Open Service-Oriented Computing for Logistics: A Case in Courier, Express and Parcel Networks

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Abstract. Logistics service providers are forced to optimize their operations due to increasing market pressure. Outsourcing and network optimization are measures to improve their market position. Although the underlying operational research problems in logistics are well documented and the business tendency towards outsourcing already manifests itself in the growth of many local multi vendor logistics providers, the connections between both parts into an innovative and integrated logistics concept is not yet established. Our OPEN Service-Oriented Computing for LOGistics (OPEN SOC LOG) approach proposes a system which integrates state-of-the-art optimization tools with a service-oriented computing concept in order to provide a spectrum of standardized and combinable services for logistics companies ranging from tour and network optimization to contractual and accounting functionalities.

1 Introduction

There is high pressure to improve the efficiency of logistics services as a result of rising energy cost and fierce competition among carriers. Additionally, society asks for higher standards of environmentally good transportation practices [1]. This is also true for courier, express, and parcel (CEP) service providers that have to fulfill in-time delivery under multiple constraints. In Germany the CEP market has grown up to 2.3 billion shipments per year with an average revenue of 6.23 € per shipment in the last 20 years. Besides the three worldwide logistics service providers, the CEP market consists of several multi national companies (TNT, GLS, Trans-o-flex, etc) and a large number of local or regional service providers with special focuses (e.g. courier same day services, express next day, in-night transport etc.). In recent years, political and public pressure to lower CO_2 emissions, and to provide 'green logistics' has forced service providers to reduce the kilometers per delivery. This is a major factor for improving environmental and economic performance [2]. One way to improve the efficiency of logistics services is to introduce collaborative optimization. This can be done by

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jointly finding optimal routes for the vehicles or sharing transportation capacity. Transportation exchanges are an example of such an instrument. However, the current transportation exchanges are neither capable of directly integrating tour planning and other optimization services for logistics nor of fulfilling the complex requirements of the CEP market [3]. The OPEN Service-Oriented Computing for LOGistics (OPEN SOC LOG) framework addresses those challenges and combines optimization and transport exchange mechanisms to provide a variety of standardized, combinable services for logistics enterprises ranging from tour and network optimization to contractual and accounting functionalities.

2 Market for Service-Oriented Computing in Logistics

As a result of the size of the CEP market, the interconnections of the participants and the complex business and transport processes which have to be supported, a variety of software applications have been developed. Until now the only approach to structure the logistics software market has been started by the IML and lead to the current Transport-IT initiative which is essentially a software catalog for transport logistics. Hence, the structure IML uses is more technically oriented rather than market oriented. This paper proposes the following supplier-oriented structure for logistics transport software:

1. Process documentation tools created by CEP networks
2. Analytical optimization approaches from universities and research labs
3. Mobile device development or depot automation from automation companies
4. Map, navigation, and route planning software from geo data providers
5. Logistics market places software used by transportation exchange providers

Important for the current software situation is the history some logistics networks in the CEP market experienced during their development over the last 20 years. A good example is the German DPD which was built as a network of German regional logistics service providers. They decided to work together for nationwide parcel deliveries rather than to hand over national requests to the big three worldwide service providers (DHL, UPS, FEDEX). Their requirement on IT systems which support trans-company shipments both commercially and process wise originated in the early days of their cooperation. They founded a central customer solutions company which controlled and monitored all regional activities including the IT solutions development. The big three historically had their own IT departments and employed their own drivers. Today, the companies outsource their drivers, the IT infrastructure and most of the software used in the depots. Companies like Pitneybowes and Siemens Automation develop software and hardware for mail and parcel sorting systems. In recent years, smaller IT process and logistics specialists have developed special solutions for mobile scanners and communication equipment, often interfacing with a central IT system. Some of them (e.g. Kratzer Automation[1]) also provide a central system

