CLOUD ARCHITECTURE FOR E-COLLABORATION IN THE INTERMODAL FREIGHT BUSINESS

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Abstract: The term *freight* refers to goods transported using different transport modes (truck, rail, ship), while inter-modality refers to the ability for seamless transfer of freight and information across the different transport modes. Because of the nature of the freight business (large number of small players, geographical distribution, complex regulatory regime, multiple standards, and IT heterogeneity) we propose that cloud computing presents an ideal platform for e-collaboration in the inter-modal transport networks (*e-freight)*. This paper identifies Cloud based collaboration scenarios in e-freight, proposes a Cloud architecture for e-freight and analyses its business and technical benefits.

1 BACKGROUND

According to (European Commission, 2001) "Co-modality" is the optimal use of all modes (land, sea, air) of transport singly and in combination.

Many current governmental, EU and industry led initiatives focus on quality and efficiency for the movement of goods, as well as on ensuring that freight-related information travels easily between modes. Such objectives require collaboration between all stakeholders involved in freight transport chains. Although such collaboration must be enabled by legal and organisational frameworks being in place, it is largely underpinned by IT. IT system interoperability and integration can enable stakeholders such as transport operators, shippers/ freight forwarders, customs and other government administrations, to seamlessly exchange information in order to improve the efficiency and quality of freight transport logistics.

To achieve efficient use of the different transport modes on their own and in combination (co-modality), stakeholders need improved means to strategically manage networks, plan shipments and to control the implementation of such strategies and plans.

In centrally managed transportation networks, coordination is achieved through centralised mechanisms such as portals and exchanges, under a single control, typically that of a large organisation such as a large freight integrator/freight forwarder, who carries out administration, marketing, pricing, billing and so on.

However, inter-modality/co-modality will gradually encourage in the future decentralised organisations to get together to form transportation networks without any prior arrangements and centralised control. Therefore, open collaboration approaches, decentralised network and communication structures, and dynamic flexibility in forming and dissolving transportation networks will become increasingly important in setting and managing co-modal transport networks in years to come.

Cloud computing has recently been receiving interest from businesses due to its inherent and attractive properties of per-use pricing and elastic scalability of computing resources. The effect has been a shift to outsourcing of not only the hardware and software IT infrastructure, but also of its administration, (open Grid , 2009). In this paper we go beyond the discussion of the obvious advantages of Cloud technologies for the freight sector, which mainly relate to the virtualisation of its IT

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infrastructure with the resulting technical and economic benefits.

Instead, this paper focuses on the analysis of how Cloud can enable the e-collaboration between transportation network participants and support the goals of co-modality.

In the remaining of the paper we discuss the patterns for collaboration that occur in a freight transportation chain, and we define Cloud architectural characteristics that enable such collaboration. Next, we identify the business and technical benefits from the proposed Cloud architecture. Finally, we identify different business models (for example private versus public cloud and cloud federation approaches) for deploying the proposed solution to the freight sector.

2 COLLABORATION PATTERNS IN E-FREIGHT

2.1 Types of Freight Organisations

There are several types of organisations involved in freight /logistic chains falling under the following categories (Freightwise, 2009):

1. Transport users: These are organisations that procure transportation services, (this includes exporters & importers and freight forwarders acting on behalf of shippers);
2. Transport service providers. These are organisations that provide transportation services, and include hauliers, operators of trains, ships, port terminals, and other logistics services;
3. Transport infrastructure providers responsible for managing the transport infrastructure such as ports, roads and rail lines;
4. Transport Regulators: these are regulatory authorities, specifically customs, safety & security agencies, police (immigration) and animal welfare and associated organisations.

Consequently, there is a wide variety of IT systems used by the above organisations including

- internal systems used for procuring, planning and managing transport related activities (e.g. booking services);
- community systems (e.g. commerce exchanges for bidding on transport services);
- authority systems such as port systems used for monitoring and controlling movement of ships and cargo;
- and, finally, information services systems offering for example weather, traffic and other safety related information.

2.2 Collaboration in Freight Industry

Collaboration in the freight business is driven amongst others by the need to optimise the utilisation of transportation resources and to better balance risks. Collaboration requires interoperability amongst the above types of systems. However, the interoperability problem is not a static but a dynamic one, because of the following two types of collaboration that occur in the freight industry:

- Type A collaboration across partners who have worked together before and have established agreements and long term alliances;
- Type B collaboration which is a more loose cooperative network between organisations (that includes authorities too) and therefore form a more dynamic (on-demand) freight logistics network.

