AgroGrid: Composition and Monitoring of Dynamic Supply Chains

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Abstract

AgroGrid is a Business Experiment within EU project BEinGRID. The motivation behind AgroGrid is to introduce Grid technology in the agricultural sector and to create a Grid-based market in order to enable companies to deploy their capacities extensively as well as to ensure food safety via efficient tracking and tracing of goods and SLA-based monitoring mechanisms. In this paper we present the architecture of the AgroGrid system with above mentioned capabilities, focusing on the process of dynamic supply chain composition and SLA based monitoring of established supply chains.

1 Introduction

Today's consumers have increasing requirements according their food. Beside high quality, guarantee of origin and ethical correctness they also want to have individualized agricultural products concerning their state of health (e.g. in case of an allergy) or their way of life (e.g. vegetarians or competitive athletes). But from the nature of things, individual composed food (e.g. muesli, www.mymuesli.com) is produced in small units and partially with special components. Companies alongside the food supply chains (SC) will have to meet consumers' requirements to succeed in future market competition. Therefore, they will have to interact in dynamically changing relations to offer small units of individualized food in addition to the traditional food sales in long term contracts and huge batch units. But today contemporary food supply chains are far away from this dynamically interaction. They are characterized by fixed partner structures with long term contract relations. For this reason, they cannot handle consumer requirements properly and have no way to deal with overcapacities according their output. Another problem is the absence of efficient tracking and tracing mechanisms within food supply chains. At the moment, tracking and tracing is done by isolated systems or in a paper-based way on the company level or in close supply chains. While this might still work in fixed structures it will not be an adequate method in situations with dynamic and fast changing interactions for small quantities of food. On the other hand, Grid technology offers functionality which supports building of dynamic Virtual Organizations (VO)

[6][7], negotiation, monitoring and evaluation of Service Level Agreements (SLAs) [5][8][9] to cope with the raising needs.
The motivation of AgroGrid [4] – a Business Experiment within EU project BEinGRID [3] – is to create a Grid-based market place for capacity allocation and to enable companies to offer their capacities extensively and, simultaneously, to ensure food safety via efficient tracking and tracing of goods and SLA-based monitoring and evaluation mechanisms.
In this paper we present the architecture design of the AgroGrid system [1], which provides services for the composition and monitoring of dynamic supply chains in agriculture food industries using Grid technology, making use of trust-building commercialization support mechanisms.

2 AgroGrid Architecture

The AgroGrid architecture can be subdivided in four logical blocks, as shown in Figure 1. These logical blocks correspond to main functional blocks: Portals, VO-Management, Track & Trace and SLA-Management.

