The footprint of food
– A suggested traceability solution based on EPCIS

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Abstract
The management of agri-food supply chains is a complex task, being not less complicated through the increasing globalisation of agri-food markets. Together with globalisation comes harsh competition on price, increasing variety of products, longer transport distances and more complicated supply chains. Due to several food scandals the latest decades, governments and consumers are increasingly concerned with food safety. This implicates a need for extensive changes in the agri-food supply chains with regard to transparency, integration and food-tracking technologies. The purpose of this paper is to propose and discuss a traceability solution for food supply chains based on the EPC Information Services (EPCIS).

1 Introduction

The food industry can indisputable be held out as the most important industry in the world, and agri-food companies today are subject to tremendous pressure of the ever-changing business environment. During the last decades there has been an increased focus on food safety, accompanied with an understanding that food in itself has a non-negligible probability of being contaminated. In order to reduce the risk of food contamination, there are requirements both on how food is processed and treated (that is, reducing the probability of contamination), as well as requirements with regard to the withdrawal of products that are already shipped (that is, reducing the consequences of contamination). Figure 1 illustrates the food supply chain under study.

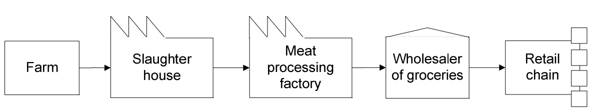


Figure 1: Food supply chain from farm to fork

Being able to efficiently recall a harmful product requires that information is available about the product's location "on time" and preferably "on line", whether any other products have been contaminated by the product, and alternatively where these contaminated products are. Traditionally, making the links between the input and output of a production process has been made using proprietary and in-house solutions. Upon request from the authorities, this information has been provided either on paper or using a non-standardised electronic format.

On the technological side, we are today at the beginning of integrating RFID into business workflows and cross company supply chains [1, 2]. RFID tags contain information that can be read from a distance, which considerably increases the number of points where data can be obtained through-out the supply chain compared with today's bar-code-systems. This technology is developing fast, and the use is exponentially increasing in industry. As RFID tags are getting better and cheaper and standards evolve, new possibilities in the use of RFID for tracking and tracing the material flow through the supply chain arise.

Furthermore, EPCglobal, a GS1 subsidiary, has defined standards for both RFID communication (that is, radio interface and protocols), numbering schemes (called Electronic Product Codes, EPC) and an infrastructure for collection and exchange of EPC related information (called EPC Information Services, EPCIS). EPCIS [3] seems to become the de facto standard for exchange of RFID/EPC events, and it is thus natural to see if this solution may be used to implement value-chain traceability and also internal traceability in the industry.

One should also note that there recently has been an increased research effort on electronic traceability (e.g. [4], [5] and [6]), and on traceability and RFID/EPC (e.g. [7] and [8]), for instance by using various XML-based tracking standards. However, most of these seem to focus on proprietary solutions for data exchange. On this background we think there is a potential for a traceability solution based on the standards defined by EPCglobal, as these also provide the users with a way of collecting and sharing information related to logistics and business transactions.

This paper is structured as follows: In section 2, we present the methodology selected for this research project. Section 3 covers the requirements for track and trace in the meat industry, while section 4 gives an introduction to the structure of EPCIS and how EPCIS events are constructed and handled. In section 5 we propose an EPCIS-based concept for tracking and tracing, followed by a discussion of the solution in section 6. Section 7 concludes our work, and includes some thoughts on future research topics.

2 Methodology

Development of conceptual constructions is often one of the first steps when conducting research, irrespective of whether the research is descriptive, exploratory or confirmatory. In this paper we combine insight from practice, operations management (OM) theory and information systems (IS) theory to construct a possible solution for tracing meat from farm to fork, based on simple EPCIS queries.

The practical insight is gained in the €3 million action research project Smart Flow of Goods (2007-2009) [9], which is funded by the Norwegian Research Council. In action research projects researchers are involved in and facilitate improvement processes. Being both participants as well as observers, the researchers get detailed insight into processes, procedures and data in the companies ([10], [11] and [12]). The proposed suggestion was developed in a joint team of both researchers and practitioners.

3 Requirements for track and trace systems in the meat industry

A meat supply chain can be decomposed into breeding in production farms, slaughtering at the abattoir, partition and refinement in processing plants, bringing the meat to the market in retail chains and HoReCea (hotels, restaurants and catering), and finally meat consumption by people (as illustrated in Figure 2).