We expect that transportation networks will adopt a layered model for business networking, comprising of an inner layer representing long term alliances linked to value strategies (Type A collaboration), a number of intermediate layers of progressively looser relationships, and an outer layer comprising of 'on demand' services linked to responsiveness strategies (Type B collaboration). Each layer may be characterised by different quality of relations and strategic convergence requirements, and would therefore require different interoperability strategies from an IT point of view. Therefore, in practice, both Type A and Type B collaborations need to be supported.

Type A collaboration can be supported by fairly fixed system integration/interoperability solutions, such as point to point connections using web services or other middleware architecture. This is possible, because the collaborating systems and their interfaces/APIs are known in advance, and therefore interfaces can be designed and implemented. These are essentially static and long term interoperability solutions.

Type B collaboration, however, is between systems that have to discover each other and agree the rules for interoperability at runtime.

Thus, the second type of collaboration requires more loose coupling between the participants systems and is the main focus of this paper.

Of course, type A collaboration can also be improved with the use of Cloud technologies, by moving part or whole of the integration middleware on the Cloud, and by utilising Cloud based integration services. This will result in typical Cloud derived benefits such as efficient utilisation of computing resources and reduction in IT costs.

Type B collaboration leads more naturally to a service oriented (SOA) solution. Dynamic collaboration and coordination of transport chain participants requires a service architecture, comprising service registries and a service discovery facility, to allow respectively the publication and discovery of transport related services.

S*ervice matchmakers* are required to match transport service supply with demand. A service matchmaker must be able to understand concepts in the service description, such as price and location, i.e. the start point and destination of the requested or offered service). Such capabilities go beyond the abilities of conventional web services (i.e. WSDL service descriptions) and into the realm of *semantic web services*.

Ontologies are essential in service match making and interoperability, as they serve to integrate the different standards and formats that are used in the freight sector and to achieve semantic interoperability.

A Cloud architecture needs therefore to address the problem of standard heterogeneity. For example, there are several data and document standards employed in the transport sector such as GS1, CEN, UN/CEFACT, UBL/OASIS and others.

Finally, a Cloud architecture needs to address the problem of dynamic interoperability of heterogeneous systems such as port systems, internal transport planning and operation systems, safety and information systems for sea transport and others.

In the next section we explain how the coordination and interoperability is manifested in transport planning, execution and monitoring activities.

2.3 Collaborative Transport Chain Planning

In transport network planning, collaboration involves all participants exposing their internal resource availability, plans and other requirements/constraints to other participants in the transportation network, in order for a transportation plan to be established, that contains an accurate and mutually agreed plan of responsibilities, deadlines and actions for transporting the cargo from origin to final destination. A transport plan can undergo several iterations during which it is usually optimised in terms of duration and resources. At this stage, costs and payments are also established and negotiated. A Cloud approach to transport chain planning needs to leverage service oriented concepts to expose internal databases and systems of the participants in a controlled manner. Internal booking systems of shippers need for example to interoperate with pricing systems of service providers. Such operations need to be carried out according to the security and other controls of the different participants, as confidential data about the cargo may not be revealed until the time is appropriate. In some cases, even the identities of the participating organisations may be kept confidential until contracts are exchanged.

2.4 Collaborative Transport Chain Execution

During this stage, information generated at any point of the transportation chain must be easily accessible by all interested parties. A Cloud infrastructure can allow such information to be replicated across cloud storage systems, and its existence to be notified to al interested parties, through reliable event based notification mechanisms. In this approach, the Cloud can become a high performance message relay that transcends the communication and other networks used by the transport chain participants. A typical Cloud application for transport chain execution is meeting the mandatory reporting requirements as the cargo carrying vessels arrives at different ports and terminals. Cloud, for example, can be used to implement the concept of Single Windows (UN/CEFACT, 2005) which refers to the streamlining of cargo and traffic information exchange between authorities and between authorities and other stakeholders. Services can be deployed on the Cloud for 'one stop reporting', allowing operators to submit a single report, which is then relayed to all relevant authorities.

