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E-BUSINESS FRAMEWORK ENABLED B2B INTEGRATION

Doctoral Dissertation

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Abstract

Standards for B2B integration help to facilitate the interoperability between organisations. These standards, often called e-business frameworks, guide integration by specifying the details for business processes, business documents and secure messaging. Extensible Mark-up Language (XML) is used in modern e-business frameworks instead of Electronic Data Interchange (EDI) formats. Having XML as the data format is not enough for integration, but e-business frameworks are needed to guide how XML is used. This work analyses the many partly competing and overlapping e-business frameworks how they differ in support for business processes, documents and secure messaging. In addition, the effect of standardisation organisation to the outcome of the e-business framework is studied.

In this work, one e-business framework, RosettaNet, is used to tackle the challenges of product development (PD) integrations. A proof-of-concept implementation of a RosettaNet integration is provided to support PD and the lessons learned are discussed. The current specifications lack good processes for PD integrations, while they fail in specifying the concepts needed for document management. Furthermore, there are interoperability problems due to a lack of expressivity of the schema languages to encode the business documents, and the current setup of integration takes a very long time.

RosettaNet has a lot of flexibility in the specifications, and thus just supporting the same standard process is not enough for interoperability. With semantic technologies, many shortcomings of the current standards for B2B integration can be solved, as they make it possible to present constraints the current technologies have problems with. This work presents a practical case of B2B integration with semantic technologies and describes the benefits of applying such technologies.

Keywords e-business framework, B2B integration, interoperability, semantic Web Services

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Tiivistelmä

Standardit tukevat organisaatioiden välistä järjestelmäintegraatiota. Integroinnin standardit määrittelevät organisaatioiden välisiä liiketoimintaprosesseja, -dokumentteja sekä määrittelevät turvallisen tavan kommunikoida. Nykyaikaiset standardit ovat XML-perusteisia vanhemman EDI-formaatin sijaan. XML:n käyttö ei ole riittävästi takaamaan integraation onnistumista, vaan tarvitaan tarkempaa sopimista, miten XML:ää käytetään integraatiossa. Joukko yritystenvälisen integroinnin standardeja määrittelee tämän. Tässä työssä analysoidaan useaa, osittain kilpailevaa, yritystenvälisen integroinnin standardia ja tutkitaan miten ne tukevat liiketoimintaprosessien, -dokumenttien ja turvallisen viestinvälityksen määrittelyjä ottaen huomioon myös standardointiorganisaation vaikutuksen lopputulokseen.

Tässä työssä RosettaNet-standardia sovelletaan tuotekehitykseen liittyvissä integroinneissa. Työssä esitetään prototyyppi tuotekehitystiedon integroinnista RosettaNetin avulla ja keskustellaan saavutetuista kokemuksista. Nykyiset spesifikaatiot tuotekehitysprosesseille ovat tarpeisiin riittämättömiä, koska tuki dokumenttien hallinnan käsitteistölle on puutteellinen. Myös RosettaNetin käyttämien XML-skeemakielien puutteellinen ilmaisuvoima aiheuttaa ongelmia dokumenttien yhteentoimivuudelle. Lisäksi integraation tekeminen on hidasta verrattuna tyypillisen tuotekehitysprojektin kestoon.

RosettaNetin tarjoamissa spesifikaatioissa on paljon joustavuutta, joten saman standardiprosessin tukeminen ei tarkoita, että järjestelmät ovat yhteentoimivia. Nykyspesifikaatioissa ja niissä käytettyjen skeema-kielten ilmaisuvoiman puutteet voidaan osittain paikata käyttämällä semanttisia teknologioita. Tämä työ esittää, miten integraatioissa voidaan saavuttaa semanttisia teknologioita käyttämällä parempi yhteentoimivuus.

Asiasanat sähköisen liiketoiminnan standardit, yritystenvälinen integraatio, yhteentoimivuus, semanttiset web palvelut

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Preface

I have been fortunate in having an opportunity to work on a topic of my interest. Before my doctoral studies, I had studied enterprise information systems, industrial management and publishing technologies. The introduction of XML to data intensive applications brought a connection to my previous studies and work. I was lucky to have a chance to come to Software Business and Engineering laboratory (SoberIT) to work on this subject of my interest. The financial support in different phases has come from the laboratory, the Graduate School for Electronic Business and Software Industry (GEBSI) and the Finnish Funding Agency for Technology and Innovation (Tekes).

I have many people to thank for help in my efforts. My research colleagues in the NetData and NetSetup projects have helped significantly with the product development related research, and the students in software project courses have also participated in implementing our ideas into software prototypes. I have had countless interesting discussions about research and life with people at SoberIT, particularly by the coffee table or at lunch. Writing publications together with many co-authors has always been fruitful. Further, the opportunity to teach SoberIT students on B2B integration has helped me to understand the domain better.

To list all the contributing individuals would make a very long list – I trust they know that I appreciate the conversations and co-operation with them. Certain people deserve a special mention. Juha-Miikka Nurmilaakso has had an important role in making conceptualisation of e-business frameworks, and the comparisons we have made among different e-business frameworks have complemented my more product development -oriented focus well. My initial supervisor and instructor Prof. Timo Soininen was invaluable help in academic writing and guiding my post-graduate studies. My scientific writing and understanding in general about academic research evolved by tackling the numerous comments and excellent suggestions made by Prof. Soininen to my research papers and research plans. The visiting research time at Digital Enterprise Research Institute (DERI) in Galway, Ireland, was a great opportunity to learn more on the applications of semantic technologies. I have had the pleasure of working on common ideas and papers with many DERI researchers. I would especially like to thank Dr. Tomas Vitvar and Armin Haller for the work on common scenarios. At the later stages, Prof. Matti Hämäläinen, as the new thesis instructor and supervisor, has helped in finally fitting all the pieces together to form this thesis.

I want to thank the two pre-examiners, professors Matti Rossi and Jeffrey Nickerson for their comments and suggestions to the manuscript. Their comments increased the quality of this work and provided suggestions for future research.

I thank my parents, sister and two brothers for their encouragement and support. I thank also all my friends for the good company they have offered. The hobbies carried out together have been perfect way to balance the life. Finally and most importantly, my wife Katri has challenged and supported me along this journey. She has taught me a lot about the world and life.

Espoo October 2007

Paavo Kotinurmi

Table of contents

List of publications

This work is based to a large extent on the following publications, which are referred to in the text by their roman numerals:

I Kotinurmi, P., Borgman, J. and Soininen, T., 2003. Design Document Management in Networked Product Development Using Standard Frameworks, *International Conference on Engineering Design*, August 19-21, Stockholm, Design society, 10 pages.

II Kotinurmi, P., Laesvuori, H., Jokinen, K. and Soininen, T., 2004. Integrating Design Document Management Systems Using the RosettaNet E-Business Framework, *6th International Conference on Enterprise Information Systems (ICEIS)*, April 14-17, Porto, Portugal, pp. 502-509.

III Nurmilaakso, J. and Kotinurmi, P., 2004. A Review of XML-Based Supply-Chain Integration. *Production Planning and Control*, Vol. 15(6), pp. 608-621.

IV Nurmilaakso, J., Kotinurmi, P. and Laesvuori, H., 2006. XML-Based e-Business Frameworks and Standardization. *Computer Standards & Interfaces*, Vol. 28(5), pp. 585-599.

V Kotinurmi, P., Vitvar, T., Haller, A., Boran, R. and Richardson, A., 2006. Semantic Web Services Enabled B2B Integration, *2nd International Workshop on Data Engineering Issues in E-Commerce and Services*, June 26, San Francisco, CA, USA, Springer, LNCS 4055, pp. 209-223.

VI Haller, A., Kotinurmi, P., Vitvar, T. and Oren, E., 2007. Handling Heterogeneity in RosettaNet Messages, *22nd Annual ACM Symposium on Applied Computing*, March 11-15, Seoul, Korea, ACM Press, pp. 1368-1374.

The author's contribution to the publications

I The author of this thesis was the primary author of this paper. He converted common business requirements to requirements for standards support and IT architecture. In addition, he made the comparison of approaches for integration, selection of the e-business framework used and the architecture of the solution, and wrote the discussion to related work. Jukka Borgman brought the business requirements from case studies he had conducted. Timo Soininen guided the methodology and helped in the academic writing.

II The author of this thesis was the primary author of this paper. He was the principal architect behind the solution proposed, and responsible for the main requirements and results. He also implemented the XSLT transformations between the internal data model and RosettaNet PIPs. Hannu Laesvuori was responsible for implementing the RN adapter and RosettaNet messaging server related parts. He also wrote the main portions of section 3. Katrine Jokinen was responsible for implementing the PDM adapter and Rule Engine parts of the solution. She was also responsible for the internal data model. Timo Soininen contributed to the academic writing.

