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Realizing chain-wide transparency in meat supply chains based on global standards and a reference architecture

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ABSTRACT

One of the key concerns in meat supply chains is to provide chain-wide transparency, whereby food operators capture and share transparency data across the supply chain. To meet this concern a chain-wide transparency software system is needed that is able to address the desired stakeholder requirements. Unfortunately, designing and implementing a chain-wide transparency system is not straightforward. In this paper we provide a systematic approach for designing and implementing chain wide transparency systems. To this end, we first present a reference architecture that represents a generic design of such systems. Secondly, we discuss the systematic approach for deriving concrete architectures from the reference architecture based on stakeholders' requirements. Finally, we illustrate our approach with the design and implementation of a transparency system for beef supply chains.

1. Introduction

Lack of transparency in meat supply chains is a major problem, which has become evident from recurring crises and scandals involving meat products. A chain-wide transparency system will enable food operators to manage transparency data within their facilities (*i.e.* internal transparency) and to share transparency data with other food operators and stakeholders (*i.e.* external transparency) (Moe, 1998; Bertolini et al., 2006; Gandino et al., 2009; Bosona and Gebresenbet, 2013). When suitable internal and external transparency systems are not in place chain-wide transparency fails.

Internal transparency requires capturing the events that take place within the food operators. In the meat sector these events concern the things that happen to animals (such as birth, feeding, treatment, movement and slaughtering), and meat (such as splitting, cutting, mixing, transport and storage). To realize external transparency all food operators across the entire supply chain should use an internal transparency system and in addition these systems should comply with common standards for sharing transparency data.

In literature various chain-wide transparency systems are proposed. The most influential are food regulations which all food operators are required by law to comply with. In Europe, for instance, food operators must comply with the General Food Law (EC, 2002), regulations on mandatory registration of animals (EC, 2000, 2004, 2015), and regulations for tracking and tracing of meat products (EC, 2007, 2011). The state of chain-wide transparency in European meat supply chains is currently largely determined by these regulatory mandates. Regulations, however, do not specify how the systems have to be realized. Moreover, regulatory requirements are not strict enough to cover the needs of all stakeholders and mandate greater level of transparency. As a result current chain-wide transparency systems in place are not adequate (Kassahun et al., 2014).

Several researchers addressed the shortcomings of current transparency systems, often focusing on parts of the larger puzzle. Some focused on farms and proposed transparency systems for capturing and sharing transparency data about animals beyond what is mandated by regulations, such as data on what the animals are fed and when and how they are treated (Shanahan et al., 2009; Voulodimos et al., 2010). Others focused on meat processing facilities and showed how a meat product can be tracked as it undergoes various transformations (cutting and mixing) during meat processing (Mousavi et al., 2005; Donnelly et al., 2009). Still others focussed on the sharing of transparency data and demonstrated how transparency standards can be used to address this aspect of chain-wide transparency (Shanahan et al., 2009; Thakur et al., 2011; Feng et al., 2013). Although several meat supply transparency systems have been proposed, designing and implementing a chain-wide transparency system for a particular meat supply chain remains a difficult problem.

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A common solution for addressing such problem is the use of a *reference architecture* (Cloutier et al., 2010; Angelov et al., 2012). A reference architecture is a generic design that assists architects to derive *concrete architectures* for particular contexts. In this paper we present a reference architecture for chain-wide transparency systems. Depending on stakeholder requirements the reference architecture can be used to derive different alternative concrete architectures. However, deriving a concrete architecture involves many different design decisions and likewise it is not easy to derive a feasible architecture. Moreover, once a concrete architecture has been derived implementing the system based on the architecture is far from trivial.

In this paper we provide a systematic approach to support the design and implementation of chain-wide transparency systems. To this end, we first present a reference architecture that represents a generic design. Secondly, we discuss the systematic approach for deriving concrete architectures from the reference architecture based on stakeholders' requirements. Finally, we illustrate our approach with the design and implementation of a Chain-wide Meat Transparency System (CMTS) for beef supply chains.

The rest of the paper is organized as follows. Section 2 provides background information about the reference architecture. Section 3 summarizes related work and provides the problem statement. Section 4 describes the process for deriving a concrete architecture from the presented reference architecture. Section 5 presents CMTS demonstrating how its architecture is instantiated. In Section 6 we conclude the paper.