3 A CLOUD ARCHITECTURE FOR E-FREIGHT

Based on the requirements for collaboration and system interoperability in e-freight identified in the previous sections, in Figure 1 we provide a conceptual architecture for Cloud based freight collaboration. Such architecture can be utilised by the combination of several commercial and open source Cloud technologies. Our aim is to define an collaboration architecture for e-freight using Cloud concepts that remain stable even when the implementation technologies change. The architecture diagram of Figure 1 shows the major subsystems and components that comprise a collaborative Cloud for e-freight. According to the architecture, transport chain participants are granted access to the Cloud by a set of authentication/authorisation services. After been authorised by the Cloud, they can advertise their transport services (offerings) or transport service requests, and participate in transport chains. Exchanges are mechanisms for forming virtual transportation networks within the Cloud, in which participants can securely collaborate via message based communications and document sharing.

Exchanges contain message queues, i.e. high performance message Cloud middleware that allows the store and forwarding of large volumes of messages under defined QoS rules. Organisations can subscribe to existing queues for publishing and receiving messages (notifications) or they can create their own queues. Queue subscription can be by topic (e.g. for receiving notifications for requests for a particular type of cargo or for a particular destination point). Message queues are the mechanisms for members of an established transportation chain to communicate safely and reliably with each other. As all queues are entirely Cloud based, participants do not need to own any middleware system as part of their internal IT.

The Process Choreographer allows the execution of transportation processes such as plan, execute and monitor. The Process Choreographer knows the sequence in which messages must be exchanged in a particular transport chain and enforces their sending/receiving in a correct sequence. To enable loose coupling, the Process Choreographer controls only the interactions between the partners processes rather than their internal processes. Thus, internally the partners can implement any process management system such as an ERP system, a process orchestration (BPEL based) or other type of Business Process Management (BPM) system. The Process Choreographer service can operate as an event machine or state based machine that interprets notifications (messages) received by the message queue during the execution stage of the transport chain, or by updates to documents (for example an update to freight delivery status). The Process Choreographer responds to such updates by sending new messages/notifications to the transport chain participants, using the message queue mechanism discussed above.

To disambiguate the content of messages, the Process Choreographer utilises ontologies for freight. Thus, with the use of ontologies, messages are automatically converted to the format suitable for the intended recipient. This ability supports the goal of interoperability, by not forcing participants to use the same document standard.

Finally, Document Storage in the architectural diagram, refers to a distributed Cloud storage service that allows simultaneous publishing editing and accessing of documents pertaining to a transportation chain planning execution. The storage of such documents is distributed over the Cloud. Access to a document's contents is through the use of *view* mechanisms that allow controlled access and modifications to a document's contents. This approach also simplifies the task of interoperability as it allows many participants to share and collaboratively update the same document.

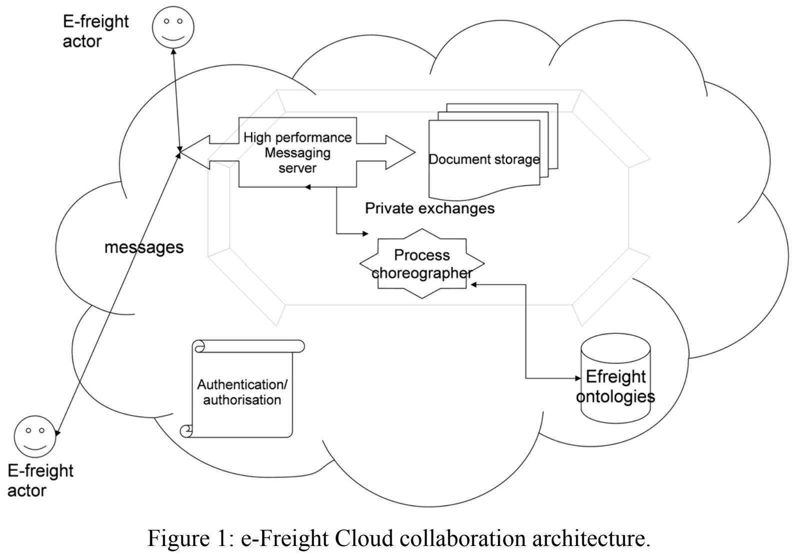

Figure 1: e-Freight Cloud collaboration architecture.

