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# LOGICAL—Development of Cloud Computing Platforms and Tools for Logistics Hubs and Communities

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***Abstract*—Logistics service providers (LSP) are facing an increasing complexity of the logistics sector, i.e. growing levels of process fragmentation plus increasing speed, customization and service demands of logistics clients. Adequate powerful, integrated ICT infrastructure and tools are a prerequisite for keeping pace with the ever increasing service level demands within international logistics. The Cloud Computing technology offers significant advantages for data, process and service management and integration. To cope with the related innovation and migration needs, the Central Europe project LOGICAL focuses on the development and implementation of innovative cloud computing technologies. Special attention is devoted to international cooperation of SME-size LSPs. This paper introduces the conceptual basics of LOGICAL, basic use cases requested by the LSPs, and the addressed target groups of LOGICAL clouds. The results of an extensive user survey and demand analysis are presented as well as the related consequences for the cloud architecture.**

## I. Introduction

### A. Mega Trends and Challenges for Logistics

ONGOING globalization and economic growth are drivers of continuously increasing demands for the volume and speed of logistics capacities and operations. In addition to the simple growth of flow quantities, there is an augmenting effect of the trend towards more and more customized and individualized production and delivery. Logistics service providers have to cope with clients' expectations to change the logistics processes from push to pull direction. Value added service components need to be included and managed as a part of growingly complex supply chains. Frequently, several service partners contribute to fragmented overall logistics processes. The benefit of this increase of complexity is added value in logistics, the challenge, however, consists in the additional need for control and IT-support.

In some EU countries, logistics is now among the top three economic sectors. The related growth rates, however, are kind of alarming, especially if looking at the development of cargo traffic on European corridors. 2011 for instance, cargo transit traffic on German freeways was predicted to grow by 150% within 15 years [4]. This calls for additional infrastructure and intermodal cargo transport capacities. Logistics, on the other hand, is a highly sensitive early-indicator of cyclical economic fluctuations. In recent times of recession the logistics sector "overreacted" leaving significant parts of the logistics assets and infrastructure unused. Therefore, optimization and "smart use" of existing resources are actual demands of highest priority.

Smartness in logistics corresponds with the general industrial developments towards cyber physical and smart systems which are interconnected via web based platforms (keyword: "industry 4.0"). The feasibility of these developments is strongly related to the rapid progress of internet based IT-solutions such as cloud computing. Web based connectivity of smart objects with "product memories" opens perspectives of self organizing and highly flexible production processes provided that the related logistics processes are compatible and still capable for just-in-time / just-in-sequence supply. Keeping pace with the related computational innovation requirements is one of the main requirements of maintaining competitiveness in logistics—a major challenge especially for logistics service providers of SME-size (SME: small and medium sized enterprises).

### B. Logistics hubs and Communities

Logistics hubs, such as airports, seaports, freight villages and others, usually provide multimodal traffic and transport infrastructure and intermodal freight shift facilities. Moreover, a characteristic feature of these hubs is the local agglomeration and availability of multiple logistics service providers with different service profiles and specializations. Fig. 1 illustrates the segmentation and heterogeneity of logistics service chains by means of the example of an airport and the air freight supply chain between producer and final product recipient. The control and optimization of the total logistics service chain in terms of cost, duration, service level and flexibility requires highly sophisticated and integrated IT-support.

In a growing number of European logistics hubs the community of local logistics service providers created collaborative

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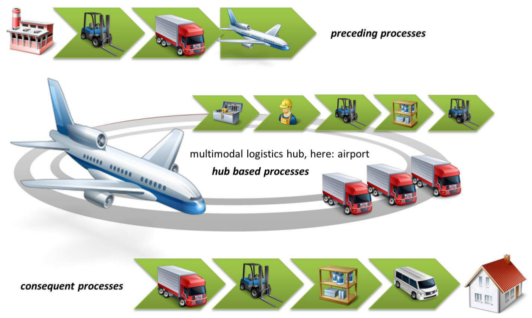


Figure 1. Chain of basic logistics processes

organizations, such as cooperation networks, logistics clusters or hub specific service enterprises, which provide 4PL-services in order to configure, coordinate and manage heterogeneous multi-agent service chains or to take care of mutual common interests, activities and facilities. One of the natural tasks of these organizations is to promote technological innovation within its logistics community and to provide supporting means and tools for this purpose. Within this context, supporting the development and operation of cloud computing tools for logistics communities and providing help in the related migration process could be a new area of value added activities for logistics networks, clusters and hub service organizations.