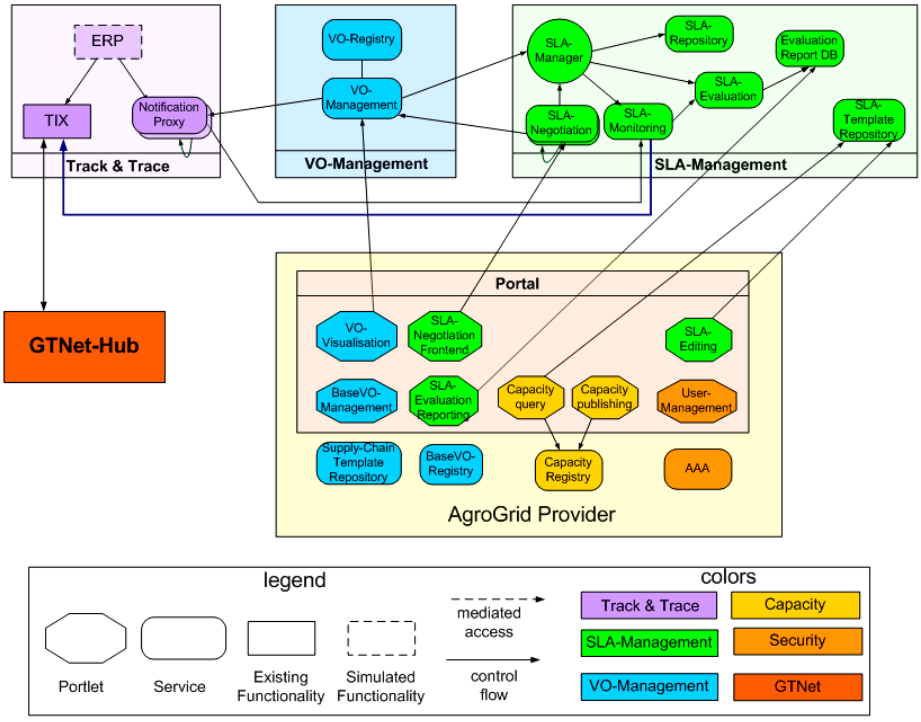

Figure 1: AgroGrid Architecture

The **Portal** provides AgroGrid users with a common, web-browser based, user-friendly, and secure interface to certain AgroGrid services. The AgroGrid portlets and services hosted on the portal enable AgroGrid users to perform registration and discovery of capacities, allow negotiation of SLAs and building of supply chains. The

AgroGrid portal allows supply chain members to access SLA evaluation reports, as a result of the evaluation of monitoring data, referring to quality and environmental conditions of food trade units during their production, storage, transportation or delivery.

The **VO-Management** is used for setup and administration of partner memberships in the supply chains which are managed by a supply chain manager (**SC-Manager**). The relationship between the SC-Manager and each of the SC-Members is expressed by a Service Level Agreement. These SLAs are monitored and evaluated by SLA-Monitoring and SLA-Evaluation, part of the SLA-Management logical block.

The tracking and tracing infrastructure of AgroGrid is based on GTNet (Global Traceability Network) [2]. The **Track & Trace** block consists of an Enterprise Resource Planning system (ERP), Traceability Information Exchange (TIX) [2] database and a Notification Proxy. The *ERP* serves as a source of tracking & tracing information, as well as a source of monitoring information about quality and environmental conditions during the production, storage, transportation or delivery of food trade units, located on the SC-Member's sites. The tracking and tracing information, as well as monitoring information provided by the ERP are stored in the local TIX database. Local storage of data is important for not violating company's data ownership - a crucial criterion for companies deciding whether to join the AgroGrid market place or not. The local TIX provides also interfaces for querying of traceability and monitoring information stored in the TIXs of the supply chain members. The access to TIXs of the supply chain members is mediated by a local TIX, and is secured by mechanisms provided by **GTNet-Hub** (Global Traceability Network-Hub) [2] which connects all TIXs. The Notification Proxy offers interfaces for submission of messages and manages their subscription, publication and notification. The Notification Proxy notifies supply chain members and the local SLA-Monitoring service about occurred delivery events.

The **SLA-Management** block consists of SLA-Negotiation, SLA-Monitoring and SLA-Evaluation services which are compliant with WS-Agreement [5]. The SLA-Negotiation service allows negotiating of the SLA between a capacity requestor and a capacity provider. The negotiation of SLA includes the negotiation of price, attributes, quality parameters of food to be delivered, environmental conditions of food during the transport or storage, compensation in case of SLA-violation, and other SLA-terms. The SLA-Monitoring service is responsible for the monitoring of SLAs which were successfully negotiated. In order to obtain monitoring information, the SLA-Monitoring service performs querying of monitoring data which is located not only in the local TIX database, but also in the TIXs of the supply chain members. The queried information is transformed into the metrics which were defined in the SLAs then. The monitored SLA-metrics are compared and evaluated in the SLA-Evaluation service against the evaluation criteria which were defined in the SLAs. In case of SLA violation detection, the SLA-Evaluation service notifies affected supply chain members about any occurred violation. The result of the SLA evaluation is stored in the evaluation report database and is accessible via the AgroGrid portal to supply chain members. The evaluation report serves for checking of successful SLA fulfilment, and, in case of a detected SLA violation it serves for the determination of penalty and compensation.