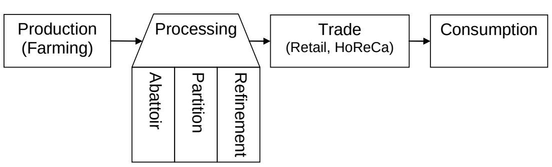


Figure 2: Overview of a meat supply chain

Traditionally, there have been disputes on how to implement traceability in the food chain. In most cases barcodes have been used as information carriers, although often only for internal operations. Also, the specific cost of the implementation is a major obstacle in adopting traceability for the industry. Only a few food manufacturers have experienced the trauma of having a food scandal, and thus experienced how much money and work is spent and lost on correcting the crisis.

When implementing a traceability solution, the basic requirement is that ingredients and products are uniquely identified and related. In addition, this information should be made available by efficient and non-proprietary methods.

Thus, we put forward that an EPCIS-based traceability solution for the meat industry should:

(1) Uniquely define the ingredients that have been used in each product
(2) Be based on predefined queries provided by the EPCIS standard
(3) Provide both upstream and downstream traceability

4 An introduction to EPCIS

RFID technology enables fast and automatic identification of objects, making it possible to perform identification at higher rates and less costs than with traditional technologies such as barcodes and written text. However, in order for RFID to become an efficient tool for entire value-chains, there is a need for standards and solutions enabling the exchange of RFID-related information. EPCglobal has defined standards for such information exchange, by providing the Electronic Product Code (EPC) standard as well as the EPCglobal Architecture Framework [13]. Figure 3 describes the functions and interfaces of the highest level of the EPCglobal Architecture Framework, called EPC Information Services (EPCIS), which aims at describing how the EPC-related information can be collected, stored and shared both within and across enterprises.

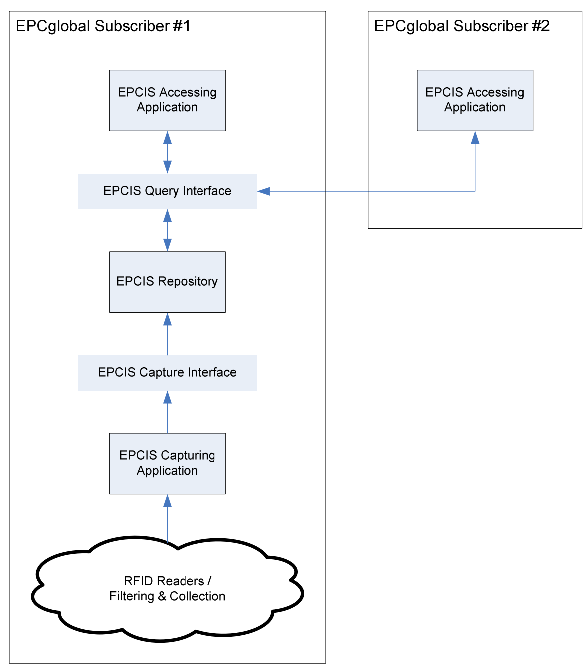


Figure 3: An overview of the EPCIS architecture [13]

A company or business unit will typically collect data (EPC numbers, business locations, etc.) from its RFID readers using one or several EPCIS Capturing Applications[1], and these applications will in turn convert the information to EPCIS Events that are transmitted to the EPCIS Repository via the EPCIS Capture Interface.

The EPCIS 1.0 standard defines four different event types. Together, these events make it possible to report that:

- one or more EPC tags are created, observed, or destroyed (**ObjectEvent**)
- one or more EPC tags are aggregated to, or disaggregated from, a larger unit, such as a crate or a pallet (**AggregationEvent**)
- one or more EPC tags are associated with, or disassociated from, a business transaction (**TransactionEvent**)
- a (non-identified) quantity of a certain item type is associated with an action (**QuantityEvent**).

For each event there are defined several fields depending on the event type, containing information about for instance which EPC codes are observed (the epcList field), the business location where the items are observed (the bizLocation field) or the identity of a "parent" in an aggregation process (the parentID field).

In order to retrieve data from the EPCIS Repository, an EPCIS Accessing Application submits an inquiry to the repository using the EPCIS Query Interface. The EPCIS standard defines one type of query for this interface, namely the SimpleEventQuery, and this query enables searching for events that conform to the defined input parameters (such as event types, EPC numbers, locations, read points, business transactions, etc.). Note that as the EPCIS data will be more or less confidential, the access to the EPCIS Repository will normally be available only to trusted partners.

5 Suggested solution

We suggest a traceability solution based on EPC and EPCIS, making use of the EPCIS TransactionEvent in order to construct the logical link between input and output. The output identity is stored in the parentID field, while the input identities are stored in the epcList field. The rationale behind using parentID for the process outcome is that only one event should be created for each finished product. The alternative would be either (a) to create one event per input-output relation, or (b) not being able to transmit the event until all of one input-type has been used. Furthermore, the two fields bizTransactionList and bizLocation are used to associate a traceability event with business transactions and business locations, respectively. We also suggest that the field bizStep is used to describe that an event contains traceability information according to a specified format, enabling different solutions and standards to exist in parallel without (too much) confusion. As the traceability information is not related to a physical read point, we also propose that the readPoint field is not used.