### C. R&D-Projects InterLogGrid and LOGICAL

The "Netzwerk Logistik Leipzig-Halle" is a logistics cluster organization of the logistics region Leipzig-Halle in Central Germany. It comprises about 110 member institutions; more than 85% of those are private enterprises in addition to the regional municipalities, chambers of commerce and academic institutions. In total the cluster members employ about 17,000 people with a comprehensive annual turnover of 1.5 bio. €/yr. In the recent past the hub-region experienced a strong growth of logistics activities due to the high increase of air freight operations at Leipzig/Halle airport. Thus, in 2011 the Leipzig-Halle logistics region was evaluated to be "the most dynamic logistics region in Germany" [9] and a well-established European Gateway-region [6]. The Leipzig-Halle logistics cluster is directly or indirectly involved in the following two joint research projects which aim at the development of cloud computing tools for the logistics application domain.

InterLogGrid was started in 2009 as a part of the German D-Grid Initiative [8], sponsored by the Federal German Ministry of Education and Research (BMBF). InterLogGrid aims at grid- and cloud based representations and compositions of the basic logistic processes as displayed in fig. 1. The project developments include an application oriented survey, demand and use case analysis, a logistics ontology and a uniform service-oriented modelling approach to the virtual composition of complex logistics service chains. The project partners are the airports of Leipzig/Halle and Stuttgart, departments of the universities of Leipzig, Stuttgart and Karlsruhe and the companies AHP, Jessele, PSI and SALT Solutions. Additional project specifics are presented in [7]. The developments of InterLogGrid were essential input to the European R&D-project LOGICAL.

LOGICAL was started in 2011 within the Central Europe programme of the European Regional Development Fund. LOGICAL's objective is to enhance the interoperability of logistics businesses of different sizes, to improve the competitiveness of Central European logistics hubs through a decrease of transaction costs (better access to systems of global players), and to promote collective (sustainable) modes of transport (multi-modal cooperation). LOGICAL partners develop pilot-versions of regional logistics clouds, and bring a transnational cloud computing tool to operational capacity. Beneficiaries of the project are especially small logistics companies that can reduce their transaction costs and hence increase their ability to collaborate with global players. The 14 project partners comprise institutions and enterprises from 6 Central Europe regions (Germany, Poland, Czech Republic, Hungary, Slovenia and Italy) and include an airport, a sea port and several freight villages as well. Additional project specifics are presented in [1].

### D. Target/User Groups

*1) Logistics service providers (LSP):* The main target group of the logistics clouds are small and medium sized logistics companies in a specific logistics region. This includes logistics service providers of different sizes and complexity. The LSPs may benefit from introducing cloud computing in the following areas: improvement of their competitiveness, improvement of their level of computational innovation capability, saving of resources (e.g. reduction of fuel consumption by transport optimization), improvement of their service level and thereby increase of customer satisfaction.

Regarding the supply chain, the use of cloud computing can help LSPs in achieving a better data integration to customers and partners by improving the "web-compatibility" of the company's IT system.

*2) Shippers of all logistics-related industrial and trading sectors:* An additional target group of logistics cloud development are shippers with high service level requirements in their overall service and supply chains (including outsourced / contracted partitions). LSPs and shippers can benefit from cloud computing likewise. Shippers may fulfil their strategy of outsourcing non-core processes more rigorously and gain the capability to offer final recipients full tracking and tracing services on customer's premise, improvement of the service level, faster adaptation to changing customers demands, higher cost efficiency, reduction of throughput time and facilitation of overall process planning and optimization.

*3) Logistics hubs & clusters:* Logistics hubs, clusters and networks are potential logistics cloud operators and cloud service vendors, if they want to support the regional logistics economy. Strengthening the local logistics community and offering high-level but low-priced software products can be an important benefit for site marketing and settlement support for investors. Moreover, the provision and operation of a regional logistics cloud is a strong argument for the existence and benefit of a logistics cluster or hub based collaborative organization since these services support the site attractiveness and the competitiveness of the member community.