[1] `www.kratzer-automation.com`

for the communication with the decentralized scanners and act therefore as full service IT outsourcing partners. Companies like the PTV, with a background in map and navigation software development, focus on network and tour planning. University or research labs[2] concentrate more on special intra company optimizations. Additionally, logistics market places arise[3], driven by the requirement for cooperation. Until now they have been freight marketplaces for bulk goods of full truck load (FTL) and less than truck load (LTL) but do not have a relevance for the CEP market. OPEN SOC LOG will fill the identified gaps in the logistics software market and unify three targets:

1. Inter company processing and commercial operations
2. Intra and inter company real time optimization
3. Interconnection between heterogeneous devices

For the current providers OPEN SOC LOG will be positioned as a supplement to the current solutions and will help to distribute further their own solutions through the network characteristics of OPEN SOC LOG.

3 OPEN SOC for Courier, Express and Parcel Networks

There is few literature on service-oriented computing applications for logistics. Talevski et al. [4] present a SOC-based framework for logistics service providers. They emphasize the importance of standardized SOC alliances especially for smaller and medium sized companies in the logistics sector. The introduction of combinable SOC structures is appropriate to foster cooperation and collaboration in the logistics sector. Unfortunately, the work of Talevski et al. [4] mainly focuses on the SOC aspect and does not mention in detail the requirements and types of services that are needed in logistics environments [5]. This is essential for effective and broad application of such a system. Therefore, we introduce the OPEN SOC LOG framework with requirements and services needed in logistics.

3.1 A Pragmatic Definition of OPEN SOC LOG

Web services deliver a wide range of content in a machine-readable way [6, p.3]. In this context the terms service-oriented computing (SOC) and service-oriented architecture (SOA) are often used. SOC is a new paradigm in computer science, that aims at an easier integration of existing application components to construct and implement new applications [7]. This includes web services, but has also a broader scope. Generally, SOC can be seen as an approach to couple already implemented functionality on heterogeneous and distributed systems [8]. SOA is a building block within the concept of SOC. 'SOA supports service-orientation in the realization of the strategic goals associated with service-oriented computing' [9]. We base our project on the concepts of the 'Reference Model for Service Oriented Architecture'[4] [10]. The basic elements of this reference model are:

[2] www.iml.fraunhofer.de
[3] www.transporeon.com
[4] www.oasis-open.org

Service: The service is offered by a provider and grants access to a capability for a consumer. For OPEN SOC LOG the service consumer requests information from the service provider, who returns the requested information (e.g. daily route planning).

Dynamics of services: The dynamics represents three concepts that are required to interact with the service:

- **Real world effect:** The real world effect describes the consequences of the online transactions to the real world. For OPEN SOC LOG, an example would be that after a tour optimization a driver actually drives the previously calculated tour.
- **Visibility:** It is required that the service consumer is able to find ('see') the service. Moreover, the provider has to describe the service he offers thus enabling the consumer to find the requested service. As a prerequisite, the service has to be accessible for the operation process. This service registry is based on the idea of a triangular relationship between a *service requester*, a *service provider*, and a *service registry* in the SOA concept. This enables the supplier to register the service it offers and the consumer to find the solution that best fits its needs [11]. In our case, an OPEN SOC LOG service provider would register its service (e.g. route planing, tour planning, Geo coding etc.) at the *service registry* and a CEP service provider (*service requester*) would search for its preferred service (or combination of services) in the *service registry*.
- **Interacting with services:** In many cases the interaction with the system is performed by sending messages, but it might also be done by modifying a shared data resource. For OPEN SOC LOG both ways are feasible and no decision regarding that concern has yet been made.

About services: In addition to the dynamics of the service within its environment, the 'about service' deals with aspects of the service description and execution. There are no specifics concerning OPEN SOC LOG.

