, a central repository of published components and standardized procedures for selection and implementation of components. Concerning component-independency, a clear distinction should be made between the different types and levels of integration as defined in the conceptual framework. Decoupling of these layers makes it possible to change process configurations, without changing applications. To make the right successive steps, it is important to take into account the conditional and requiring interdependency between the different types of integration (see Fig. 2).

A Service-Oriented Architecture (SOA) approach is very suitable to realize rapid (re-)configuration. It is a process-oriented and component-based approach in which service providers publish web services in a service directory, service requestors search in this directory to find suitable services and bind to that service and use it based on information from the directory and standardized procedures (Leymann, 2003; Erl, 2005). Also ebXML is based on this philosophy, whereas the emphasis is on standardized messages instead of web services.

The vision for the future is to support development of architecture, standardization and infrastructure for a rapid (re-)configuration approach at all defined levels of integration, based on a SOA- and ebXML-like approach. This development should connect to existing worldwide cross-industry standards and industry-specific data standards. Additionally, domain-specific configuration guidelines must be developed for selection and implementation of a coherent set of components that solve specific business problems in arable farming. Fig. 4 shows a schematic representation of such an architecture with a focus on farming.

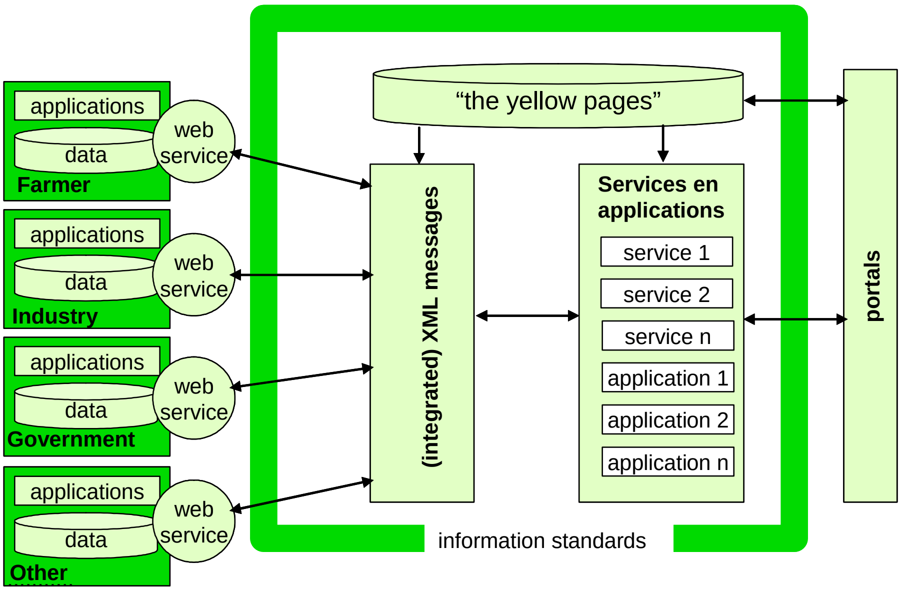

Figure 4. The service-oriented architecture (SOA) philosophy as applied for farming

Lessons learnt from the past (see e.g. INSP, IMOPA in previous paragraph) show that this should not be just an exercise for academics or business consultants, but businesses themselves must take the lead and all relevant stakeholders should be involved. Successful adoption and application implies arrangements at different institutional levels: industry-wide central institution, coalitions of cooperating enterprises and individual organizations (service requestors and providers). Although some national, sector-specific initiatives (like KodA and EDI-Teelt) can take the lead, international harmonization is desirable.

Work in progress

The results of this study were thoroughly discussed within the KodA program by the partners. It was concluded that:

- the KodA partners endorse the viewpoint on integration and standardization of the study but
- emphasize that development must be linked to real business cases and problems of partners that are involved in KodA; this means that developments should prove noticeable benefits for farmers and
- activities should link up with other national and possibly international initiatives so that resources are used efficiently.

This task can be characterized by the dilemma of the chicken and the egg: which one came first? A generic infrastructure with standards is first needed before successful applications can be developed on it and applications can only be called successful when they elaborate on the generic infrastructure. Hence, it was decided to start a project, dealing with relatively simple cases, but it should result in a general established line along which more complex cases can be dealt with in the future. This project comprises the following activities:

- provide for access to data of some data source by a web service from which these data can be retrieved 24 hours a day, 7 days a week, according to a public and commonly agreed standard.
- professionalization of the current authority 'EDI-Teelt' by:
  - updating, developing, maintaining and publishing the current standards in a service-oriented architecture;
  - making long-term agreements with the organizations involved in terms of service level agreements (SLA's) in order to ensure the availability and quality of the data;
  - writing a business plan to set up a new organization of 'EDI-teelt' (working name 'EDI-teelt+') that can sustain according to general market principles;
- description of the aforementioned activities in a procedure so that other cases of opening up data can be treated in the same way.

A case studies on pesticides was chosen to provide for proof of feasibility. In this case study, a basic list of permitted pesticides is published by law by two governmental organizations: PD and CTB. A quick-win application is that the farmer can check *real time* whether a specific pesticide is permitted or not by using a web service. This application can be addressed, like a 'subroutine', within an existing software package. Probably, this is not really a 'killer application' but it will provide a proof of principle of how the service-oriented architecture will work. The case studies is schematically represented in Fig. 5.