The **GTNet-Hub** connects all TIXs of the BaseVO-Members (see Section 4) and thus of the supply chain members. The GTNet-Hub maintains security mechanisms, which allow only authorized parties to access TIXs of the supply chain partners. The query of a certain food trade unit in a local TIX is mediated by GTNet-Hub to TIXs of the supply chain members who have located the food trade unit in the past.

3 Scenario Description

AgroGrid addresses the problems in the area of information distribution, building and monitoring of dynamic supply chains. In order to provide better understanding of the problem addressed in AgroGrid, we describe in this section a food related scenario as envisaged in AgroGrid.

Participants of a supply chain for apricots are operating in traditional boundaries delivering apricots in the traditional quality measures. They only deliver the amount of apricots asked for by their contract partners. In addition to the traditional distribution channel, the producers of apricots can offer overcapacities or specially treated batches (e.g. organically produced apricots treated meeting special allergic requirements) in the Grid-based market by registering them in the AgroGrid system. Capacities in AgroGrid include any products and services offered by a participant, e.g., food products, transport and storage capacities. The local consolidator searches for these special apricot capacities, using the AgroGrid system, if needed. The consolidator finds and contracts a provider of special treated apricots located in turkey and creates a critical mass of goods for export activities. The consolidator finds and contracts logistic companies, using the AgroGrid system, for delivering the apricots to retailer markets in Germany. Therefore, transport companies offer special containers for shipping the apricots. During the shipping, transport, and delivery, the quality and environmental conditions of food-trade units are monitored against negotiated SLAs. In this case the SLA contains also information about the treatment of the apricots to meet the special allergic requirements. The monitoring data is evaluated and stored in an evaluation report. In case of a SLA violation, the affected parties are notified immediately, about the level of violation and about the resulting penalty, as agreed in the SLA.

4 Composition and Structure of Dynamic Supply Chains

A **supply chain** in AgroGrid is represented by a Virtual Organization formed by those BaseVO-Members, who participate in the sale, delivery, and production of particular product or food trade unit. The **BaseVO** in AgroGrid is a pool of potential collaboration partners who are principally willing to share the traceability and monitoring information about trade goods which are, will be or were located on their company sites. For this purpose, each company maintains a TIX database, which is connected through GTNet with TIXs of other companies.

The following sections give details on the composition and structure of the supply chain concept used in AgroGrid.

4.1 Building dynamic supply chains

The composition of supply chain in AgroGrid is based on market mechanisms – law of supply and demand. By using the AgroGrid system, a company wanting to offer its capacities, publish them in the AgroGrid capacity registry, providing details on offer validity, product quality, quantity, pricing (optionally) and link to local SLA-Template repository, where the SLA-Template is stored. The other companies are now able to query and discover capacities stored in the AgroGrid capacity registry, and retrieve the associated SLA-Template. The SLA-Template contains in addition to the capacity, details like pricing, environmental condition of food during transport and storage, penalties in case of SLA violation, and delivery date. A requester of certain capacity, after selecting capacity from the capacity registry and retrieving the SLA-Template from a certain capacity provider, sends an offer to the capacity provider. The offer contains SLA-Template with modified or unchanged SLA-terms. The provider may reject the offer or may send a counteroffer to the capacity requester. If the provider accepts the offer, then he sends an acceptance notification to the requester with the (link to) accepted SLA.

After a party has established the SLA with one provider or capacity requester, it might select further capacities and initiate the negotiation process, in order to establish the SLA with further capacity providers or requesters. This procedure allows a chaining of parties, based on bipartite SLAs, in order to create *dynamic* supply chains of parties who participate in the sale, delivery and production of particular product or food trade unit.

The *dynamicity* of supply chains in AgroGrid refers to the timely extension of the supply chain by new partners, and to the possibility to remove or replace a supply chain member, who violated SLAs many times, by new supply chain members.

The structure of a supply chain, as envisaged in AgroGrid, is explained in the following section.

4.2 Supply chain structure

This section explains the structure of a supply chain in AgroGrid using an example.