The suggestions above are summarised in Table 1.

Table 1 Suggested use of TransactionEvent fields

Field	Description
action	Value: ADD
parentID	The product identity (e.g. SGTIN[2])
epcList	The input identity (e.g. SGTINs)
bizTransactionList	Associates the transaction with production or purchase order (either internal, external or both)
bizLocation	Identifies the location where the process has been performed, represented with a GLN[3]
bizStep	Should indicate that this event contains traceability information conforming to a specified format (e.g. urn:epcglobal:epcis:bizstep:trace)
readPoint	Not in use (optional according to the EPCIS 1.0 specification)

In order to retrieve the traceability information, the predefined query called SimpleEventQuery should be used. This query will return events that match the provided input criteria, such as a specific parentID or EPCs present in the epcList. The example below presents a set of parameters that could be used when querying for traceability information:

```
SimpleEventQuery (
   eventType = TransactionEvent;
   EQ_action = ADD;
   EQ_bizStep = urn:epcglobal:epcis:bizstep:trace;
   MATCH_epc = {...};    (if searching for descendants)
   MATCH_parentID = ...   (if searching for ancestors)
)
```

Figure 1 Example of suggested parameters in SimpleEventQuery

Note that the SimpleEventQuery can be further restricted with regard to other EPCIS event fields, such as eventTime (indicating *when* an event was created) and bizLocation (indicating *where* an event was created). Using the aforementioned parameters, SimpleEventQuery can be used to implement both downstream tracking (where products containing a specific ingredient are identified) and upstram tracing (where ingredients used in a specific product are identified). Upstream tracing is achieved by recursively using the *MATCH_parentID* property of the SimpleEventQuery, while downstream tracking can be performed by recursively using the *MATCH_epc* property of the SimpleEventQuery.

[1] In principle the data may also come from other sources, such as barcode readers and manual entry.

[2] SGTIN – Serial Global Trade Item Number

[3] GLN – Global Location Number

5.1 An example of track and trace with EPCIS

Below an illustrative example is given, with eight traceable units (*TUs*) ranging from TU1 to TU8. Four traceable units (TU1, TU4, TU6 and TU7) are split and merged into four new traceable units (TU2, TU3, TU5 and TU8).

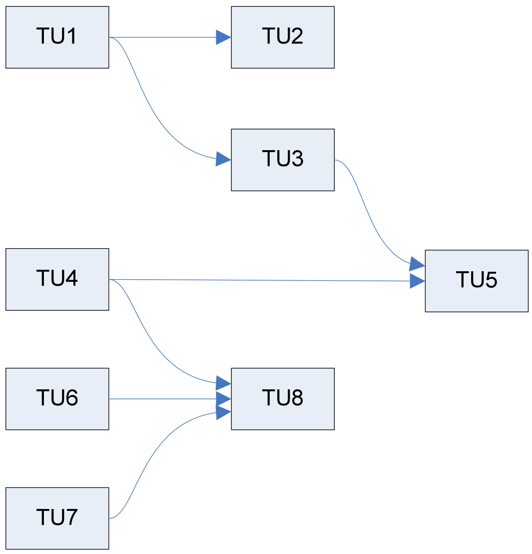


Figure 4: Relationship diagram of eight traceable units

The traceability messages in the example above would be as follows (TransactionEvent are denoted *TEvent*):

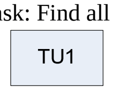
- TEvent(parentID=TU2 ; epcList={TU1})
- TEvent(parentID=TU3 ; epcList={TU1})
- TEvent(parentID=TU5 ; epcList={TU3,TU4})
- TEvent(parentID=TU8 ; epcList={TU4,TU6,TU7})

5.1.1 Downstream tracking

If one should wish to identify all the traceable units that have TU1 as either direct or indirect ingredient, this can be performed by a recursive search using SimpleEventQuery with the MATCH_epc parameter.

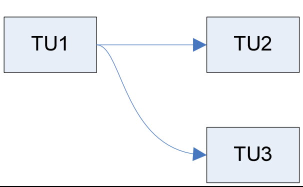
Queries and results

Task: Find all descendants of TU1



SimpleEventQuery (MATCH_epc = {TU1})

Query results:
-TEvent(parentID=TU2 ; epcList={TU1})
-TEvent(parentID=TU3 ; epcList={TU1})

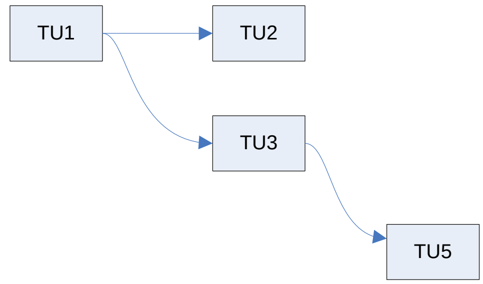


SimpleEventQuery (MATCH_epc = {TU2})

Query results:
- no events found

SimpleEventQuery (MATCH_epc = {TU3})

Query results:
-TEvent(parentID=TU5 ; epcList={TU3,TU4})



(As TU4 is not a descendant of TU1, it has been omitted from the figure.)