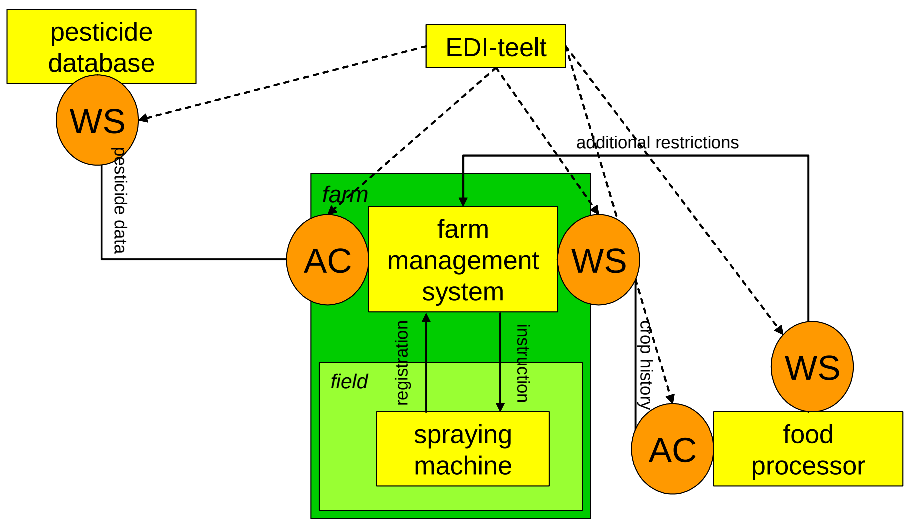

Figure 5. Schematic representation of the case study on pesticides that demonstrates the service-oriented architecture. Web services that communicate with each other by XML messages form the basis, but appropriate interaction and agreements between underlying organizations is of crucial importance. The standards authorization body 'EDI-teelt should maintain an facilitate the architecture.

The first challenge in these case studies is to implement the technical part: making the communication between systems components work by web services. However, this is just the technical part of the work and there are already many worldwide protocols, standards, procedures and toolkits available on how to implement an SOA-architecture. The real challenge is to co-ordinate the agreements between several organizational units involved. The organization in view 'EDI-teelt+' is expected to play a key role in this. On behalf of the total arable farming sector they can negotiate about the content of messages that web services provide and make contracts on availability and quality of the service. Beside this organizational role, EDI-teelt+ can also play a role in integrating standards at a precompetitive stage, before information is used in a commercial application. So, in one case a webservice can directly communicate with a web connector of a commercial application or EDI-teelt+ can play a director's role and possible integrate it with other information. Time will learn how heavy the role of EDI-teelt+ in this process will be in the future.

Conclusions and future challenges

The presented results provide an in-depth investigation of the problem of information integration in AFSCNs and a vision for future. Developments should follow a service-oriented architecture (SOA) approach, and should support companies to focus on their business processes. At the same time attention must be paid to the organizational aspects. A step-by-step approach in which business partners themselves are responsible, organizational embedding and involvement of all relevant stakeholders are important success factors. In the arable farming sector this is initiated by further professionalization of the existing standards authority 'EDI-teelt'.

It can be concluded that major steps have to be made for successful information integration in AFSCNs. Main research challenges are:

- How to construct sector-specific SOA-architectures, adopting worldwide cross-industry standards and building upon existing industry standards?
- How to use business process management (BPM) concepts, including 'best practice' models, to allow flexible configuration of specific processes integrations?
- How to organize broad commitment, to embed developments in sustainable institutional arrangements, and to let it grow organically?

These challenges are faced in different sectors and in different countries independently. A concerted action is needed for coordination and knowledge exchange at the European level.

References

Erl, T., 2005. Service-Oriented Architecture (SOA): Concepts, Technology, and Design. Prentice Hall.

ESPRIT, 1996. Computer-Integrated Agriculture. http://cordis.europa.eu/esprit/src/results/res_area/iim/iim5.htm

Giachetti, R.E., 2004. A Framework to Review the Information Integration of the Enterprise. International Journal of Production Research 42(6), 1147-166.

Lazzarini, S.G., Chaddad, F.R., Cook, M.L., 2001. Integrating supply chain and network analyses: the study of netchains. Journal on Chain and Network Sciences 1(1), 7-22.

Lee, J., Siau, K., Hong, S., 2003. Enterprise Integration with ERP and EAI. Communications of the ACM 46(2), 54-60.

Leymann, F., 2003. Web Services: Distributed Applications without Limits: An Outline, BTW, Leipzig.

Tan, P.S., Lee, E.W., 2004. Services Technology for the Industry. JSSL.

Wolfert, J., Schoorlemmer, H.B., Paree, P.G.A., Zunneberg, W., Van Hoven, J.P.C., 2005. KodA: from knowledge to practice for Dutch arable farming. In: Boaventura, J., Morais, R. (Eds.), Proceedings of the joint EFITA/WCCA 2005 conference, 25-28 July, Vila Real, Portugal, pp. 883-888.

Wolfert, J., Verdouw, C.N., Beulens, A.J.M., 2007. Integration and standardization in arable farming practice: a service-oriented approach. In: Parker, C., Skerratt, S., Park, C., Shields, J. (Eds.), EFITA Glasgow 2007: Proceedings of the 6th Biennial Conference of the European Federation of IT in Agriculture, Food and the Environment, 2-5 July 2007. Glasgow Caledonian University, Glasgow.