*4) Logistics-related software developers and vendors:* The main benefits of a logistics cloud for logistics-related software developers and vendors result from the the ongoing change of the IT and software market. In the long run, software developers and vendors simply will be forced to offer cloud-compatible versions of their products due to the growing demand of their clients.

## II. Cloud Computing: Features and Promises

### A. General Features and Status of CC

*1) Cloud Computing:* According to the commonly accepted definition of the National Institute of Standards and Technology "cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction." [5]

Cloud computing services are deployed on demand by a self-service access like a portal or an API so the customer is able to provision his computing capabilities when and how he needs them. The second important fact of cloud computing is the usage of widespread technologies to provide the services like the internet, standardized protocols and mostly web based solutions that can be accessed by a web browser instead of a fat client. To enable a fast provisioning of the cloud services a pooling of the underlying resources and services that provide multi-tenancy is necessary. Since the cloud's IT-services are virtualized it is easily possible to scale rapidly up or down according to the demands. To implement such a scalability of services it is necessary to measure the use and capacity of all the services including the services that are used by the requested services. Thus, the resource usage is monitored, controlled and reported by the cloud for the administrations tasks of the cloud computing provider as well as information demands of the cloud service consumer.

All services provided in a cloud are being charged on a pay as you go accounting model, i.e. the customers do only pay when they use a service according to the resources consumed. This is called the pay per use principle.

*2) Layers of Cloud Computing:* [2], [3], [5] and many more agree that cloud computing is a layered model of different abstraction levels. The most basic layer is Infrastructure as a Service (IaaS). IaaS provides very basic IT-infrastructure services like CPU-cycles, RAM or disk space. Very often these resources are bundled in so called virtual machines whereas the name implies the fact that these resources are virtualized.

The Platform as a Service-layer (PaaS) utilizes the services provided by the IaaS-layer to provide a development and runtime environment. By those PaaS services software developers are able to create their own software services and offer them to their customers.

The next layer is Software as a Service (SaaS). SaaS provides a complete application to the customer without the need to care about licence models of the software or the demand of resources. All technical requirements, updates and patches are handled by the cloud service provider, the customer can confine himself to doing his business with the software solutions. Typically the SaaS-layer is being charged on a per user basis or per transaction basis so the pay as you go-paradigm is met.

Following the everything as a service (XaaS) approach the projects interLogGrid and LOGICAL define two additional layers on top of the Cloud Computing stack. The first additional layer is Logistics Applications as a Service (LAaaS) that is comparable to SaaS. The different name has been chosen to emphasise the domain specificity of the software that will be provided. The second additional layer is Logistics Processes as a Service (LPaaS). This layer provides services of supply chain management. Thus, LPaaS is on top of the LOGICAL cloud stack. (Fig. 5)

### B. Economic Implications for LSP

The specific "pay per use" feature of cloud computing as a service which is consumed according to the actual user demands is an attractive advantage and perspective ("promise")—especially for logistics service providers of SME-size. It allows for externalization of IT cost in logistics services, i.e. the transformation of fixed cost (depreciations on investments into IT equipment and software, software maintenance cost and parts of the labour cost of the corporate IT department) into variable cost which can be accounted for in advance and covered by proportional service sales revenues. Due to obsolete investments into the modernization of corporate IT equipment, companies can reduce the IT-bound capital, thus increase their equity ratio and shorten their balance sheet. Even more important: The cost structure of the logistics services may be shifted slightly towards higher cost elasticity in spite of higher computational service levels achieved. Considering the intense market volatility of logistics services, the latter advantage will be appreciated by logistics service providers since memories of the last recession period are still rather vivid in the logistics community.

## III. IT in Logistics: Status Quo and Demands

### A. Survey Methodology

As part of the work package "end user participation" of the joint research project "InterLogGrid" a survey of the status quo of IT application in logistics and of the related improvement demands was carried out in 2010-2011 within the Leipzig-Halle logistics cluster and updated by March 2012. The target population consisted of the LSP-community (appr. 40) within the cluster. Every LSP of the cluster was invited to participate in the survey, approximately 80% of the addressed companies finally took part.