III The author of this thesis was the second author of the paper. Juha-Miikka Nurmilaakso was the principal author and responsible for most parts of this paper. The author of this thesis wrote the XML part of the paper as well as the discussion and conclusion part regarding the role of XML technologies in e-business frameworks.

IV The author of this thesis contributed to the analyses on competition and co-operation between different e-business frameworks. The first author, Juha-Miikka Nurmilaakso, was mainly responsible for the commonalities, differences and regularities between the XML-based e-business frameworks and their standardisation. The third author, Hannu Laesvuori, participated in presenting e-business framework as well as general commenting of the paper.

V The author of the thesis was the primary author of this paper, provided the case and example instance files, and performed the evaluation. The other authors provided WSMX system and SWS specific issues.

VI The author of the thesis provided the examples and the main ideas for SWS extending RosettaNet specifications. Armin Haller provided the choreography part to the paper and implemented the axioms in WSML language. Tomas Vitvar contributed particularly to the section on SWS technologies. Eyal Oren contributed to the clarity of the paper.

List of Abbreviations

AIAG	Automotive Industry Action Group
ANSI	American National Standards Institute
B2B	Business-to-Business
BPEL	Business Process Execution Language
BPM	Business Process Management
BPML	Business Process Modeling Language
BPMN	Business Process Modeling Notation
BPSS	Business Process Specification Schema (ebXML)
CAD	Computer-Aided Design
CBL	Common Business Library
COM	Common Object Model
CORBA	Common Object Request Broker Architecture
CRM	Customer Relationship Management
cXML	commerce XML
DAML	DARPA Agent Markup Language
DL	Description Logic
DTD	Document Type Definition
DUNS	Data Universal Numbering System
EAI	Enterprise Application Integration
EAN	European Article Numbering identifier
ebXML	Electronic Business XML
ebXML CC	ebXML Core Components
ebMS	ebXML Messaging Service
EC	Engineering Change
ECO	Engineering Change Order
ECR	Engineering Change Request
EDI	Electronic Data Interchange
EDIFACT	Electronic Data Interchange for Administration, Commerce and Transport
ERP	Enterprise Resource Planning
GTIN	Global Trade Identification Number
H2S	Human-to-System
HTML	Hypertext Mark-up Language
HTTP	Hypertext Transfer Protocol
HTTPS	HTTP over an encrypted Secure Sockets Layer (SSL) or Transport Layer Security (TLS) transport mechanism
ICT	Information and Communication Technologies
IT	Information Technology
IDOC	Intermediate Document (internal SAP ERP system standard)
MG	Message Guidelines
MIME	Multi-Purpose Internet Mail Extensions
OAG	Open Application Group

OAGIS	Open Applications Group Integration Specification
OASIS	Organisation for the Advancement of Structured Information Standards
OIL	Ontology Inference Layer
OWL	Web Ontology Language
OWL-S	OWL Services
PD	Product Development
PDM	Product Data Management
PIP	Partner Interface Process (RosettaNet)
PO	Purchase Order
RDF	Resource Description Framework
RDF(S)	Resource Description Framework Schema
RFQ	Request for Quote
RNBD	RosettaNet Business Dictionary
RNIF	RosettaNet Implementation Framework
RNTD	RosettaNet Technical Dictionary
S2S	System-to-System
SCI	Supply Chain Integration
SCM	Supply Chain Management
SGML	Standard Generalised Mark-up Language
SME	Small and Medium Size Enterprise
SMIME	Secure Multi-Purpose Internet Mail Extensions
SOA	Service-Oriented Architecture
STEP	Standard for the Exchange of Product model data
SW	Semantic Web
SWS	Semantic Web Services
Transformation	Transformation between files in same formats, e.g. XMLa to XMLb.
Translation	Transformation between different data formats, e.g. EDI to XML.
UBL	Universal Business Language
UDDI	Universal Description, Discovery and Integration
VAN	Value Added Network
VDA	Verband der Automobilindustrie
VE	Virtual Enterprise
W3C	World Wide Web Consortium
WfMS	Workflow Management System
WS	Web Services
WSDL	Web Services Description Language
WSMO	Web Service Modeling Ontology
WSML	Web Service Modeling Language
WSMX	Web Service Execution Environment
xCBL	XML Common Business Library
XML	Extensible Mark-up Language
XML Schema	W3C XML Schema language (XSD)
XPDL	XML Process Definition Language
XSL	XML Stylesheet Language
XSLT	XSL Transformations

1 Introduction

1.1 Background

Information systems and information and communication technologies (ICT) are increasingly important to support the daily operations in organisations. In the current networked business environment, the information systems need to work with other internal and external information systems, but they are seldom interoperable with other systems. The lack of system interoperability causes significant costs. Brunnermeier and Martin [12] have studied interoperability in the United States automotive supply chain and estimated one billion dollars to be the annual cost of poor interoperability between Computer-Aided Design (CAD) systems for product data exchange in product development. According to McComb [109], more than half of the 300 billion dollars annually spent on systems integration is spent on resolving semantic issues.

With the rising interest in e-business and e-commerce activities, inter-organisational information sharing has grown in significance. E-commerce has been defined as the buying and selling of products using ICT [156]. E-business is the electronic integration of all operations within business that links customers, suppliers, partners, and employees [47]. E-business covers not only buying and selling but also marketing, collaborative planning and design activities, where collaboration is facilitated by ICT. Organisations increasingly collaborate also in product development activities, and thus there is a need to integrate information systems to reach similar benefits as experienced in order fulfilment activities [46][96]. The expected e-business growth in both volume and scope is fast [96], but little is known about real-world business-to-business (B2B) e-business implementations [23].

Because organisations use heterogeneous information systems, B2B integration is needed for conducting e-business [112]. One way of facilitating B2B integration offering potential cost and extensibility benefits, is to apply e-business frameworks that provide standards and specifications enabling businesses to communicate efficiently over the Internet [143]. The aim of e-business frameworks is to facilitate integration with less implementation effort for each e-business partner organisation. Extensible Mark-up Language (XML) -based e-business frameworks employ XML technologies and the Internet to provide this functionality [127][143]. However, there have been many standardisation activities for e-business, causing confusion as to which e-business framework an organisation should support. It is generally hard to know whether the frameworks are substitutes or complements to each other. In addition, the frameworks are not interoperable [143]. Despite the importance of standards, there is a lack of papers describing technical standards for e-business [122] or standardisation [103], and there are few experience papers of B2B integration using e-business frameworks [125][140].

Furthermore, new semantic technologies promise to enable more flexible integration that is more adaptive to changes that might occur over the lifetime of a software system [69]. Although the use of semantic technologies for B2B integration has been proposed [49][155], there is still a lack of realistic, publicly implemented scenarios demonstrating the benefits of these technologies and their role in practical integrations.

This thesis discusses standards for B2B integration, and presents interoperability experiences on B2B integration to support working in heterogeneous and distributed environments. The thesis also discusses ontology research and XML, and thus investigates topics outlined in March et al. [105].

1.2 Research objectives and research questions

This thesis aims to clarify the role of different standards and technologies in B2B integration. The first objective is understanding the role of XML technologies and different e-business frameworks. To reach the objective, this thesis seeks answers to the following research questions:

1. What are XML-based e-business frameworks and how do they relate to each other?

Sub-questions to answer this question are:

   a. What are the most important issues specified in e-business frameworks?
   b. How do standard development organisations affect the outcome of the standards?
   c. Do the different e-business frameworks complement or compete with each other?
   d. How do e-business frameworks assist in B2B integrations?

The second objective is to provide experiences of B2B integration implementations using e-business frameworks. To support product development (PD) B2B integration needs, the RosettaNet e-business framework is used. Traditional B2B integrations with older Electronic Data Interchange (EDI) technologies do not support PD processes, which makes PD B2B integration an interesting research topic. The project-oriented nature of PD further makes it an interesting domain for B2B integrations. Also, the current typical B2B integration set-up times [135][140][155] are not acceptable for PD. These objectives give rise to the second set of research questions.

2. How does RosettaNet support the needs for B2B integration in networked PD?

   Sub-questions to answer this question are:

   a. How does RosettaNet support interoperability in document management in networked PD projects?

   b. Is there something missing from RosettaNet?

   c. Are there special requirements for B2B integration when supporting networked PD activities?

   d. Where does the time go in systems integration projects?

The third objective is to provide experiences on applying semantic technologies to B2B integration using e-business frameworks, as they promise more automated B2B integration process set-up [155]. The e-business frameworks have not used semantic technologies, while e-business in general is regarded as an area that would benefit from semantic technologies [14][49]. The objective is to clarify the roles of semantic technologies with the ones currently used in e-business frameworks and to describe the architecture and implementation of B2B integration using semantic technologies. These objectives give rise to the third set of research questions.

