Data Interoperability Assessment Towards the Resilience of Data Exchange Systems

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Abstract. Data interoperability allows data exchanges among Information Systems, their subsystems and their environment. The multiplicity of these exchanges and the increasing amount of exchanged data can generate dysfunctions with negative impact on the overall performance of the communicating systems. Data interoperability should therefore be continuously assessed and improved. We summarize in this paper a work in progress where we provide an assessment of data interoperability, we exploit services provided by a messaging based middleware, in order to collect information about IS interactions allowing to assess their level of data interoperability. We propose a Messaging Metamodel that aggregates the collected information. The latter supplies a set of indicators, presented through queries and visualizations, that are confronted with interoperability requirements allowing us to detect interoperability problems and provide their potential causes. We also discuss current and future research work, where we consider the process of establishing data exchange systems, from design to maintenance, with the aim of enhancing the reliability and resilience of data interoperability.

1 Introduction

Most Information Systems (IS) are now made up, and are part, of communicating subsystems. If these systems are able to share and exchange information without depending on a particular actor and are able to use the exchanged information and function independently from each other, we can qualify them as interoperable systems Chen et al. (2008). When established among communicating IS, interoperability ensures an increasing in productivity and efficiency for inter and intra enterprise processes. Technologies such as Cloud, IoT, CPSs confer on Information Systems a wider reach with even more data exchanges and interoperability needs. Exchange systems must take into account more constraints: the adaptation to hybrid

development and deployment technologies, the integration of new communication protocols, the appearance of new architectural paradigms. Besides data exchange systems must be reliable and secure to guarantee the overall quality of service of the communicating systems. This lead us to consider the means of data interoperability [1] as a central element of our study. We argue that the exchange system that is set up to allow data interoperability must be considered as a system in its own right, with the ability to: configure it, put it into service, trace its operations, assess it, boost its performance and make it evolve. This allows to harness the process of establishing exchange systems, from design to maintenance, with the aim of enhancing the reliability and resilience of the overall data interoperability.

We first addressed the assessment part of the process. We consider effective data interoperability, meaning interoperability that is already established Cornu et al. (2012) and that we assess once the communication has started or is completed. We focused our study on publish/subscribe data interaction based on Message Oriented Middleware (MOM) Curry (2004). The latter helps build flexible, scalable and loosely-coupled architectures. Such interactions are implemented by our industrial partner Berger-Levrault (BL) [2] through the use of BL-MOM, an in-house messaging-based API, developed by Berger-Levrault. It establishes asynchronous routing between communicating programs following the AMQP protocol Vinoski (2006). BL-MOM uses RabbitMQ [3], a reliable open source communication mediator, as the underlying message broker and provides helpers to facilitate creating messages schema, interoperability pivots (publishers and consumers) and messaging operations over this broker.

In the remaining sections of this paper, we present in section 2 out first results in providing means of control, assessment and maintenance of data interoperability interactions. We summarize our approach Amokrane et al. (2018) for data interoperability assessment, expose the proposed analysis system, its underling metamodel and a subset of the reported queries and indicators that enable the evaluation of data interoperability. We then present in section 3 current and future research work. Section 4 concludes this paper.

2 Messaging Analysis System for Data Interoperability Assessment

In this work, we contribute to data interoperability assessment by monitoring exchange systems and the undertaken message interactions. We supervise the underlying communication mean: the massage broker RabbitMQ and collect information presented in a set of indicators, queries and visualizations. This continuous assessment of data exchanges related architecture and the existing interactions provide indication about effective data interoperability.

2.1 Motivation and Related Work

Interoperability assessment evaluates the ability of enterprises or systems to undertake common activities or exchange data. Several interoperability assessment approaches have

1. Considering interoperability concerns (data, services, processes and business) Chen et al. (2006), data interoperability addresses what makes systems with different data models work together.

2. Software provider specialized in the fields of education, health, sanitary, social and territorial management; for public institutions

3. `https://www.rabbitmq.com/`

been proposed since the emergence of the concept of interoperability: maturity models (LISI, LCIM, OIM...), interoperability score Ford et al. (2007) or degree of interoperability Daclin et al. (2008). However, these methods do not allow to precisely indicate or locate interoperability problems and mainly focus on general notions. Also few interoperability assessment methods address the effective (post implementation) evaluation of data interoperability and few are tooled Leal et al. (2019). These methods have nonetheless provided the fundamental concepts that allow formalizing and evaluating interoperability by indicating whether interoperability problems exist or not. On the basis of these concepts, other approaches Mallek et al. (2012); Leal (2019) have defined a set of interoperability requirements (e.g. *"Partners provide permissions for data updates*" ,*"Received data is conform to required data*"...) that should be verified in order to achieve interoperability. We use a set of selected data interoperability requirements to analyze existing data exchanges, highlight interoperability problems and specify their potential causes.