Due to the complexity of the questions, the questioning had to be carried out on user's site in face-to-face interviews of several hours duration with the manager, branch manager or an IT specialist. In most interview sessions it was necessary to include an introduction into the features and advantages of Cloud Computing, a discussion of the cost-benefit issues, and an explanation of safety-relevant aspects (data safety, stability, reliability).

The survey was based upon a detailed uniform questionnaire covering the size, economic and budget parameters, service profile and client orientation of the investigated companies, the available and applied IT equipment, the effective utilization of the software functions to different operational domains (general business IT functions, specific logistics operations), indicators of attitude towards IT in general, internet based services and familiarity with cloud computing features. Most important, a comprehensive structure-diagram of IT-tools at use, their data flows, internal and external interfaces was created for each company including the related deficits, problems and innovation needs.

Based upon these interviews a total sample volume of 32 interviews was gathered (full coverage of the questions by 21 participants, partial coverage by 11) with an SME-fraction of more than two thirds. Every cluster member willing to cooperate was included in the survey, neither a random sampling procedure nor a systematic configuration of the sample according to the statistical features of the main population of regional logistics service providers could be applied. Thus, the sample and the related findings of the regional survey cannot be considered to be statistically representative for the regional logistics community or for the cluster organization. With a coverage of more than 50% of the potential user community for cloud computing tools in the Leipzig-Halle logistics cluster the findings are still useful.

### B. *Survey findings*

The majority of interviewed LSPs are freight handling/freight forwarding companies. A large fraction of these (>70%) is offering freight charter services, followed by direct deliveries (>60%) and by compound cargo transport and logistics services (>50%). Approximately 44% are engaged in contract logistics. Nearly 60% of the companies are offering warehousing services. About 37% of the companies are offering cross-docking and freight commissioning services.

With respect to the modal split of the transport service, 84% of the survey participants are offering or are qualified to handle road transport, 22% air transport, 28% sea transport, 16% inland water transport.

More than 50% of the interviewed logistics service providers include value added services in the spectrum of their service offer, such as freight tracking and tracing, customs clearance, palletizing and intermediate storage (72% each), labelling (62.5%), and quality and function testing and surveillance (56%).

About one half of the interviewed companies are at least offering to include processing and partial assembly steps into the scope of their services.

The 5 most dominant shipper sectors as clients of the interviewed logistics service providers are consumer goods, machinery, automotive sector, CIT equipment, electronics/opto-electronics/semi-conductors.

The sample LSPs were interviewed regarding their general attitude towards IT support in logistics, their internet use and familiarity with the concepts of Cloud Computing. Fig. 2 illustrates the interview results.

85% of all interviewed companies acknowledge that the use of IT is important or very important for them. About 69% support this statement with respect to their corporate strategy. 78% of the companies are using web-based services, in many cases map-based services, like Google Maps et al. At time of being questioned, only 3% of the interviewed companies knew about the concept of "Cloud Computing". After having been given a short introduction into Cloud Computing, about 13% of the interviewees admitted that their company was already applying Cloud Computing in some areas to some (minor) extent without being aware of this fact.

As a result of the survey interviews and their implicit instructive elements, some 59% of the interviewed logistics service providers stated that they were planning to make use of Cloud Computing in the future provided that suitable software tools would be available.

Fig. 3 represents the status quo of software use for different business and branch specific purposes within the investigated logistics community. It displays the application distribution of software classes and of some specific commercial software products within the survey sample.

A clear and unique correlation of a software product application to one specific functional area was difficult in many cases, because many software products typically support multiple functions. In these cases only the predominant application field was recorded creating some fuzziness of the percentage numbers in fig. 3.

The last part of the survey interviews covered the potential use of new Cloud Computing solutions including the question, which improvements the company would want to achieve. Fig. 4 illustrates the corresponding survey results.