3. How do semantic Web Service technologies enhance e-business framework based integrations?

   Sub-questions to answer this question are:

   a. How do RosettaNet and semantic Web Service technologies relate to each other?

   b. Is there need for additional expressive power of semantic Web Service technologies in current e-business frameworks?

   c. How would a solution combine e-business frameworks and semantic Web Service technologies for practical B2B integration scenarios?

1.3 Research methodology

The research questions address new solutions to existing problems in B2B integration. To be able to reach the objectives and answer the research questions, this research builds B2B integration prototypes and evaluates them, especially in the case of supporting networked product development. The study also builds models to present the relations of different technical standards and e-business frameworks to help to position the role of different standards and technologies to each other. The process of constructing and evaluating innovative IT solutions make it possible for researchers and practitioners to understand the problem and evaluate the feasibility of their approaches [124]. The primary methodology to guide the research was first *Constructive research* [80] and later *Design research* [72].

Furthermore, case study research guidelines [5][168] have been used in the data collection to understand the problem domain. The data collection used semi-structured interviews that were taped and transcribed, and available documentation and examples from information systems. Academic literature has been studied during the whole process. Initially, a literature search was done to understand the problem area and to find related research. Later, a systematic literature review was done according to the structured approach by Webster and Watson [165].

1.3.1 Constructive research methodology

The constructive approach means problem solving through the construction of models, diagrams, plans, organisations, etc. This mode of research is widely used in technical sciences, mathematics, operations analysis, and clinical medicine. In general, it is suitable for applied research, and the industrial relevance of the research is important. Constructive research has the following phases [80].

1. Finding a suitable problem of both practical and research interest
2. Obtaining a general understanding of the problem
3. Innovatively constructing a solution
4. Demonstrating that it works
5. Showing the theoretical connections and research contribution of the solution
6. Examining the applicability of the solution

1.3.2 Design research in information systems

Design research has its roots in engineering and sciences of the artificial [145]. Improving the practise and solving problems is essential, as the utility of the solutions is important. In the design paradigm, knowledge and understanding of the problem domain and its solution are achieved by building and application of designed *artifact*. IT artifacts are defined as constructs (vocabulary and symbols), models (abstractions and representations), methods (sequence of activities) and instantiations (implemented and prototype systems) [106]. The result of design research is a purposeful IT artifact created to address an important organisational problem. The artifacts need to be described effectively, enabling their implementation and application in an appropriate domain. According to Vaishnavi and Kuehler [158], the research steps in design research are the following:

1. Awareness of a problem
2. Suggestion
3. Development
4. Evaluation
5. Conclusion

1.3.3 Research steps in constructive and design research

The research steps are similar in both methodologies. The first step of design research corresponds to steps one and two in constructive research and is about understanding relevant problems. The suggestion and development steps corresponds to step three “innovatively constructing a solution” in constructive research. Evaluation in design research corresponds to step four “demonstrating that it works” and partly step six “examining the applicability of the solution” in constructive research. Conclusion in design research includes presenting the research contribution and the relevance to practise. This corresponds to step five “showing the theoretical connections and research contribution of the solution” in constructive research.

1.3.4 Motivation for using design research

This work was started with the constructive research approach, but since 2004 the design research methodology has been followed, as design research is widely used in the information systems discipline, within which B2B integration is studied. Furthermore, the constructive research methodology guidelines [80] are targeted to “management accounting”, while design research has an information systems focus.

The knowledge provided about e-business frameworks resembles explanatory case studies. However, the research results are models and abstractions about what is standardised in the e-business frameworks, as well as a set of propositions and statements expressing relationships between different e-business frameworks and their standardisation. These can be considered as artifacts and are thus evaluated and positioned in comparison to other academic research in e-business frameworks.

The proof-of-concept prototype developed to support networked PD projects is a pure IT artifact, instantiation. A proof-of-concept architecture and implementation is developed and evaluated according to the guidelines of design research. In addition, the work on applying semantic Web Service technologies also follows the guidelines of design research.

1.3.5 The research process

1.3.5.1 Awareness of the problem

The awareness of the problems related to B2B integration was gained from a literature study and the continuous implementation efforts. The literature review was conducted according to the structured approach by Webster and Watson [165]. The first step of the literature review was taken by going through the relevant top journals of Computer Science and Information Systems. The choices of journals were ACM SIGMOD record, Communications of the ACM, Communications of the Association for Information Systems, Computers in Industry, Computer Standards & Interfaces, IEEE Computer, Information Systems Frontiers, Information Systems Research, Information & Management, Journal of Manufacturing Technology Management, Journal of Systems and Software, MIS Quarterly, Production Planning & Control, and VLDB Journal. Due to the recent increase in e-business and business process automation, the journals were examined starting from the year 2001. Articles with a promising abstract were studied in order to eliminate articles not related to the research. In addition, certain relevant conference proceedings were browsed, such as the IEEE conference on e-commerce technologies and the World Wide Web conference.

In addition, a set of keywords was defined such as “e-business architecture”, “e-business framework”, “e-business framework (also RosettaNet, ebXML) implementation”, “PDM integration”, and “Semantic Web Services”. Also other similar keywords used by different articles for e-business frameworks were used to locate potential articles. Then a number of electronic collections were searched, such as the ACM digital library, Citeseer, EBSCO host, IEEE Explore, JSTOR, Lecture Notes in Computer Science, Science Direct and the Web of Science.

The second and third step of the structured literature review were taken by backward and forward citation analyses [165] from the key articles and their authors. With these methods, a few more articles were found. The literature review came up with all important articles and many new ones. The articles were classified in following groups: B2B integration, e-business framework comparisons, e-business framework implementations, and IT support for product development. Scholar Google[1] was also used to check forward citations. Chapter 3 summarises the literature review findings.

The implementation experiences increased also the understanding of the problems. These resulted in study of need for faster setting up of B2B integration and need for technologies that are more expressive to help interoperability.

1.3.5.2 Suggestion & Development

During the thesis, implementations have been made in applying RosettaNet standards to B2B integration (Chapter 5, publication I and II). Later, also semantic technologies have been applied to tackle some problems in the current RosettaNet specification based on experiences with earlier implementation efforts (Chapter 6, publications V and VI). Simultaneously, classification of the different possible standards for B2B integration has been done resulting in classification of different e-business frameworks (Chapter 4, publications III and IV).

1.3.5.3 Evaluation

Evaluation has been conducted according to design research evaluation guidelines [72] and by comparing the thesis artifacts to related academic research. The preset criteria for the artifacts are given and the artifacts have been evaluated based on how those are accomplished.

Furthermore, Kasanen et al. [80] view artifacts as products competing in the market of solution ideas and provide different steps for the validation of industrial relevance. The following guidelines for validation have also been used for the present artifacts.

- Weak market test: Is any business practitioner willing to apply the artifact in question in his or her actual work?
- Semi-strong market test: Has the artifact become widely adopted by companies?
- Strong market test: Have the business units applying the construction systematically produced better financial results than those, which are not using it?

1.3.5.4 Conclusion

The main conclusions are presented in this thesis. The contributions to practice and research are discussed in chapter 8. In addition, new research questions have been identified.

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[1] http://scholar.google.com/

1.4 Scope

The literature review focuses on B2B integration standards and implementations. In addition, support for PD using IT solutions is included, as well as existing semantic Web Service based B2B integration efforts. The actual B2B integration implementation experiences section concentrates on B2B integrations with RosettaNet.

This thesis work concentrates on technical aspects of interoperability that arise only after trust and willingness to collaborate exist. With reference to the Business Interoperability Framework [97], the study focuses on technical interoperability issues regarding collaborative business processes and information systems. Thus, strategic and organisational issues and integrations using portals are excluded.

1.5 Key contribution of the thesis

The new knowledge provided in this work is summarised in figure 1.

- B2B integration and the role of XML-based e-business frameworks is conceptualised. It is shown that e-business frameworks mainly specify *business documents*, *business processes* and *messaging* issues, and the role of different technologies in the B2B integration is shown. Competitive and co-operative issues between important e-business frameworks are pointed out.
- The support offered from RosettaNet to B2B integration matches the requirements to support PD processes. However, shortcomings in current RosettaNet specifications to support interoperability are pointed out. Building a prototype solution also helps identifying some special characteristics of support for PD that need to be reflected in the integration architecture. These include the need for a fast set-up of the B2B integration process.
- Finally, it is shown how semantic technologies have potential to enable a more flexible integration and quicker integration set-up. A solution to handle heterogeneities to address the shortcomings of existing RosettaNet specifications is presented.