- **Execution context:** The basic idea behind execution context is to describe everything related to the execution of the service. This contains information on the infrastructure as well as agreements concerning the execution process. There are no specifics concerning OPEN SOC LOG.
- **Policies and contracts:** The regulation of the agreements for the usage of a service and the relationship between provider and requester is summarized under the topic 'policies and contracts'. For OPEN SOC LOG this is an important topic, as the service consumer is charged for its request and in return has a precise expectation of the results and the QoS.
- **Service description:** The service description contains all information required to use the service. For the OPEN SOC LOG scenario this description would contain details about the information required for the optimization process and an accurate definition of the results that service is going to deliver. This is especially important for the service broker to find the suitable combination of services via UDDI.

In addition to the above listed concepts, OPEN SOC LOG has to fulfill more requirements that are specific to our application domain:

1. Motivation, market development and standardization
2. Trustworthiness, privacy and security
3. Computational complexity
4. Billing and service level agreements

These specific requirements to service-oriented computing will be discussed in detail in section 4. Nevertheless we can already give a general definition of OPEN SOC LOG:

OPEN SOC LOG is based on the idea of SOA but extends the design principles to features required to fit the needs of the logistic planning domain. The term 'open' reflects the aim of using a standardized way to allow as many customers as possible to make use of this framework.

For reasons of simplification, we stick to this formal definition approach and leave out further technical details, such as SOAP and underlying XML.

3.2 The Case of Courier, Express, and Parcel Networks: KolOptNet

The research project *KolOptNet*[5], jointly realized by the chair of IT-based logistics of the Goethe University Frankfurt and Pick Point AG, focuses on the optimization of last mile delivery of CEP service providers [12].

The common industrial application is characterized by a periodical calculation of optimal tours (e.g. once a year). In order to improve the efficiency of a CEP delivery network the KolOptNet solution allows a daily optimized and simulation-based tour planning. The optimal tour is determined by solving a vehicle routing problem with time windows. Moreover, we simultaneously consider the effects of driver learning which reduce the delivery times by up to 40%. Therefore, we calculate regular tours for all drivers, which can be adapted every day. The set of potential recipients is aggregated within a delivery corridor.

The cost efficiency of the network is further improved by integrating collaborative aspects. Neighboring subcontractors may exchange dispositive customers who are situated between regular tours of two drivers. Fig. 1 illustrates the allocation of dispositive recipients to regular tours. This collaborative transportation planning is realized by introducing combinatorial auctions, which have proven their usefulness in this context in several previous studies [13]. In addition, we allow flexible delivery corridors in our optimization model instead of the commonly used fixed areas. Such drivers have to adapt stepwise to the new conditions in the flexible area by exploiting learning effects [12]. Finally, we aim at providing an integrated software prototype using service-oriented architecture (SOA) which combines the route planning and the combinatorial auction services. The modularly designed system uses historical as well as the current days data to determine the sorting plans for the packages and the optimal delivery tour. Furthermore, we transfer our output data to the wireless mobile package delivery scanner devices which in turn collect data from the generic delivery process.

[5] `www.koloptnet.de`, the project is funded by the IKT2020 initiative of the Federal Ministry of Education and Research (Grant No. 01IS09016B).