Identifying and analysing frequently encountered IT-problems, malfunctions and functional deficits is among the most valuable survey results. The most significant findings of these observations, based upon a reduced sample size of 21 full information providers, are the following:

- Approximately. one third of the interviewed LSPs already use at least one web-based software solution. Thus, introduction of additional web-based solutions, such as cloud computing, would not start at a level of zero.
- Professional software products are predominantly used for general business functions (e.g. financial accounting, ERP, CRM.). In other (branch-specific) areas frequently applications of MS Office products are used by the LSPs. In single cases (SME size LSPs) even complete warehouse management, fleet management and even financial accounting functions etc. were covered by user-made Excel and Access sheets.
- At least 50% of the interviewed companies are using MS Office (Outlook) for CRM with clients and business

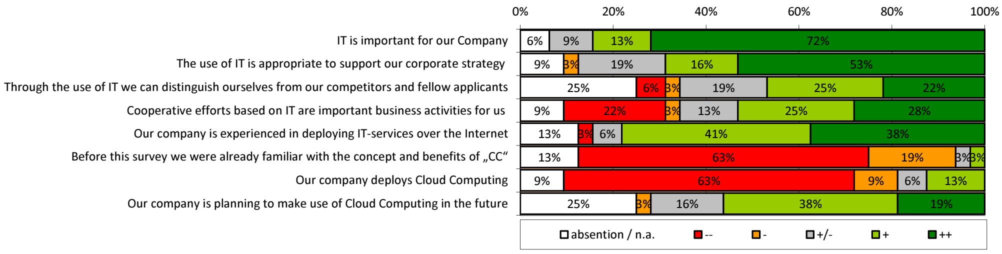


Figure 2. Statements on IT and Cloud Computing

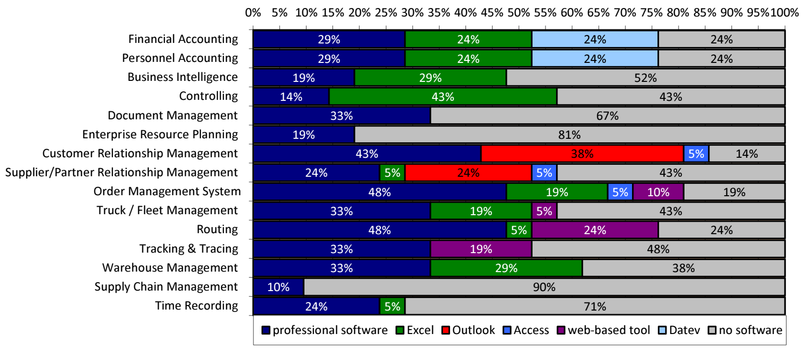


Figure 3. Software that is used in the logistics companies

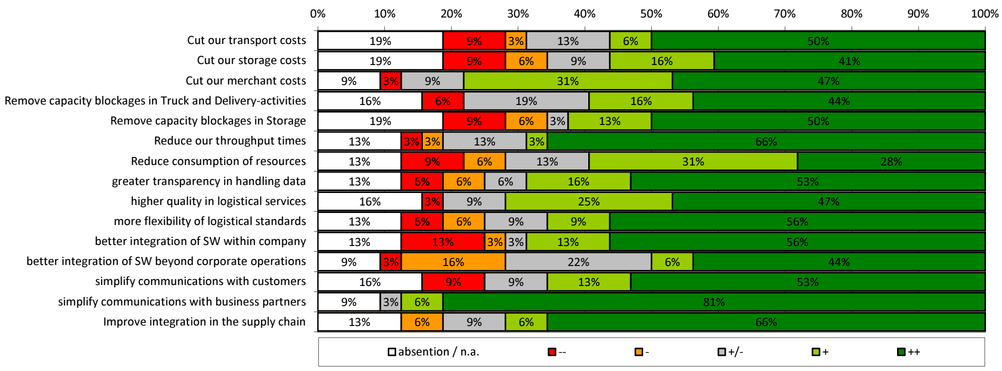


Figure 4. Statements on expected benefits of a new IT-Solution

partners.

- Approximately 25% are using DATEV for financial accounting (sometimes in cooperation with an external tax consultant on contract basis).
- Nearly 30% are using SAP with at least one module.
- An average member of the sample group uses 7 separate software products of different brands. The maximum number of different software tools was 20.
- More than 50% of the companies use 2 software products with redundant functions, Thus, partially multiple / redundant data storage is state-of-the-art in more than one half of the companies.
- Typical interface problems: Within survey about 70 "data stream interfaces" were identified (transfer of data from one software system to another). 55% of these interfaces needed manual input or did not work reliably.

Especially the identified data-interface deficits and malfunctions can be considered to be critical in terms of staying competitive. They cause significant additional cost (personnel), time loss (manual data input or adaptation) and introduce avoidable sources of error and data inconsistency. Non-existing or malfunctioning interfaces are obstacles for total process monitoring and control and for introducing comprehensive SLA-standards of heterogeneous LSP consortia as well.