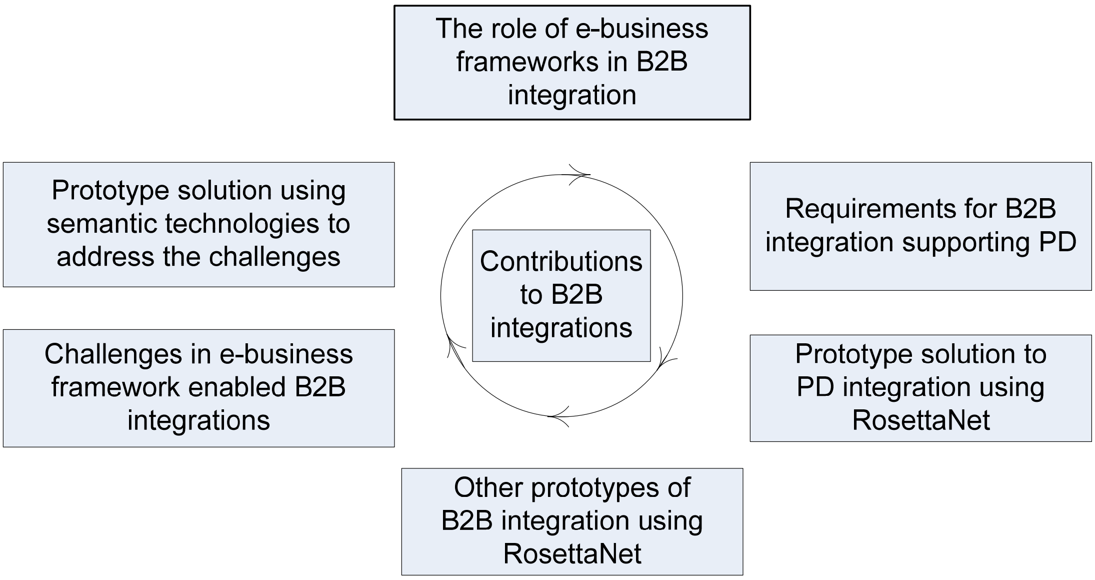

Figure 1 The contribution of the thesis

1.6 Structure of the thesis

The first chapter presented the background, objectives and scope of the research, as well as explained the research methods and gave a summary of research contribution. Figure 2 presents an overview of the contents of each individual chapter.

Chapter 2 presents the motivation and background for B2B integration. It introduces the main technologies and prominent e-business frameworks. This chapter is intended as an introduction to the basic concepts and technologies. The chapter is extended background from the individual publications.

Chapter 3 summarises the existing scientific knowledge on the basis of a literature review of the research domain of this thesis. The existing research on e-business frameworks, information systems integration, IT support in networked product development and to B2B integration using semantic technologies are reviewed.

Chapter 4 summarises publications III and IV and extends the evaluation by positioning the results with related research found in the literature review

Chapter 5 summarises the experiences presented in publications I and II on using RosettaNet for practical integration scenarios. The evaluation here is an extended version of the publications, based on design research guidelines and literature review.

Chapter 6 summarises publications V and VI on applying semantic technologies to B2B integrations and RosettaNet. The chapter also builds partly on chapters 4 and 5, tackling the problems experienced with the technologies according to the experiences with RosettaNet integrations.

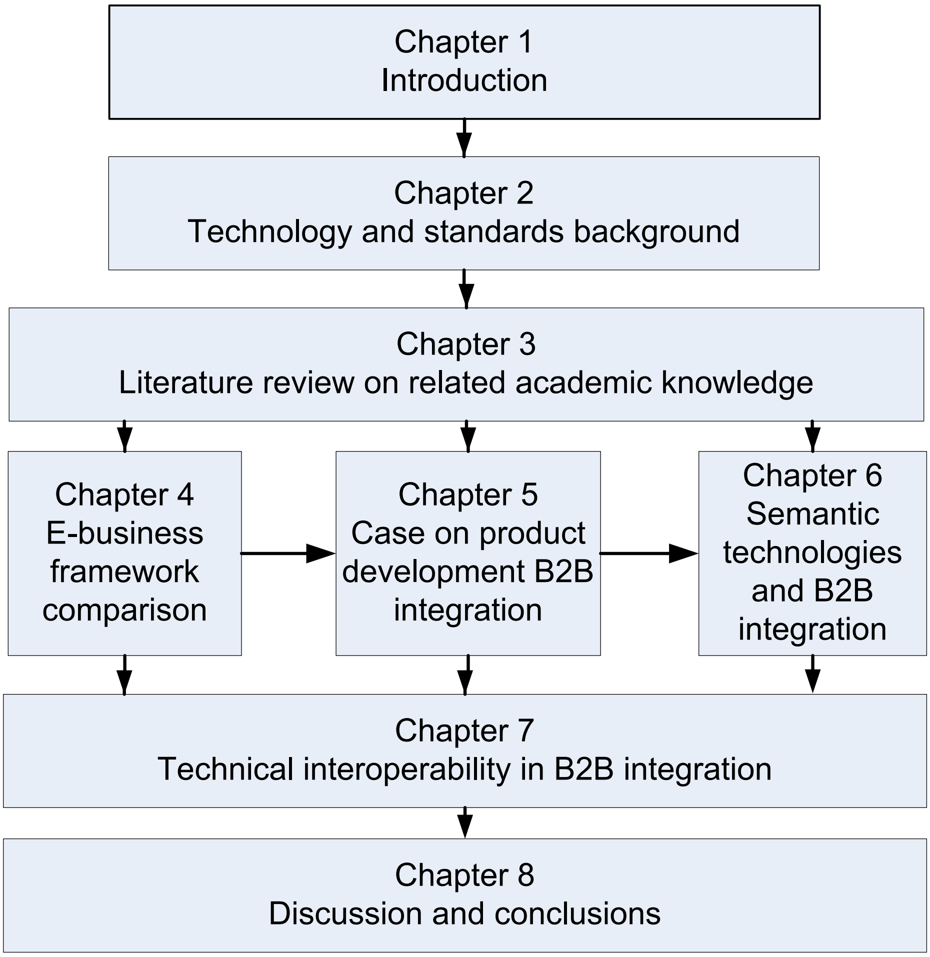

Figure 2 The structure of the thesis

Chapter 7 summarises the main lessons learned. It combines the experiences on e-business frameworks, RosettaNet integration and semantic integration and discusses implications to technical interoperability.

Chapter 8 contains the conclusions of the research, discusses the practical relevance and scientific rigor of this work, and finally presents topics for future research.

2 B2B integration, XML and e-business frameworks

This chapter presents the motivation for B2B integration and standardisation. The basic integration architectures and the most important technologies, Electronic Data Interchange (EDI) and XML, used in B2B integrations are introduced, as well as the current state-of-the-art technologies for B2B integration. Finally, the role and motivation for XML-based e-business frameworks and the most relevant frameworks are introduced.

2.1 B2B integration

Business integration is the creation of tighter coordination among discrete business activities conducted by different individuals, work groups, or organisations, so that a unified business process is formed [107]. Business integration can be just internal integration within one company or it might be external *business-to-business* (B2B) *integration* that takes place across organisations. In general, the benefits of B2B integration come from many sources. The major cost savings result from reduced data entry, personnel and communication costs, and the other benefits come from a faster trading cycle, improved cash flow, security and error reduction and improved corporate trading relationships [99].

Systems integration refers to the creation of tighter linkages between different computer-based information systems and databases [107]. Systems integration is often required to achieve B2B integration and can be considered as automated B2B integration. There are also several general architectures for B2B integration [14][100][147][167]. The architectures have some commonalities: there is physical connectivity to communicate the data. The data needs to be obtained from source systems and saved to target systems, and this often involves transforming the data in different business documents. In addition, there is a process layer at the top of technical stacks. Figure 3 presents a framework for business integration by Stohr and Nickerson [147] that shows a connection to other activities in organisations. Not all processes are formal and need to be automated by systems integrations, but many activities are better done by faxes, e-mail, face-to-face meetings or using other collaborative tools. As Markus [107] points out, integration in a software systems sense is not sufficient to ensure organisational efficiency and effectiveness. Organisations consist of individuals, departments and functions, which need to be integrated for the organisation to be successful. In this work, I concentrate mostly on the systems integration aspects. In figure 3, the systems integration required is presented from the most concrete on the bottom to the most abstract on top. They point out that integration in one layer depends on integration at lower levels in the hierarchy. For example, integration at the applications level requires a common understanding of the data integrated, which in turn implies integration at the data level.