SimpleEventQuery (MATCH_epc = {TU5})

Query results:
- no events found

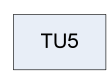
All descendants identified

5.1.2 Upstream tracing

In order to identify all the ingredients of traceable unit TU5, one should perform a recursive search using the SimpleEventQuery with the MATCH_parentID parameter.

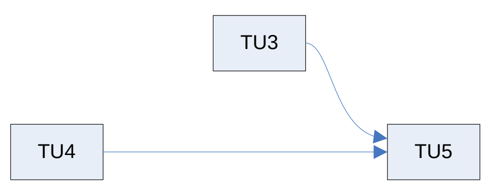
Queries and results

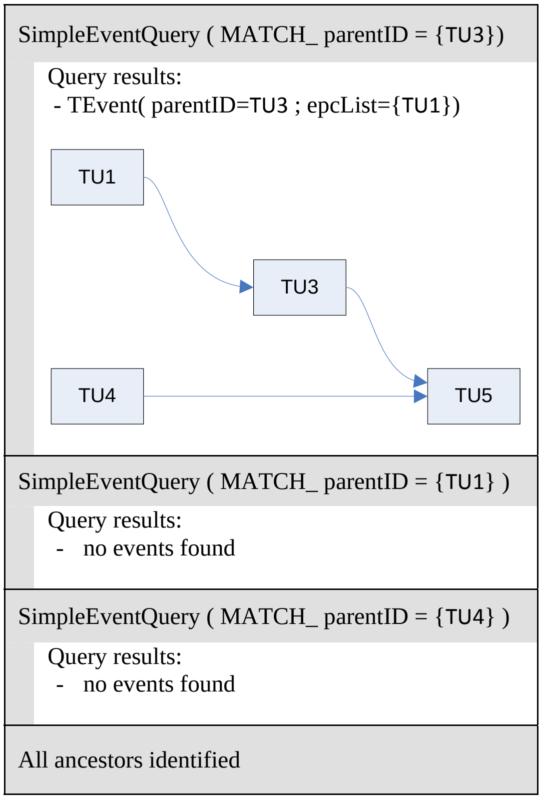
Task: Find all ancestors of TU5



SimpleEventQuery (MATCH_parentID = {TU5})

Query results:
-TEvent(parentID=TU5 ; epcList={TU3,TU4})





6 Discussion

A solution as described in this paper may provide full and instant traceability both within and between companies, by employing standardised numbering schemes and information exchange. Although the presented solution suggests the use of EPCIS, this does not mean that using RFID is prerequisite for implementing traceability. Consequently, the standardised numbers may be represented by any physical means, ranging from written text and barcodes, to data matrix codes (two-dimensional “barcodes”) and RFID tags. The only requirement should be that the numbers are encoded according to an internationally acknowledged format, and that all partners in the value chain can decode the identification into its numerical form.

The suggested traceability solution should be applicable for both internal and external traceability, although for traceability between different companies some extra measures should be taken. First, all involved companies have to use unique identifiers in order to avoid ambiguities. This could be ensured by using numbering schemes provided by GS1/EPCglobal. Second, one may assume that companies want to administrate their own data, and that information must be collected from several different locations in order to construct the complete traceability picture. Regarding the question of finding all the locations where information about a product is stored, EPCglobal has presented the concept of a Discovery Service. This service is planned to have the role of a search engine for traceable units, enabling any (authorized) user to find the (logical) location where information about a certain traceable unit is stored. However, the specifics of this concept are not yet completely agreed upon. Third the traceability information about the flow of goods between trading parties could be used to monitor parameters that may very well be stock exchange sensitive. This is an obstacle that needs to be taken into account using this solution for external traceability. Finally, there are also the issues of security and run-time speed (or latency). These topics should be subject to further studies before a complete and viable traceability solution can be expected.

7 Conclusions and further research

In this paper we have presented a conceptual solution on how EPCIS can be used to achieve both upstream and downstream traceability. The solution requires only standard EPCIS events, and provides complete traceability information through recursive searches through one or more EPCIS repositories.

A natural next step would be to perform practical tests with regard to scalability and latency, and also to look at issues regarding how to collect distributed information through the EPCIS Discovery Services.

8 Literature

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