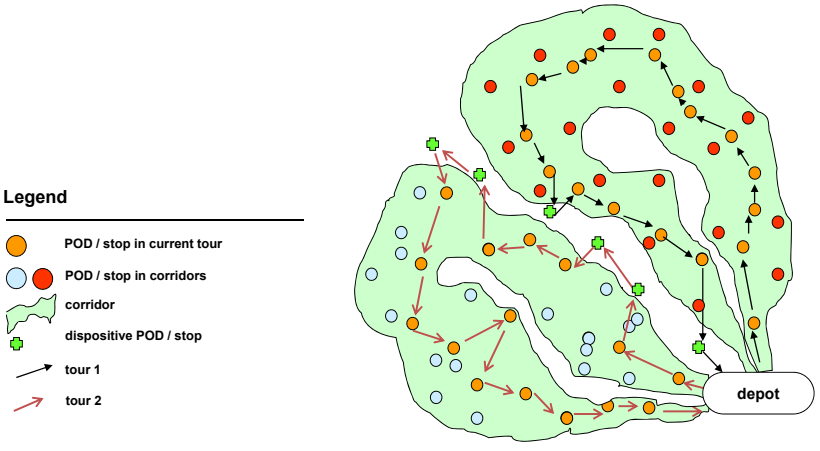

Fig. 1. Integration of dispositive recipients into regular tours

4 Challenges of OPEN SOC LOG

Referring back to our definition in Section 3.1, OPEN SOC LOG is based on the SOA description while extending the design principles to features specific to the logistics planning domain. The term 'open' implies the use of standards in order to attract as many costumers as possible. With respect to the economic and technical properties we must also consider privacy and security issues as well as service levels concerns. The reasons are now explained according to section 3.

4.1 Motivation, Market Development and Standardization

Although logistics market places have become important for bulk goods logistics, they have not reached a relevant penetration in the CEP market yet. This comes from the fact that single trade values in the CEP market are too small to justify the setup costs unless there is a high degree of automation. The similarity of goods in the CEP industry is much higher than in the bulk goods logistics such that automated trading and order processing could work. But why should a supplier or customer actively participate in a new logistics market place which has not yet shown to have the critical mass to fulfill most of the requests or offers? The motivation could arise from individual optimization results the requester can get out of the OPEN SOC LOG framework. At the beginning, small local network optimizations for local requesters could ensure growth and usage of the platform. After that initial phase the broader usage of individual optimization advantages can be stimulated. This reflects the current situation in the bulk goods market places. Within a norming phase individual service providers encounter supply and demand structures which push market liquidity. Only by defining an open standard, the OPEN SOC LOG framework will be able to collect the critical mass of users that is required to generate considerable economies of network while fostering collaboration in the logistics network [14].

4.2 Trustworthiness, Privacy and Security

The OPEN SOC LOG has to overcome the issue of trustworthiness and privacy. With privacy, the participant fears that his personal data will be a common good or at least something which makes him dependent on the platform. This could keep him away from providing his network and parcel information. Trustworthiness addresses a special problem of game theory where the participants can improve their position in the negotiation process through deception. Whereas the privacy issues have to be overcome by technology and contractual design, the trustworthiness issue can be solved by special mechanisms [15]. On the technical side OPEN SOC LOG has to provide the common security mechanisms [7].

4.3 Computational Complexity

Optimization problems in CEP networks are often NP-hard. For this reason heuristics seem to be an appropriate solution method. Additionally, real-world constraints are often more complex than the ones used in the operations research literature. Complexity reduction is required at the expense of solution quality. OPEN SOC LOG enables the use of clustering methods and supports driver learning [12]. Due to this computational complexity, we have to define service levels for the services providers. Calculating a solution for a routing problem may take a long time if the optimal solution is required, but while the use of heuristics normally significantly reduces calculation time, it also reduces the quality of results. A trade-off between complexity reduction and service quality must be integrated into the billing services.

4.4 Billing and Service Level Agreements

In order to provide a powerful instrument for logistics service providers, the platform, with its services, has to ensure that the acceptance and realization of a request can be provided for a reasonable price. Otherwise the cost for backup strategies for the requester will be to high. Additionally, the platform has to ensure proper billing, payment and the creditworthiness of the platform participants. The platform will therefore use standard toolkits like credit check which are provided as web services to overcome that hurdle. In connection with the calculation time/quality trade-off, the OPEN SOC LOG framework should also provide reasonable service level agreements [7,16].