	Resource/ Integration Need	Examples of Integration Mechanisms	Enabling environment /Infrastructure	
Organizational Integration	Organizational Units (Functions/Departments)	E-mail, collaborative software, lateral teams -------------------------------------- Top Management Strategy, budgets, performance metrics	Organization policies/ structure	
	Decision Makers	Email, collaborative software, knowledge management systems -------------------------------------- Face-to-face meetings, job design, performance metrics		
Systems Integration	Business Processes (both internal & external to the firm)	Workflow, Collaborative Systems, SCM, CRM, Web Services -------------------------------------- Process owners, teams, performance metrics, service level agreements	Standards	Systems Architecture
	Applications	Inter-process communication, RPC, Messaging, ERP, Web Services	Networks	
	Data	Data Dictionaries Databases, XML	Platforms	

Figure 3 Framework for enterprise integration [147]

A requirement for the automation of inter-company business processes is that the different information systems supporting the business process can communicate. The information systems participating in the automated interactions between organisations are typically heterogeneous in terms of interfaces. The underlying data model in the information systems differ - same terms can have a different meaning or different terms mean the same thing. For example, “Nokia” as a value for an organisation can refer to the Nokia company or a city called Nokia in Finland, and organisations might do business with both. An example of different terms referring to the same thing is that any given product model, such as Nokia Phone 3510i, can be referred to in different systems by “N3510i” or “Nokia3510i” or the system can have the same information split to multiple fields “Nokia Phone”, model=”3510”, version=”i”.

To solve this kind of heterogeneity, common agreements are needed for the source systems to integrate with the target systems. To avoid doing the same integration work when integrating with different organisations, there has been a lot of standardisation to specify common document exchange patterns for B2B integration. Having standards enables the reuse of same definitions with multiple partner organisations and thus make the enterprise architecture simpler and less expensive to maintain. It also makes the integration more loosely coupled so that changes in the information system of the partner organisation do not affect the collaboration as long as the use of the standard stays the same [88].

2.2 Manual vs. automated B2B integration

Figure 4 illustrates manually conducted information exchange. When a person initiates the sending of a business document to company B, the different steps in the process require printing out the information, packing and sending it through postal delivery, fax or e-mail. In company B, someone has to open the incoming letters/faxes/e-mails and manually type in the information so that the data is available in their information systems for their employees to work on the data. This process is slow and it takes time to just communicate the information. The steps in the delivery also cost and entering information manually is also error-prone and can potentially cause problems. Moreover, when the need for information exchange grows, the number of people needed in typing the data into the information systems manually increases linearly.

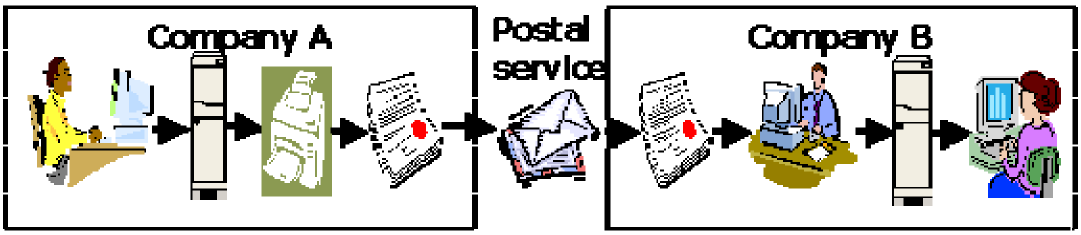

Figure 4 Manually conducted business process

In the automated process accomplished by systems integration, there is no need to print, send through post or fax, open the package and re-key the data. Figure 5 illustrates automated delivery using commonly agreed business documents and secure messaging without manual process steps. The automated process is fast and there is no place for typing errors in company B. When the need for data transfer is high, the frequency of data transfer (volume) is high, or the risk of human errors is high, then system-to-system integration efforts are financially justifiable. However, the automatic transfer of information between systems requires a much higher level of harmonisation in working practices, as the systems need much more structured information and are less flexible than humans who can make interpretations [60]. Not all processes are suitable for automation. If there are many exceptions and changes in the processes, information systems are rigid and slow to adopt to such changes.

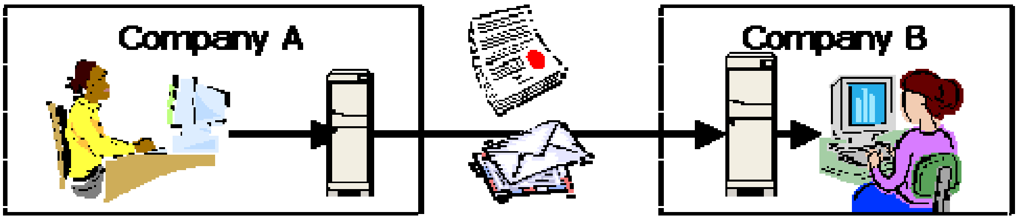

Figure 5 Automated business process

2.3 Degrees of automation in B2B integration

There are many degrees of B2B integration complexity, ranging from partly to fully automated interaction between the participating information systems. In the most complex case, the process is fully automated. For example in the case of automatic inventory replenishment, a system can automatically order products from partners, based on current stock levels going below the reorder point. This needs previous agreements and in B2B integration. For instance, there must be a predefined logic that can automatically decide, when there is need for filling the inventory without any person to verify the details. The fully automated B2B integration typically uses EDI or XML-based e-business frameworks although such integrations can also be built point-to-point by the partners.

Semi-automated integration is human-initiated or includes human decisions, such as approval in the process steps, to initiate B2B integration or to accept the information into the company's own information systems. The process steps exchange information without the need for humans to print out or type in information, as they use the company's information systems, while the systems themselves can automate the information exchange to the partners needing the information. The actual B2B integration usually happens by either using EDI or XML-based e-business frameworks.

B2B integration can be also manual from one partner's point of view, as a small and medium-sized enterprise (SME) might not even have an information system [146][157]. An SME can integrate to its partner so that there is a human performing all the steps of receiving a business document, making a decision based on it and then forming and sending the responding business document to the partner. If the manual sending happens using the same EDI or XML standard business documents that could be automatically created, then it is still considered B2B integration as the interface between the partners is the standard business document that goes to the information system as with other partners. Manual integration work does not scale to lots of business documents, but more automated solutions are needed [21].

Fully automated integration is the fastest for the overall process. It is also the most rigid to changes and the most complex to implement, as the decisions need to be described by logical rules to produce and check the documents automatically.

Integrating partners through a Web portal to enterprise information systems using intranets or extranets is considered manual B2B integration, as the integration happens on the human user interface level. For example, a manufacturer company has a portal for its suppliers, the portal provides the suppliers with information about the forecasts of future component needs and quality information about past shipments. The portal offer one user interface to manufacturer's potentially many information systems. However, from the supplier's point of view, the portal is just another information system interface and the end-users need to extract or copy the same information manually to their own company's information systems. This means that the end-users need to learn to use the different portals as well and not just their own systems. The transition path and the roles of portals and systems integration to more full automation is discussed in Schemm et al. [141], who also state the desire of bigger suppliers to use systems integration over portals.

2.4 Standardisation

The first B2B integrations were just point-to-point integrations without the use of standards. Car manufacturers were the first to drive the standardisation of B2B integration [136]. Originally, big car manufacturers wanted to use their internal data standards for the exchange of business documents. As more and more companies tried to impose their internal, proprietary data formats on their business partners, more and more companies were confronted with the necessity of maintaining multiple point-to-point formats. The push towards the standardisation of data formats used for exchanging business documents was initiated by developing standards for more or less well defined industries or supply chains.

The case study of Ford e-business implementation illustrates the transitioning from proprietary solutions towards the use of standards [60]. In 1985, Ford set up a proprietary network covering all their European sites and including links with their most significant dealerships and suppliers. Ford adopted the German Automotive Association VDA (Verband der Automobilindustrie) business document standard, as it was available at the time. Ford joined the Organisation for Data Exchange by Teletransmission in Europe (ODETTE), the Electronic Data Interchange (EDI) project established by the European Automotive Industry Association, but later withdrew because they sought to gain an advantage by introducing electronic commerce ahead of their competitors, without waiting for sector-wide business documents to become available. When other manufacturers implemented the ODETTE business document standards, Ford’s policy forced the suppliers to maintain parallel systems. Large car dealerships also needed internal systems capable of linking to both Ford and other manufacturers to avoid the danger of being bound to Ford by non-standard systems. As the costs for suppliers of dealing with two incompatible standards became apparent and the competitive benefits of a proprietary system for links with suppliers eroded, Ford agreed in principle to migrate to the EDIFACT document standard when it becomes adopted in the US. The network externalities of increasing EDI diffusion mean that it may be in the interests of all players, even the largest, to move to open systems [60]. This case demonstrates well certain difficulties in establishing common standards. Even nowadays, the VDA standards are in use in the automotive industry, and there are also proprietary formats used by individual partners.