2. Background

2.1. Software architecture

Every software system has a software architecture that defines its design. This is not different for a chain-wide transparency system. A software architecture describes the components of the system, the interactions among the components, and the interaction of the system as a whole with its environment (ISO/IEC/IEEE, 2011; Bass et al., 2012; Tekinerdogan, 2014). A software architecture is an abstract representation that identifies the gross-level structure of the system and is important for supporting the communication among stakeholders, for guiding the design decisions, and for analysis of the overall system (Tekinerdogan, 2014).

A software architecture that addresses the concerns of specific stakeholders is here referred to as concrete architecture. Hereby, a stakeholder is defined as an individual, team, or organization with interests in, or concerns relative to, the system. A concrete architecture defines the boundaries and constraints for the implementation and is used to analyse risks, balance trade-offs, plan the implementation project and allocate tasks (Tekinerdogan, 2014).

Concrete architectures can be viewed as instances of a reference architecture, which is a generic design. In turn, a reference architecture is derived from the knowledge and experiences accumulated in designing concrete architectures in the past (Cloutier et al., 2010; Angelov et al., 2012). The concrete architectures differ from one case to the next depending on the requirements of the stakeholders involved. Reference architectures can be used descriptively to "capture the essence of existing architectures" or prescriptively to guide the development of new ones (Cloutier et al., 2010). Fig. 1 depicts the relations between reference architecture and concrete architectures.

2.2. A reference architecture for chain-wide transparency systems

We have provided an initial architecture for CMTS in an earlier study (Kassahun et al., 2014) to discuss the different concerns in meat supply chains. Fig. 2 depicts the complete reference architecture that elaborates on this earlier work. The figure is described in detail in the following sections.

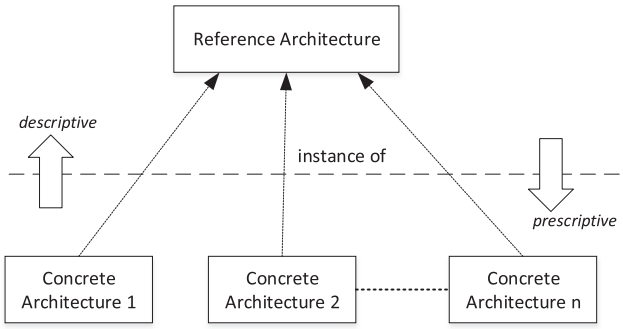

Fig. 1. Relation between reference architecture and concrete architectures.

2.2.1. Stakeholders

The reference architecture distinguishes between three main types of stakeholders, *food operators* (*fo*), *end-users* (*eu*), and *third-party* (*3p*) service providers. Food operators provide transparency data about their products and operations. End-users are individuals and organizations who wish to access transparency data. Third-party service providers facilitate chain-wide transparency by providing and managing transparency software systems. The stakeholders are summarized in Table 1.

2.2.1.1. Food operators. Five types of food operators are identified based on whether or not they have an internal transparency system in place and what type of transparency system it is. We identify two types of food operators who do not have their own private transparency system. They contribute to chain-wide transparency by transferring transparency data to the shared repository, where the data will be stored and managed. Small food operators, such as farmers, who use basic IT systems, enter data manually through the web interface of the shared repository; and they are labelled as *type 1 food operator* (fo_1). Large food operators, such as slaughterhouses, who have advanced IT systems in place, will most likely use automated batch data transfer, and they are labelled as *type 2 food operator* (fo_2).

We further identify three types of food operators who have a private transparency system. These systems are considered part of the chain-wide transparency system. Food operators who use a *legacy* transparency system (see next section for the definition of legacy) are labelled as *type 3 food operator* (fo_3); and those that use a standards-compliant (STD) transparency system are labelled as *type 4* (fo_4) or *type 5* (fo_5) depending on where the system is deployed. Food operators who deploy and manage their own transparency systems are fo_4; those who use on demand transparency systems following a cloud business model are fo_5.

2.2.1.2. End users. We can identify four categories of end-users: *consumer/shopper*, *business partner*, *food authority*, and *third-party*. Consumers and shoppers are individuals who mainly want to know more about the meat products they buy or consume. Business partners are the business customers and associates of the food operators, including the food operators of the supply chain. They need access to transparency data as part of their business dealings. Food authorities are legal authorities who need to, and are mandated, to access transparency data. Such is the case, for instance, during food alerts. Third-parties are those who provide transparency, certification or accreditation services.