We have interpreted the selected requirements to allow their verification over a messaging based exchange system. For this we needed to gather data. We advocate that middleware infrastructures, such as the messaging broker RabbitMQ used by BL-MOM, convey enough information about the exchange network's architecture and interactions to enable the assessment of the level of data interoperability. Even if RabbitMQ offers a management console it only focuses on low level monitoring information such as, frequency of messages, infrastructure performance indicators or memory usage without of course any correlation with business information. Therefore, we performed data collection, aggregation with business elements and data rendering allowing to verify data interoperability requirements.

2.2 Proposal and First Results

We propose to verify interoperability requirements using a set of indicators provided through queries and visualizations on the basis of collected data (Figure 1). We supervise and monitor RabbitMQ by interrogating its services to collect information from several sources:

— Message traces provided by RabbitMQ tracing plug-in; they are overwritten by contextual business elements about the communicating applications characteristics provided by BL-MOM.
— History of events of creation and deletion of RabbitMQ resources, provided by RabbitMQ Event Exchange plug-in.
— Current configuration of the broker audited through the use of RabbitMQ REST management API.

We propose a Messaging Metamodel Amokrane et al. (2018) that aggregates the collected data. It provides a single point of control and enables depicting the indicators. The Messaging Metamodel represents the messaging structure implemented through message queuing and exchange system following the AMQP protocol. It also integrates dynamic aspects, as the lifecycle of architecture components is depicted by specifying creation and deleting dates and timestamps. Messaging concepts are linked with business related concepts providing accordingly the business context of the data interactions. We use Moose, a Smalltalk based open source software and data analysis platform Ducasse et al. (2005) to implement: the Messaging Metamodel, consumers and importers to populate it and data interoperability related indicators, queries and visualizations.

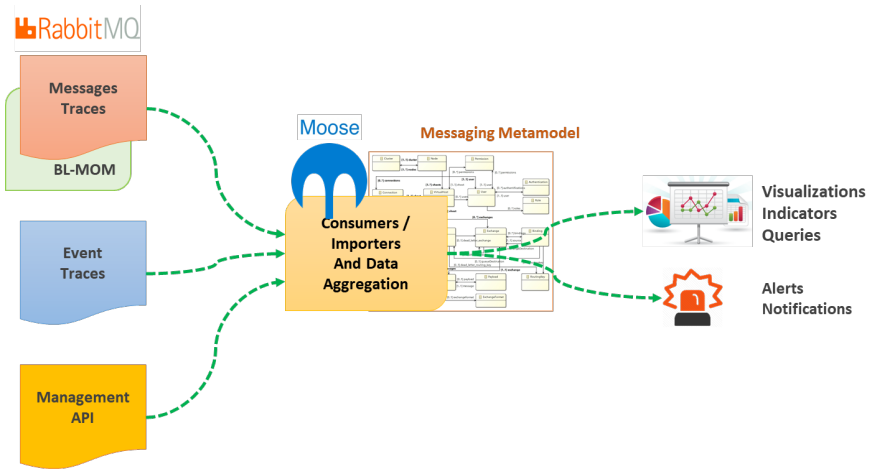

FIG. 1 – *Collecting and monitoring system of data exchanges*

As our focus is on messaging mechanisms as a way to convey data among interoperable systems, we instantiate the proposed requirements Mallek et al. (2012); Leal (2019) by referencing messaging paradigm concepts, defined in the messaging metamodel, in order match locally identifiable elements. We can thus precisely locate interoperability problems that represent situations where the requirements are not verified. A data leak can, for example, be detected by the presence of unauthorized consumers, or be prevented by supervising authentication attempts. Along with the indicators that showcase these problems, we provide potential causes. If, for example, partners show no interaction over a certain period of time (requirement "*Data is exchanged among partners*" not verified), this can indicate the unnecessity or the obsolescence of the interaction due to a configuration change (consuming on another channel) or a change at the process level. This can further indicate a permission problem or the invalidity of the exchange format. Maintainers inspect the proposed messaging indicators to determine maintenance actions taking into account the identified potential causes.