In general, standardisation brings order into the uncertainty by reducing variety [38]. With standards in place, the negotiations related to establishing B2B integration should be smaller, as the standard creates a ready template and common terminology and structure for the exchanged information [135]. In addition, the B2B integration solution based on standards should be easily extended to cover more partners than proprietary point-to-point links. The building of software products to support standards is also good for software vendors, as they can sell their solution to more organisations.

2.5 Electronic Data Interchange

The development of Electronic Data Interchange (EDI) standards for B2B integration began in the 1970’s. There are two main EDI syntax standards in use. The first standards of the US version of EDI, American National Standards Institute’s (ANSI) ASC (Accredited Standards Committee) X12, were published in 1983. The EDI for Administration, Commerce and Transportation (EDIFACT) originated in 1985 to address the problems caused by different standards on both sides of the Atlantic. The EDIFACT standard development is United Nations (UN) led. The X12 syntax is the most commonly used EDI syntax in North America, while EDIFACT is the dominant standard in the rest of the world.

The UN/EDIFACT syntax (ISO 9735) defines the structures used for interchange of business data. The syntax defines the components of the language and how they relate to each other, while the grammar that controls the document design is described by the Message Design Rules. The UN/EDIFACT syntax, in its earliest versions, had three basic assumptions on the data and how they are interchanged. They were character-based data, batch data transfer, and predefined, structured documents. In the version 4 of the syntax, capabilities for interactive data transfer and transmission of binary data have been added, together with a set of comprehensive security mechanisms.

When EDI was introduced, information exchange was expensive. Therefore, the EDI syntax is very compact in size. This makes the EDI documents hard to read and maintain, as codes are used to represent complex values. For example the EDIFACT line item segment “LIN+1++5413634001584:EN'” tells that the line number of the order is “1”, the coded action requests or notifications are not specified “”, the product ID is “5413634001584” and the classification scheme is “EN”, which means it is a European Article Numbering (EAN) identifier.

The EDI transportation still often uses Value Added Networks (VAN) operators, although EDI does not limit transport mediums. These special connections have been quite expensive. The recent advances in EDI messaging standards, such as EDIINT specifications from Internet Engineering Task Force (IETF), have made it possible for companies to transact EDI over the Internet.

EDI has advantages over manual business interactions, such as reducing paper consumption, eliminating data entry errors, and speeding up the transfer of business information. However, EDI does not guide any document sequences or time to answer with responding interaction, and thus XML-based standards providing this are said to bring even more speed to business processes.

The use of EDI has concentrated on large enterprises, whereas SMEs have hesitated in adopting EDI. Iacovou et al. [73] found that small companies tend to lack the needed high organisational readiness and perceived benefits for EDI.

2.6 XML technologies

XML and the core XML technologies in current B2B integration are presented. Of newer technological development, XML applications relevant for B2B integration are introduced including Web Services, Semantic Web, Business Process Management and Service-Oriented Architectures.

2.6.1 XML

The Extensible Mark-up Language (XML) is a platform-independent open standard defined by the World Wide Web consortium (W3C) in 1998 [10]. XML serves as an interchange format for exchanging data between applications. It combines the flexibility of the Standard Generalised Mark-up Language (SGML) and the simplicity of the HyperText Mark-up Language (HTML). XML is a meta mark-up language for expressing structured documents, and it defines the syntax in which other specific mark-up languages can be written. However, by just having information in a XML document does not make the applications understand each other, it just provides a way to access information.

An XML document always has to be syntactically well-formed. It is well-formed when the XML document has exactly one root element, all the tags are closed and the attribute values are in quotes. This is not the case with HTML, and this is a source of many complications in applications using HTML documents.

2.6.2 XML schema languages for defining valid XML documents

An XML document can be validated against a Document Type Definition (DTD) or an XML schema that is included in or referenced by the document. DTDs originate from SGML. A DTD specifies the structure of the XML document by defining the elements of the document, occurrences of the elements and a hierarchical order between the elements. The DTD may define the required and optional attributes of the elements and alternative values of the attributes. It may also contain references to other DTDs. However, DTDs are not well-formed XML documents and provide little support for data typing and cardinality.

W3C has defined an XML-based general-purpose schema language, XML Schema [48]. It defines similar issues as DTDs, but has more expressive power. XML Schema offers a number of built-in data types and capabilities to define new types. With XML Schema, one can define, for example, how valid date values or currency enumerations should be represented in the documents. It is also possible to present cardinality constraints, such as having a choice between two or more possible elements.

Before the W3C defined XML Schema syntax there were also other schema languages, such as XML data reduced (XDR) by Microsoft and Schema for Object-Oriented XML (SOX) by Commerce One that were defined in anticipation of the coming W3C XML Schema. Besides DTD and XML Schema, there are two active schema languages, Schematron and RelaxNG. They all have their own strong points and application areas. Schematron is been used to validate issues that XML Schema cannot validate as well. However, they lack the authority gained by being a W3C recommendation. A schema language is not always needed to validate document. Lim and Wen [99] list also the use of Extensible Stylesheet Language Transformations (XSLT) and procedural code validation as options for checking the validity of XML documents.

2.6.3 Transforming XML documents

W3C defines a general-purpose language called Extensible Stylesheet Language Transformations (XSLT) for transforming XML documents from a schema to another [31]. XSLT was not intended as a completely general-purpose XML transformation language, but was designed for use as a part of Extensible Stylesheet Language (XSL), which is a stylesheet language for XML. XSL includes a vocabulary for specifying formatting and it can be used to present an XML document in a web browser. A transformation expressed in XSLT describes the rules for transforming a source document into a result document. XSLT is widely used in XML transformations. However, if two schemas are different in content, not all information can be transformed [81][98][166].

2.6.4 Web Services technologies

Web Services are services defined using XML that can be employed by other applications using Internet protocols. The basic Web Service technologies are SOAP, Web Services Description Language (WSDL), and Universal Description, Discovery and Integration (UDDI).

SOAP defines a framework for describing what is in a message and how to process it, a set of encoding rules for expressing instances of application-defined data types, and a convention for representing remote procedure calls and responses [61]. It is the messaging layer for Web Services.

WSDL defines services as collections of network endpoints or ports [29]. In WSDL, the abstract definition of endpoints and messages are separated from their concrete network deployment or data format bindings. The basic Web Service client’s code can be generated automatically from the WSDL making it easier for programmers to use the service.

UDDI provides a mechanism for clients to find Web Services [32]. With a UDDI interface, businesses can look up as well as discover services provided by external business partners. There has been public UDDI registries operated by IBM, Microsoft and SAP, but as of March 2007, all the public registries were inactive. In addition, there can be private UDDI registries for companies' internal use and for the use of their partners.

Web Services technologies, particularly SOAP and WSDL, seem to be now well supported by software vendors and programming languages.

2.6.5 Semantic Web technologies

The Semantic Web is an extension of the current Web, where information has a well-defined meaning [6]. The goal is to make computers understand more and enable for example better searches on the Internet. The new formal semantic technologies introduce languages to provide more powerful validation and inference capabilities. By design, they are targeted to tackle the interoperability problems of current Internet technologies. It is a truism of computing that to map between dissimilar data structures, a more powerful data representation is needed [70]. From more expressive model translation is possible to the less expressive model, but for the other direction it does not work.

There are multiple languages developed for realising the Semantic Web. The best known technologies are W3C recommendations Resource Description Framework (RDF), Resource Description Framework Schema (RDFS), and Web Ontology Language (OWL).

The Resource Description Framework (RDF) is an XML language for representing statements about resources in the Web as a directed graph of subject-predicate-object triples, and exchanging them between applications [95]. The subject identifies the resource using Uniform Resource Identifiers (URI), the predicate identifies the property of the subject that this statement specifies, and the object identifies the value of this property.

The Resource Description Framework Schema (RDFS) extends RDF by providing means for describing application-specific classes and properties, and indicating which classes and properties are expected to be used together. RDFS allows resources to be defined as instances of one or more classes, and classes to be organised in a hierarchical fashion.

The Web Ontology Language (OWL) extends RDFS by providing additional vocabulary along with formal semantics [110]. OWL allows complex relations and constraints to be defined between classes and properties for reasoning purposes. OWL has three increasingly expressive sub-languages: OWL Lite, OWL DL, and OWL Full. OWL Lite has least expressive power by having limited number of constructs and quite a lot of restrictions. For instance, it restricts the syntax to single class names in subClassOf statements. OWL Full allows arbitrarily complex class descriptions, consisting of enumerated classes, property restrictions, and Boolean combinations. In addition, OWL Full allows classes to be used as instances, which OWL DL or OWL Lite do not allow. It is unlikely that any reasoning software will be able to support the complete reasoning for OWL Full [110]. OWL DL is more restricted than OWL Full but still has a lot of expressive power. OWL DL is named due to its correspondence with Description Logics. OWL DL supports those users who want maximum expressiveness while retaining computational completeness and decidability. The OWL DL restrictions allow the maximal subset of OWL Full, against which current research can assure that a decidable reasoning procedure can exist for an OWL reasoner. OWL Full is for users who need maximum expressiveness with no computational guarantees or rigid syntax restrictions.