## IV. CC Implementation and Migration Requirements

The availability and offer of cloud computing capacities and tools is a necessary but not a sufficient condition for introducing this technology into everyday application by the investigated logistics community. In spite of the wide spread awareness of inadequate functionality and interface deficits of their available IT-equipment and in spite of existing concerns due to the noticed computational innovations in their environment and the growing service expectations of client, many of the interview partners expressed some reluctance to imagine migration into a cloud computing environment. Of course, safety considerations (unease regarding the storage of business data in the internet) were frequently expressed by the potential users. Above all, the step from in-house IT-equipment to cloud based data storage and processing is seen as a fundamental and irreversible change which might endanger the operability of the company if not working well.

Therefore, the user requirements include the following conditions:

- KISS ("keep it simple and stupid")—The change of IT technology and the related migration process has to be offered in such a way, that the required resources of highly qualified staff, capital and above all management time are less than that of introducing just another in-house-installation of new software. Ideally, the users would prefer a "plug & play" solution of the technology change to cloud computing.
- The migration process has to be made possible in an incremental way, i.e. the users can imagine to try the potential of cloud computing at first with non-essential functions (such as tracking and tracing, purpose specific additional business intelligence etc.), followed by applications to fleet, warehouse, shipment and freight load management before a complete order management and general business functions are migrated "into the cloud". For each phase of the migration process, the option of dropping back (restore) to the previous IT-system status is required.
- Sufficient and improved data safety and fulfilment of compliance standards has to be proven beforehand and guaranteed by the cloud computing service provider. A critical issue may consist in the question whether liability for secondary damage in case of safety gaps or cloud computing "blackout" can be included in the service level agreements.
- The promised benefits of the cloud computing concept, i.e. the solution of the existing interface problems, facilitated integration and synchronization of data exchanged with third parties and a tariff system which really meets the pay-per-use features need to be demonstrated prior to cloud migration.
- The service offer needs to exceed the pure provision of cloud computing storage capacity and software on demand. Instead, the necessary services of migration support have to be offered as a part of the whole service package.

## V. CC Use cases

The fundamental use case of cloud computing for users of any branch is outsourcing the processes "data storage, management and processing" to some web-based server capacity with the advantage of practically unlimited storage space and processing performance capacity one one hand and (more important) central synchronization of (business) data and documents on the other hand e.g. for business intelligence, DMS and other professional purposes. Some of the survey interview partners could imagine to start introducing cloud computing into their IT operations for such "inhouse" use cases, for instance in order to synchronize and integrate distributed data at different branch office locations for periodical analysis. Another standard use case consists in providing externally operating employees with some possibility to have access to corporate IT and to down-/upload data and documents from/to some corporate storage space via web link of a smart phone. The objectives of the projects "InterLogGrid" and "LOGICAL", however, focus upon multi-party usage of cloud computing for the sake of increased levels of cooperation.

### A. Logistics Mall

The basic scenario of a demand-supply matching with two parties involved is the vendor-client constellation. Matching of a suitable fit of offered products and services and related demands defines the well known functionality of an online-shop (standard e-commerce scenario). The combination of many online-shops - ideally one shop for each member of a logistics cluster, freight village or hub - in a virtual market place defines the concepts of a logistics mall The result represents a virtual image of the comprehensive service and product offer provided by the related regional logistics community. If embedded in an affiliate e-commerce management system, the implementation and operation of such a comprehensive logistics mall can be an attractive value added service of logistics hubs, freight villages and cooperative logistics organizations for their members and clients. In principle, the mall can contain the virtual representations of any kind of service and product offered by some company within the logistics community. Thus, not only modular components of logistics specific software (as suggested by [10]) but also offers of specified transport, storage, freight handling and other basic logistics services may be included.

To specify the possible basic logistics services a standardised logistics ontology will be used, which was developed in "InterLogGrid".

### B. Virtual LSP partner manual

The "classic" online-shop requires a clear description of the product or service offered and a price tag. In many cases, however, the variable features of basic logistics services are to numerous and complex for a price fixing. To enable the cooperation of different logistics service providers, first of all it is necessary to share some information about their company, capacities and logistics service offer as well. These features were acquired and aggregated within "InterLogGrid" in form of a "logistics partner manual" deployed to survey participants in written form.