5 A Service-Oriented Architecture for Open Logistics

The OPEN LOG SOC services will be implemented in WSDL. Accordingly, the message exchange will be conducted using XML files. The message based communication model is an appropriate structure for exchanging large amounts of data, processing them through the service and returning the results. The results can be trivial or complex, the feedback can be synchronous or asynchronous. As

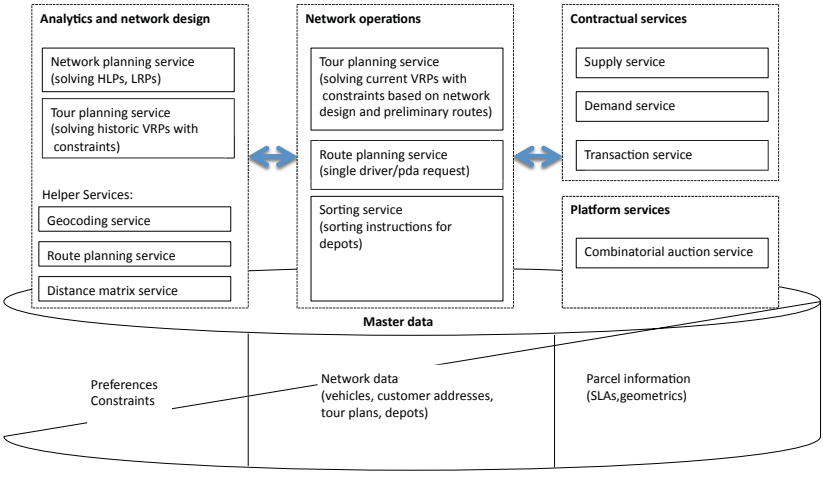

Fig. 2. Groups of services in the OPEN SOC LOG framework

described above a successful service definition must keep the services independent. Another challenge arises from the fact that logistics networks have tight time frames for the physical delivery as well as in the decision or deal making process.

The services in OPEN SOC LOG can be grouped as follows (see Fig. 2):

- Analytics and network design
- Network operations
- Platform and contractual services

The grouping reflects both the introduction of the services to the market and the attractiveness to the service requesters over time. The group 'analytics and design' can be used by local or national service providers to optimize their own business without interaction with other logistic service providers. The results of the optimization services can be used as input to 'network operations' where daily routes and tour plans can be optimized and used within the operations. The platform and contractual services fulfill two objectives:

- Commercial process support for logistics assignments
- Optimization across suppliers

and can be used in two different ways:

- Use of optimization outcomes to manually create supply and demand on the OPEN SOC LOG platform
- Use of inter organizational optimization capabilities of OPEN SOC LOG where tour plans of all connected service providers will be jointly optimized using tour optimization and combinatorial auction services.