2.6.6 Semantic Web Services

The basic XML standards for interoperation of Web Services specify only syntactic interoperability, not the semantic meaning of documents. This requires implementers to reach specific agreements on the interaction of Web Services and makes automatic composition of Web Services difficult. Semantic Web Services (SWS) solve these problems by providing a semantic layer on top of the Web Service infrastructure. Semantic Web Service technologies tackle interoperability by introducing formal languages to extend Web Services with an explicit representation of meanings. They have more expressive power than current XML Schemas in WSDL to impose semantic constraints on business documents exchanged without a custom program code. Multiple standardisation efforts aim to define a framework and a language stack for semantic Web Services aimed to automate application integration. These include OWL-S [108], WSMO [138], and WSDL-S [1]. As WSMF [50], the underlying model for WSMO, is said to have comprehensive conceptual architecture for e-commerce requirements [18], it is covered here.

The Web Service Modeling Ontology (WSMO) provides a conceptual model and a language for describing the relevant aspects of Web Services [138]. The goal of such mark-up is to enable the automation of tasks involved in both intra- and inter-enterprise integration. The mark-up of services according to the WSMO conceptual model is expressed in the Web Service Modeling Language (WSML) family of ontology languages [40]. WSML consists of a number of variants based on different logical formalisms that roughly correspond to the various OWL sub-languages. WSMO is the underlying model of the Web Service Execution Environment (WSMX) [62]. WSMX is an integration platform conforming to the principles of a

Service Oriented Architecture (SOA). Languages such as the Web Ontology Language (OWL) or the Web Service Modeling Language (WSML) have the needed expressive power to assign rules for documents for which the DTD or XML Schemas are not enough. The Internet Reasoning Service framework and implemented infrastructure (IRS-II) [115] is another infrastructure similar to WSMX based on same theoretical concepts.

Preist et al. [135] state that semantic Web Services have the potential to significantly speed up the integration process by reducing integration time from months to minutes in ideal cases. Furthermore, there are many papers discussing in general the benefits of SWS to e-business and B2B integration [13][15][39][78][91] [154][155][162]

2.6.7 Service-Oriented Architectures and Business Process Management

Service-oriented computing research targets Service-Oriented Architecture (SOA) and Business Process Management (BPM) [131]. The proponents of SOA and BPM promise more agility by having increasingly model-driven systems and more reuse. XML is the central underlying element in the standardisation of the languages to support SOA and BPM.

SOA is a recent term, which is used to point to a service-oriented approach to enterprise architectures and set of Web Service technologies that are typically used in practical implementations. The use of open standards is one major part of SOA compared to traditional enterprise architectures.

BPM refers to describing process models and possibly creating model-driven process execution. There are many XML-based technologies also used to describe processes that range from abstract behaviour to concrete process execution support. Many XML-based languages originate from the workflow systems domain to create a standard for describing process information. Among the first languages were Microsoft's XLANG and IBM's Web Services Flow Language (WSFL). The companies later combined these standards to form the Business Process Execution Language for Web Services (BPEL) [132] that was later submitted to the OASIS standardisation process. Other notable languages for describing processes include the Business Process Modelling Notation (BPMN) that is based on work done earlier on the Business Process Management Language (BPML).

There exists academic research on BPM language comparisons. Van der Aalst and Kumar [159] have compared BPEL, XLANG, WSFL, XML Process Definition

Language (XPDL), and four workflow products according to 20 different workflow patterns, which none of the languages or products support fully. They state that the software industry has ignored academic process-modeling techniques combining expressiveness, simplicity, and formal semantics, such as Petri nets and process algebras [159].

The current process languages are often divided to orchestration languages and choreography languages [132]. Orchestration languages can be used to define executable processes, while choreography languages specify abstract process behaviours. In a sense orchestrations languages define abstract and/or executable process languages to be used within a company to define executable internal processes. Choreography languages are not executable, but provide a way to present common public process message exchange between different partners. For semantic analyses on making mappings between different process languages, see Haller et al. [64]

2.7 E-business frameworks

Just having XML is not enough for B2B integration, as just exchanging XML documents does not mean that the XML documents are understood similarly. Being able to make easy-to-use interfaces, validate incoming and outgoing documents, transforming documents to support back-end systems, and defining process execution are all helpful for setting up integrations. However, without commonly agreed processes and document contents the integrations are still point-to-point formed. Therefore, standards are needed to guide interpretation of these details.

There are many papers discussing the standards for e-business, called here e-business frameworks. Late 1990’s saw the emergence of the BizTalk Framework and eCO Framework, similar initiatives such as XML/EDI, RosettaNet and Open Applications Group Integration Specification (OAGIS), which were titled as frameworks [92] or e-commerce frameworks [143]. However, as these frameworks are not just about commerce activities of buying and selling, the term e-business framework is used here to refer to these standards.

RosettaNet is introduced here. Many others, such as electronic business XML (ebXML) and OAGIS,are shortly introduced, as they are well known and still active in B2B integration standardisation. In addition, few other e-business frameworks are briefly presented.

2.7.1 RosettaNet

RosettaNet is an industry-driven consortium aiming at creating, implementing, and promoting open e-business process standards [139]. The most important components standardised in RosettaNet are Partner Interface Processes (PIPs), dictionaries and the RosettaNet Implementation Framework (RNIF). PIPs define common inter-company public processes (choreographies) such as "PIP 2A10 Distribute Design Engineering Information" and the associated business documents. Trading partners' internal private processes interact with PIPs to initiate or receive business documents. RosettaNet PIPs are divided to eight clusters noted by numbers, and the clusters are further divided to segments noted by letters. Cluster 2 deals with Product information and segment 2C defines "Product Design Information" related PIPs.

Each PIP contains a specification document, its schema(s), and message guidelines to help to interpret the schema. Most of the PIPs in this work are specified using Document Type Definitions (DTD) and Message Guidelines (MG). A specification document defines the process with Unified Modeling Language (UML) activity and sequence diagrams and textual descriptions, the roles of the partners, and necessary conditions to initiate messaging. Each PIP defines one or more business documents. The DTD and MG define the PIP service content of one business document. The DTD defines the valid XML document structure of a PIP service content. The MG introduces additional constraints and guidelines, such as what a modification date means and how the date value should be represented.

The RosettaNet Business Dictionary (RNBD) defines the common terms used in all the PIPs. In addition to dictionaries, RosettaNet uses certain identifiers, such as Data Universal Numbering System (DUNS) codes to identify companies uniquely and Global Trade Identification Number (GTIN) for products.

The RosettaNet Implementation Framework (RNIF) specifies messaging. It defines the RosettaNet business message that contains the business document specified by PIP DTD and MG, and the necessary headers and security features needed to process the messages. RNIF also defines how attachments are encoded in the RosettaNet business messages. These attachments can be of an arbitrary file format, such as AutoCAD. RNIF contains exception-handling mechanisms and makes sure that the delivery is non-repudiated, so neither the sender nor the receiver can later deny having sent/received the RosettaNet business message.

To set up RosettaNet messaging using a certain PIP, the companies involved set up a Trading Partner Agreement to specify both the business and technical aspects of the collaboration for each PIP. Example business aspects are conditions for trading, such as how certain elements are used, confidentiality, and when and how the PIP must be answered. Technical aspects include security features, such as the use of certificates for authentication and the addresses where the RosettaNet business messages are delivered.

RosettaNet had already in 2004 over 3000 documented implementations [36]. Since 2004, the PIP business documents have been specified using XML Schemas, and some of the constraints expressed earlier in MG are now machine-readable.

2.7.2 ebXML, OAGIS and other e-business frameworks

The United Nations Centre for Trade Facilitation and Electronic Business (UN/CEFACT) and OASIS (Organisation for the Advancement of Structured Information Standards) sponsored the ebXML project started in November 1999 as an 18-month project. The mission of ebXML is to provide an open XML-based infrastructure enabling the global use of electronic business information in an interoperable, secure and consistent manner by all parties. EbXML has defined a set of specifications designed to meet the common business requirements and conditions for e-business. The ebXML Business Process Specification Schema (BPSS) is an XML-based specification language that can be used to formally define the public business processes that allow business partners to collaborate. The ebXML Registry provides a set of services that enable the sharing of information between interested parties. The two specifications describing the use of registries are the Registry Information Model (RIM) and Registry Service Specifications (RS). The Collaboration Protocol Profiles and Agreement (CPPA) are used to encode a company’s e-business capabilities and technical agreements. The ebXML messaging services (ebMS) provide a general-purpose messaging mechanism to allow reliability, persistence and security. The ebXML Core Components (CC) provide the way business information is encoded in the business documents exchanged by providing building blocks for the documents. EbXML RIM, RS, CPPA, MS and CC have been approved as ISO standards.