Figure 2 shows the contract-based relationship between the members of supply chain SC1, formed by producer P, logistics companies LA and LB, consolidator C and retailer R. In the supply chain SC1 the consolidator C is the manager of the supply chain (SC-Mgr), as he has the complete view over all supply chain members. His relationship to other supply chain members is expressed by SLAs, shown by the lines in Figure 2. As shown in the figure, consolidator C has a contract with the logistics company LA, which itself has two subcontracting companies LX and LY. Therefore, the relationship between LA, LX and LY is expressed in a new supply chain SC2, in which LA takes the role of the SC-Manager. As a consequence of subcontracting, the supply chain SC2 is to be considered as a part or an extension of the supply chain SC1. Figure 3 visualizes the supply chains SC1 and SC2, showing the flow of products between the supply chain members, indicated by black arrows.

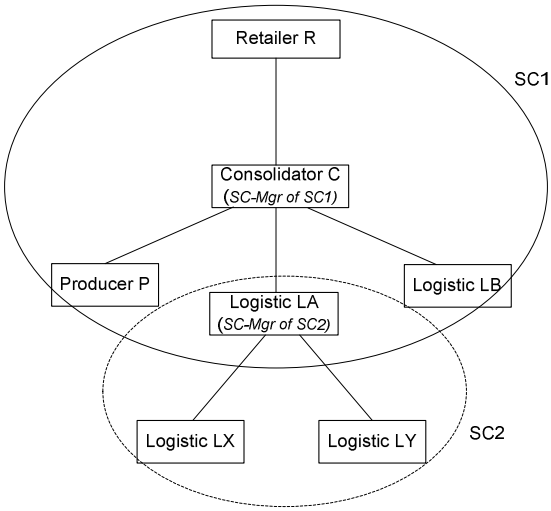

Figure 2: Contract based relationship between SC-Members

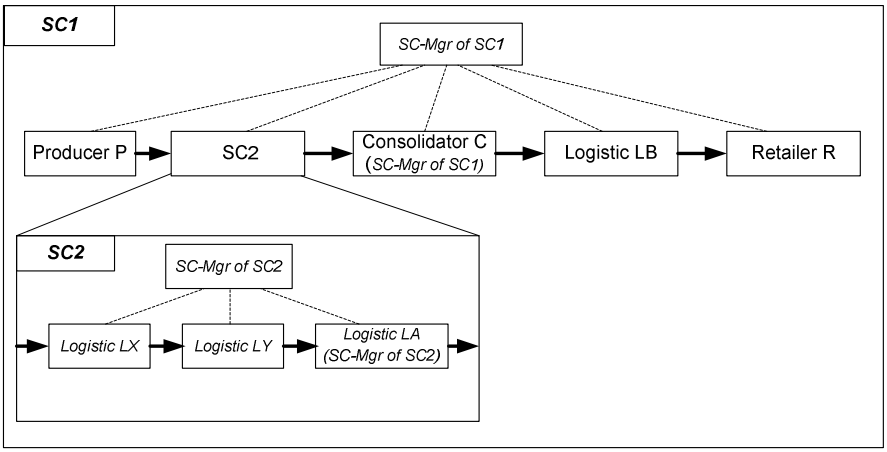

Figure 3: Supply chain structure

5 Monitoring of Dynamic Supply Chains

As already noted, Figure 3 visualizes the supply chains SC1 and SC2. The dashed lines indicate the access of supply chain manager (SC-Mgr) to TIXs of the supply chain members, in order to obtain traceability and monitoring information related to particular products shipped across the supply chain. As indicated in the figure, the supply chain manager (Consolidator C) has access only to TIXs of the supply chain members, including the logistics company LA. The logistics company LA is the supply chain manager of the supply chain SC2 and aggregates the traceability and monitoring information of logistics companies LX and LY in order to allow SC1-Manager to obtain aggregated traceability and monitoring information from LX and