3 Current and future research avenues

3.1 Predictive Analysis for Interoperability Maintenance

In the current state of the proposed work, we manage to catch individual events that may indicate interoperability problems. We also provide a set of potential causes. Finding the real causes needs further analysis. We consider analytical methods such as Complex Event Processing Fülöp et al. (2010) to analyze complex correlations in these large amounts of event data for event pattern detection in order to suggest a type of dysfunction and its cause. In addition, collecting data related to exchange interaction allows us to report on the current and past situation of interoperability communications. The collected data can help us enhance the maintenance of the exchange system by establishing a future "intelligence". Labeling dysfunc-

tion events will allow us to carry out predictive analysis to detect unusual behaviors. This can be established by analyzing deviations in indicators and finding learned thresholds.

3.2 Adaptive Mechanisms to Absorb Interoperability Problems

Some data interoperability problems are load-related. Interoperable systems can exchange large amounts of data and yet require a low latency. This is the case when interacting with IoT systems Buyya and Dastjerdi (2016). The latter are increasingly used by public institutions for the management of city facilities or user services. The increase in the volumes of exchanged data implies the implementation of exchange architectures that are able not only to support the load but also the variability of the frequency of data production. This requires distributed architectures (in both infrastructure and flow) that can be adaptable or even self-adaptable Gascon-Samson et al. (2015) to promote the system's resistance to dysfunctions while avoiding potential congestion phenomena and ensure that way reliable interoperability interactions.

Reliability also implies the guarantee of availability of the resources used to support the exchange architectures. The variability of the types and frequencies of the exchanged data can be managed by applying the principle of elasticity Al-Dhuraibi et al. (2017) to automate the scalability mechanism of allocated resources. This requires the definition of a set of configurations of exchange architectures (optimized, stable, degraded, etc.) and mechanisms to go from one configuration to another, in order to enable the resilience of the exchange system.

3.3 Dynamically Generated Interoperability Pivot

To establish new interoperability interactions, publishers and consumers modules are currently developed "manually". Besides, the remediation to dysfunctions is done in an ad hoc manner. In addition to the cost of development and correction that this implies, this does not meet the responsiveness requirements of some business and technological fields. There is therefor the need for building adaptable exchange systems using dynamic interoperability pivots Agostinho et al. (2016). Generative programming mechanisms Czarnecki et al. (2000) can be exploited to ensure automatic/semi-automatic generation of interoperability pivots, under the control of a trusted authority. This will also benefit for systems that tend to be more and more open to their environment via IoT systems. Where data interactions will have to be automatic and in a plug-and-play mode. The use of automatic/semi-automatic configuration and generation techniques will thus promote Edge Computing mechanisms for establishing "on demand" interoperability links Shi et al. (2016), where edge of network devices are not only consumers but also data producers and can even require edge to edge interactions.

4 Conclusion

Data interoperability is technically implemented with data exchange mechanisms. The latter make up an exchange system that is as critical and essential as the communicating systems themselves. The reinforcement of the exchange system reliability and robustness will help increase the quality of the overall system. We presented in this paper a contribution to data interoperability assessment performed through the analysis of messaging based exchanges among collaborating IS. Assessing and gathering data about the exchange system is an inevitable step

towards enabling its continuous maintenance, adaptation and ensuring its resilience to interoperability problems.

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Résumé

L'interopérabilité des données permet des échanges de données entre les systèmes d'information, leurs sous-systèmes et leur environnement. La multiplicité de ces échanges et la quantité croissante de données échangées peuvent générer des dysfonctionnements ayant un impact négatif sur les performances globales des systèmes communicants. L'interopérabilité des données doit donc être évaluée et améliorée en permanence. Nous résumons dans cet article un travail en cours où nous fournissons une évaluation de l'interopérabilité des données, nous exploitons les services fournis par un middleware basé message, afin de collecter des informations sur les interactions du système d'information permettant d'évaluer leur niveau d'interopérabilité des données. Nous proposons un métamodèle de messagerie qui regroupe les informations collectées. Ce dernier fournit un ensemble d'indicateurs, présentés à travers des requêtes et des visualisations, qui sont confrontés à des exigences d'interopérabilité nous permettant de détecter les problèmes d'interopérabilité et de fournir leurs causes potentielles. Nous discutons également des travaux de recherche actuels et futurs, où nous considérons le processus de mise en place de systèmes d'échange de données, de la conception à la maintenance, dans le but d'améliorer la fiabilité et la résilience de l'interopérabilité des données.