Available service capacities, however, dynamically change. In order to find a suitable service partner in real business situations a continuous update of the changing idle service capacities is necessary. This need and its coverage by a cloud computing application defines the principle of a dynamic "partner manual" synchronized with e.g. the fleet, freight and warehouse management systems of the linked LSPs.

### C. Matching Engine of logistics services

The previous use case defines the cloud representation of the comprehensive idle capacity of available basic logistics services that can be offered by the members of the associated logistics community. The opposite is the aggregate sum of needs for basic logistics services such as freight transport, storage or handling demands. In case of multi-modal freight transport for instance, matching of offer/supply and demand often is a multi-stepped and complex process. The use case of a matching engine for basic logistics services (such as transport) first of all is meant to identify matching capacity offers and demands of two parties linked with the system. Based upon this standard scenario (e.g. online freight fair) the second level of this application scenario consists in identifying groups of matching service demands and offer possibilities. A major use of this cloud application consists in facilitating the configuration of sufficient freight for covering full cargo trains between different nodes of the "LOGICAL" partner regions.

### D. Optimization of transport networks

This use case is based on the previous use cases. If more than one match of supply and demand is possible, usually an optimum solution according to predefined goal functions is wanted by the demand party. Based on information about capacities, truck routings, empty truck space, inter-modal capacities and common goal functions (cost, reliability, energy consumption, generated traffic, emissions) a simulation of the complete supply chain will create discriminant features of alternative solutions in order to identify relative optima. The aim of this matching is to reduce transport costs, time and carbon emissions for participating LSP and can be a valuable contribution be to reduce the cargo load on motorways.

### E. Management of complex logistics processes

Based on atomic logistics services their configuration to complex fragmented logistics services is possible in order to cover the complete supply chain of preceding, hub-specific and consequent processes as displayed in figure 1. The final objective consists in simulating, monitoring and management of complex logistics processes like that of a logistics hub. The supply chain process model contains different and multiple process steps (activities) which are executed by different LSPs. 4PL are the main target group of this use case which represents a strategic development direction of logistics clusters (e.g. the logistics cluster Leipzig-Halle). In this way logistics clusters can provide a modern platform for their LSP-members in order to enable and support cross-company cooperation and collaboration.

## VI. Logistics Cloud Architecture Concept

### A. The technical point of view

Concerning the LOGICAL cloud architecture there are two different points of view. The first one is the technical point of view that covers all the aspects that are necessary to operate the IT parts of the cloud while the second point of view is called the LOGICAL point of view. The LOGICAL point of view explanes the architecture that is used to implement and operate the use cases of the LOGICAL cloud.

The technical part of the LOGICAL cloud architecture comprises the five layers previously mentioned IaaS, PaaS, SaaS, LAaaS and LPaaS as shown in fig. 5. The infrastructure is provided by an increasing number of hosts that run VMware ESXi to provide virtualized resources. The individual hosts are managed by a VMware vCenter Server.

The PaaS-layer is of minor importance in the given R&D context because typically a PaaS-layer is targeted to developers who want to create services for the cloud. This functionality is not provided by the cloud itself thus the software developers have to create the applications for the SaaS layer on their own infrastructure or inside a virtual machine inside the LOGICAL cloud. What the LOGICAL cloud provides in terms of a PaaS-layer is an application server. This is provided by a clustered JBoss-Server that automatically scales depending on its workload.

The SaaS provides virtual machines with preinstalled and preconfigured software solutions as well as web services that can be accessed through thin- or thick-clients or a web browser depending on the kind of software service.

The available templates for the SaaS-layer's virtual machines can be accessed by the customers on a self service portal. This self service portal also empowers the customers to manage their virtual machines.

The LAaaS-layer is a subset of the SaaS layer while the LPaaS-layer provides composite services of the cloud as well as the logistics service providers, especially third and fourth party logistics providers.

This typical cloud stack is completed by services for billing and monitoring on the operation side and services for security, management of SLAs and management of the cloud on the management side. The monitoring service monitors the usage of all the services consumed in the cloud and provides these information in an aggregated manner to the billing service. With these information the billing service provides a view of the past invoices and of the current billing data as well as a view of the current account balance. It also handles the payment.