LY. Such an aggregated monitoring concept protects business interests of supply chain manager of SC2, by hiding the structure of the supply chain.
The detailed process of SLA-monitoring is shown in Figure 4. The monitoring infrastructure of the AgroGrid platform is based on GTNet [2] functionality, which maintains tracking and tracing information of food-trade-units stored in the local databases of all supply-chain members. The monitoring infrastructure enables monitoring of SLAs between supply-chain members, based on query of monitoring information stored alongside supply-chain members' databases. A negotiated and contracted SLA between two parties in AgroGrid contains SLA-terms defining not only the amount, quality, and price of food products to be delivered, but also environmental conditions, under which they are stored and shipped. These SLA-terms define monitoring-metrics which are used to monitor the quality and especially environmental condition of incoming, stored or shipped food trade units. Every supply-chain partner publishes the monitoring data about incoming, stored or shipped food trade unit in its local-database, allowing access only to the buyer of the food trade unit, after receiving the trade-unit-id shipped with the food trade unit. The access to the local database is managed by each partner locally, based on the GTNet access mechanisms. As a consequence of restricted access, the approach proposed in AgroGrid is based on the hierarchical SLA-Monitoring and SLA-Evaluation, which might be deployed within each partner of the supply-chain separately or at least on the site of the supply chain manager, as shown in Figure 4. The SLA-Monitoring service queries GTNet for the unique trade unit-id shipped with the food trade unit. As a result, the monitoring data from the database of the product provider or logistic company, which delivered the product, is returned. The monitored data is evaluated against the SLA-terms contracted in the SLA. If SLA violations are detected, the affected parties are informed immediately. The result of SLA-Evaluation is stored in the local database and is offered to hierarchically higher settled partner in the supply-chain – buyer of the buyer.

6 Summary and Conclusion

The approach proposed in AgroGrid enables companies in the agricultural food sector to build and extend supply-chains (managed within AgroGrid as dynamic VO) by new partners in a flexible and dynamic manner. It supports the composition of hierarchical supply-chains and ensures the monitoring of food-quality on each level of the supply-chain hierarchy, determined by the order of the supply-chain partners. The quality management mechanism proposed by AgroGrid establishes trust-building commercialization support mechanisms between all partners in the supply-chain.

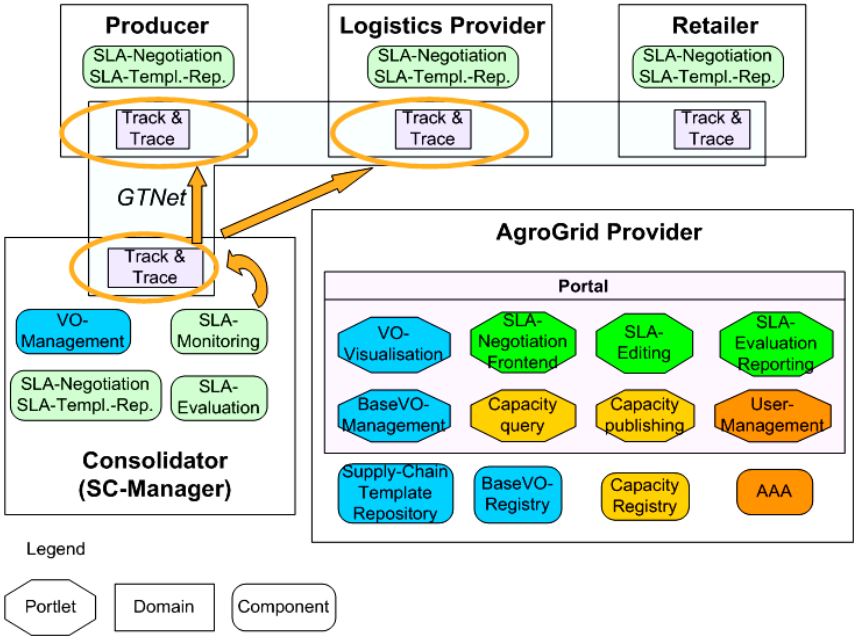

Figure 4: SLA monitoring

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