Table 1: Business Advantages.

User needs and expectations	How Cloud meets them
Customer satisfaction	A collaborative Cloud solution should contribute towards lowering the transportation costs , service reliability and performance, and therefore ultimately towards improving customer satisfaction
Improved operational efficiency (e.g. number of deliveries per day)	The Cloud approach allows the execution of a larger number of transactions (higher throughput/ performance) compared to architectures with fixed numbers of servers.
Distribution of risks amongst participants	A collaborative Cloud architecture distributes decisions and business risks, rather than aggregating and centralising them.
More accurate payments to transport service providers	The Cloud approach provides reliable information about actual service performance during transport chain execution.
Reducing the cost of non-compliance (e.g. avoiding fines for non-compliance)	The Cloud approach automates the compliance procedures (for example reporting to authorities) thus making it more efficient.
Optimal utilisation of transport resources through the network	The Cloud approach allows pooling of transport resources (e.g. vehicles, containers,..) and better sharing them throughout the transportation chain.
Transport network optimisation due to better horizontal collaboration between users and providers	The Cloud approach can optimise the network both statically and in real time, due to improved information sharing and availability.
Reduction in lost sales due to bidding failures, e.g. inaccurate bidding	The Cloud allows faster notifications for bidding opportunities to transport service requests.

4 QUANTITATIVE AND QUALITATIVE BENEFITS OF E-FREIGHT CLOUDS

Based on the collaboration requirements and the proposed Cloud architecture for e-freight, below we identify potential business and technical benefits. Some of these benefits (mainly regarding IT costs) are fairly easy to quantify, while the impact of business benefits is harder to assess and require a case by case analysis using 'what if' scenarios and simulations. We expect however that the business benefits of the proposed Cloud collaboration will typically outweigh the more obvious IT cost savings.

5 CONCLUSIONS

This paper has argued that Cloud computing represents a suitable platform for e-collaboration in the freight business. Cloud computing is currently a rapidly changing area with many emerging standards and business models (Vigfusson and Chockler, 2010).

Table 2: Technical (IT) Advantages.

IT requirements and constraints	How a Cloud Solution Meets them
Reduce operational IT cost reduction (hardware, software license & maintenance)	By migrating to the Cloud part of the IT infrastructure costs such as hardware/software purchase, licensing and maintenance are reduced
Improve and simplified communication between shippers, carriers and customers' systems	By using integration services provided by the Cloud.
Dynamic pricing algorithms based on real time demand, availability etc.	By improved availability of real time information throughout the transportation network.
Balance system performance during peak demands.	By using the Cloud's elastic resources, demand peaks (e.g. in bookings) can be handled more easily.
Reduce incompatibility information systems used by members of the transportation chain	Through the use of SOA principles, loose coupling (message queues) and event based notifications.

There are many open questions as to the ideal shape of a Cloud for e-freight, namely:

- The question of whether this should be a public (open) or a private Cloud;
- What Cloud standards to use for its implementation;
- What kind of interoperability with other systems including other Cloud systems is required;

- The business model used for the Cloud, such as who owns the Cloud.

The freight sector is characterised by a community of private companies and government/ intergovernmental agencies covering wide geographical regions and transport modes.

It is likely that under such conditions more than one Cloud approaches will emerge. Cloud ownership and control could mirror the current structures of the freight industry, i.e. the centrally coordinated networks, cooperative networks and more loose cooperative associations that currently exist in the industry. One or more of such Clouds could be concerned with legal and compliance aspects of the freight sector (i.e. to enforce standardisation and compliance across the industry). Other Clouds could be more commercial in nature, i.e. they would represent the migration of the current e-freight networks and alliances to a Cloud environment. Thus, ownership and membership of the Cloud could vary depending on the purpose of the Cloud. Some of such Clouds could be owned and managed by a single organisation such as a large freight integrator/forwarder, or a governmental or intergovernmental entity. It is possible also that non freight companies such as IT service providers could become responsible for managing some of these Clouds.

It is reasonable to expect therefore, that Cloud interoperability standards such as OCCI (OpenGrid Forum, 2009) promoted by consortia such as Open Cloud Manifesto, DTMF Open Cloud Standards Incubator, Open Group's Cloud Work Group) and others, will become very important for the success of the approach proposed in this paper.

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