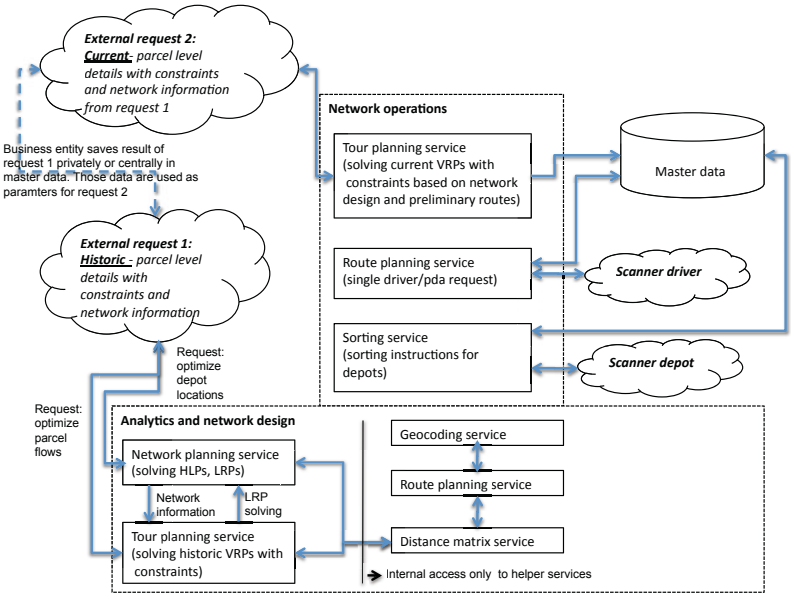

Fig. 3. Organization of technical services in the OPEN SOC LOG framework

5.1 Analytics and Network Design

Network planning and tour planning are the core services within analytics and network design. They are accessible externally by service requesters. Those services use the helper services 'geo coding', 'route planning' and 'distance matrix' to fulfill their optimization work properly. The network planning service basically solves depot and hub location problems [17]. Network planning requires parcel flows plus the planning parameters (vehicles, existing structures, etc.) as input and produces optimized locations plus tour plans as output. Route planning realizes a multi constraint VRP solution [18]. The meta heuristics used differentiate from existing solutions by integrating the driver learning aspect. The algorithm uses Ant and Tabu Search [18] optimization elements to produce good solutions within reasonable time.

5.2 Network Operations

The analytical and design services deliver optimized network data within the network operation services. The core is tour optimization applied on a day-to-day base. It uses historic tour data from prior operations [19] to optimize the daily business. This enables the OPEN SOC LOG framework to exploit driver learning extensively. The structure and relationship among network operations, analytics and design is shown in Fig. 3. Logistics service providers should not be bothered by interface and mobile scanner software development. Thus, there are

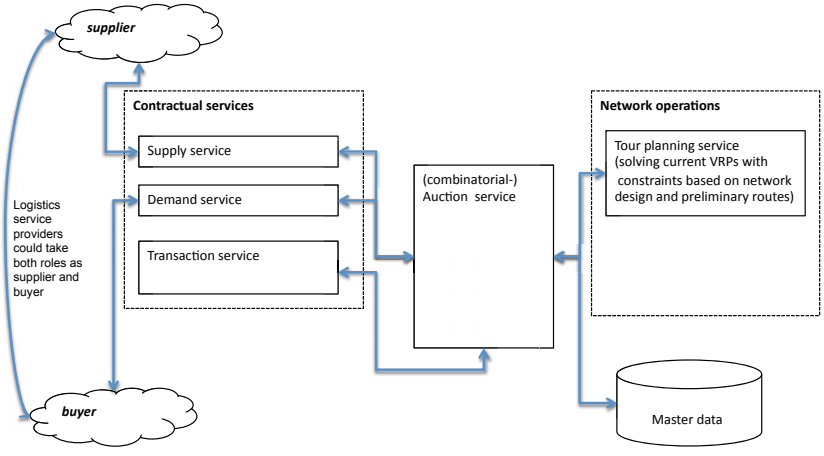

Fig. 4. Organization of business services in the OPEN SOC LOG framework

web services for sorting and driver scanners. After requesting sorting or route instructions based on a route or depot ID, the service delivers such data.

5.3 Platform and Contractual Services

The platform service basically realizes a logistics marketplace and uses combinatorial auctions for realizing complex buying scenarios where either the buyer or the seller of logistics services are not able to fulfill the logistics requirements alone [14]. As the input for the platform service has to be very accurate in terms of data structures, the supply and demand services help to translate more complex buying or selling offers into a 'clean' structure. Fig. 4 shows the input output relations of platform, contractual and network operations services. The combinatorial auction itself uses the route optimization service to evaluate the optimal exchange or trade of route elements.

6 Conclusion

The logistics software market has a lack of service-oriented logistics software which combines intra and inter-company processes. Our OPEN SOC LOG framework integrates several combinatorial optimization methods to solve large and rich VRPs while increasing provider's efficiency and therefore stimulating participation in the inter-company components. The SOA-based framework allows inter company optimizations supporting the relevant business processes especially in CEP logistics. Following the analysis of the current supplier structure in the logistics software market, the open positioning of OPEN SOC LOG will facilitate cooperation with current software companies, allowing them to use that part of the service framework which fits into their own service offering.

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