The security service and SLA management service accumulates data about the performance of the cloud services to plan the future resource handling. The second important functionality of this service is to provide alerts whenever a SLA is about to beeing not met or not met yet.

The last service provides management functionalities to the cloud provider and the service providers. New cloud services are registered to this management service to get known by the cloud.

### B. The LOGICAL point of view

All these technical considerations on the LOGICAL cloud architecture are the basis for the LOGICAL point of view. An initial and simplified first version of the LOGICAL cloud from a less technical and more practical point of view may be seen as a mall with many small shops where the customer

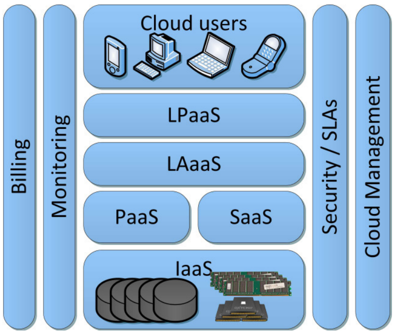


Figure 5. Architecture of the LOGICAL cloud

buys distinct services from multiple different logistics service providers. This mall is implemented as a web application inside the PaaS layer of the technical architecture so it can scale automatically. The particular shops can either be part of the web application or be an external application to provide a maximum of flexibility for the service providers.

The shops that are part of the web application can be designed by the service providers by editing a HTML / CSS template. Such an internal shop provides a back end to the service provider to administer the services sold by this shop as well as to view and manage his sales. An internal shop provides the data that is necessary for the billing directly to the monitoring service of the technical architecture.

An external shop is an application that is a web page that is loaded inside the mall in an iframe to integrate in the shop. This kind of shops needs to call the monitoring-service of the technical architecture to provide data concerning sales created by the cloud.

## VII. Development Status and Conclusion

Keeping pace with the ever increasing innovation requirements in logistics is prerequisite for logistics service providers if they want to stay competitive. Cloud Computing and its utilization for logistics is among the challenges logistics service providers have to face. The development of basic concepts for this purpose, use cases, architecture and software are the main tasks of two R&D-projects, InterLogGrid and LOGICAL.

The survey carried out within the Leipzig-Halle logistics cluster revealed a highly positive attitude of the interviewed partners towards IT support in logistics in general and openness towards cloud computing for logistics. The status quo monitoring of the survey showed significant deficits of the companies' IT equipment especially in the area of interface functionality between different software tools and correspondingly in the area of maintaining data consistency and avoidance of redundant data storage. Equally important as available cloud computing capacities in logistics are services and solutions that facilitate the migration process by professional support. Moreover, user require incremental migration with a "drop-back-option", a tariff system which really complies with "pay per use" and—above all—convincing systems and liabilities for data security and compliance.

Among other premises, migration of a user's logistics data and IT services into the cloud needs a common ontology and representation of basic logistics service-fragments (atomic logistics services) upon XaaS-level of the logistics cloud system. These basic components were included in the scope of InterLogGrid developments.

Moreover, several standard, interrelated and compatible use cases for logistics cloud services of growing complexity were derived in multiple workshops with user group members. These use cases include: a virtual market place for hub and cluster organizations (logistics mall), a virtual representation of the actual resources and service offers (virtual LSP partner manual), a platform for matching demands with actually available capacities (matching engine of logistics services), and an extension of the previous use cases towards simulation and optimization of fragmented supply chains of more than two parties. The final level of complexity is the management of complex supply chains of many partners in hubs, air- and seaports as illustrated in fig. 1.

A suitable architecture concept of a regional logistics cloud was developed in InterLogGrid. Its main components are outlined within this paper. The related infrastructure (IaaS) is provided by Leipzig University, some components are already implemented on the university infrastructure and are in test applications. The following step will consist in the assessment of feasibility and suitability of this conceptual architecture for being used as a common template of regional logistics clouds in LOGICAL. Some necessary functions for the first two use cases (virtual representation of the LSPs and their services) have been implemented in first versions and made accessible on the platform of Leipzig-Halle logistics cluster for test purposes. Still, however, the majority of required application-specific software components need further development before systematic and in depth application by the test users can start.

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