The Open Applications Group [129] is an industrial consortium, formed in February 1995 to create common standards for the integration of enterprise business applications. Since 1998, OAG has provided XML-based specifications. The OAG Integration Specification (OAGIS) defines common business documents and support for associated business processes.

The marketplace vendor Commerce One was active in developing the eCO framework and XML Common Business Library (xCBL)[2], an open XML

[2] http://www.xcbl.org/

specification for the cross-industry exchange of business documents such as product descriptions, purchase orders, invoices, and shipping schedules. xCBL is a set of XML building blocks and a document framework that defines documents for e-commerce. The CBL preceding xCBL was a part of the eCO framework [57]. The xCBL schemas have been the starting point for the work of UBL.

cXML defines business documents similarly to xCBL and UBL. The electronic marketplace vendor Ariba actively developed the standard that was initiated in 1999[3]. The further development of cXML seems now quite slow.

The BizTalk framework [114] was developed to provide a secure messaging, and the BizTalk.org repository for storing business document schemas. The BizTalk.org website was closed down in July 2002 as it was identified that similar initiatives existed [52][87]. The BizTalk server product, which was one implementation of BizTalk framework messaging, is however an integration product still used today and the product support the RNIF messaging. Although the BizTalk framework was closed down in 2002, the framework has still been referred to in academic publications [56][59][83][112].

OASIS hosts a standardisation activity called Universal Business Language (UBL)[4]. The purpose of UBL is to develop a standard library of XML business documents (purchase orders, invoices, etc.) by modifying an already existing library of XML schemas, the xCBL. UBL 1.0 was declared an OASIS Standard in November 2004 and contained eight different business document schemas that belong to the order-to-invoice procurement process. UBL 2.0 [8] became OASIS standard in December 2006 and defines 31 document types. UBL provides standard business document schemas constructed with ebXML CC guidelines. The associated processes are described with diagrams and textual descriptions.

Although many e-business frameworks was covered here, the list could still go on. For instance, e-speak promoted by HP has been listed among the frameworks [83]. E-speak defines an open, integrated platform for e-services with features such as service discovery, negotiation, and service composition. E-speak defines conventions using XML documents that allow e-services to dynamically discover and negotiate with each other [79]. E-speak does not define any standard XML business documents to use but has defined elements of secure messaging. The emergence of various Web Services standards discontinued the e-speak project.

[3] http://www.cxml.org/
[4] http://www.oasis-open.org/committees/ubl/

3 Literature review

3.1 E-business frameworks in the literature

There are lots of publications on e-business frameworks. Some publications compare different frameworks based on some of their characteristics. Some concentrate on presenting basic classification on what is standardised in the e-business frameworks. Some publications advance to presenting architectures and systems of applying e-business frameworks to B2B integration. Overall, the significance on e-business frameworks is increasing with rising implementation figures [35][36][119][120].

Nelson et al. [119][120] have studied many standardisation organisations and present a standards adoption and diffusion model, empirically tested with a cross-sectional survey. The survey covering 15 standard developing organisations and 102 firms concluded that the growth in adopting these standards is very fast. Standards are on the verge of significant widespread diffusion considering the number of integrations (volume), different document types used (diversity) and the number of partners involved (breadth). Faster growth is expected across trading partners (breadth) than with new document types (diversity).

Damodaran [35][36] discusses RosettaNet adoption and challenges. He states that the adoption is quick and there are thousands of implementations. He discusses challenges related to document sizes and further automation of interactions, as currently over 50% of the time spent on implementations goes to data transformations.

3.1.1 Comparison of e-business frameworks

This subchapter briefly presents papers comparing or classifying e-business frameworks. Dogac and Cingil [41] compare four e-business frameworks and MESChain, which is an XML-based supply chain architecture developed at the Middle East Technical University (METU). Electronic Commerce Promotion Council of Japan [45] compare six e-business frameworks according to the Open EDI reference model based Business Operational View (BOV) and Functional Service View (FSV) properties. Kelkar et al. [81] introduce requirements for catalogue support and compare six catalogue document standards from e-business frameworks. They conclude that support for complex pricing models is limited in these business document standards. Kim et al. [83] compare 4 e-business frameworks based on their support for e-service components. The article identifies the components of e-service frameworks and compares frameworks based on several identified dimensions. Kok [86] discusses RosettaNet and ebXML convergence and how ebXML BPSS and CPPA specifications could be used in conjunction with RosettaNet. Li [98] compare seven frameworks and he used the size of DTD files to address the complexity of the frameworks studied. Medjahed et al. [112] compare five frameworks and divide e-business frameworks to communication, content and business process layers. Nurmilaakso [125] compare eight e-business frameworks. In addition, he classifies 18 other frameworks to document-centric, cross-industry, industry-specific and process-centric frameworks. Shim et al. [143] compare five e-business frameworks. Zhao [171] classifies 15 frameworks into eight categories having one to three frameworks in each.

Table 1 draws together the different articles discussing e-business frameworks. The dimensions and values represent typical comparison values. The *term for e-business framework* shows the name these authors used for them, as there certainly is no established terminology to refer to these. The next row lists all the *e-business frameworks compared*. The possible values for these typical frameworks are “eCO”, “xCBL”, “ebXML”, “RosettaNet”, “OAGIS”, “BizTalk” and “cXML”. *Other frameworks compared* lists the other standards included in the comparison as e-business frameworks, which are not in more than two comparisons. *Processes, documents and messaging* all get values “yes” or “no”. If the paper addresses some of these in close detail, it is also separated. *Competition and co-operation* highlights how e-business frameworks are mentioned to compete/co-operate according to the articles.

Table 1: E-business framework comparison					
Publication	Dogac and Cingil [41]	ECOM [45]	Kelkar et al. [81]	Kim et al. [83]	Kok [86]
Year	2001	2003	2002	2003	2003
Term for e-business framework	B2B e-commerce frameworks	B2B standard	Commercial XML standards	B2B e-service frameworks	B2B standard
Frameworks compared	eCo, BizTalk, RosettaNet, cXML	EbXML, RosettaNet, OAGIS	cXML, xCBL, RosettaNet, OAGIS	eCO, RosettaNet, BizTalk	RosettaNet,ebXML
Other frameworks compared	MESChain (Mention OAGIS and ebXML)	Yes (Web services, EDIINT, JEITA)	Yes (20 in total, BMEcat and EAN.UCC mentioned)	e-Speak	No
Processes	Yes	Yes	No	No	Yes
Documents	Yes	Yes	Yes	Yes	Yes
Messaging	No	Yes	No	Yes	Yes
Competition and co-operation	Compete most of the time. Messaging complementary.	Addressed (speculative values for RN/OAGIS)	Yes (transformations lose information)	No	Messaging competing, otherwise complementary
Publication	Li [98]	Medjahed et al. [112]	Nurmilaakso [125]	Shim et al. [143]	Zhao [171]
Year	2000	2003	2003	2000	2001
Term for e-business framework	XML-based industrial standards for EC	B2B interaction framework	e-business framework	e-commerce framework	XML-based Frameworks for EC
Frameworks compared	BizTalk, CBL, cXML, OAGIS	BizTalk, cXML, ebXML, eCO, RosettaNet	RosettaNet, ebXML, cXML, OAGIS, xCBL	ECO, BizTalk, RosettaNet, cXML	BizTalk, cXML, ebXML, eCO, OAGIS, RosettaNet
Other frameworks compared	Yes (IOTP, OCF and RETML)	No (other techniques such as WS compared)	Yes (26 in total, e.g. BPML, papiNet, XPDL)	Yes (OBI)	Yes (15 in total, WSDL, SOAP, RDF)
Processes	No	Yes	Yes	No	No
Documents	Yes	Yes	Yes	Yes	Yes
Messaging	No	Yes	Yes	Yes	Yes
Competition and co-operation	Yes (transformations lose information)	Not discussed	No	Yes (not compatible)	Yes (one picture on the situation)

The terminology referring to these standards for B2B integration is far from consistent across the papers. Even the same paper can use multiple terms to refer to these frameworks. Concerning the frameworks compared, RosettaNet is included most papers. Another remarkable thing is that already closed e-business frameworks, such as BizTalk.org are still discussed [83][112].

Concerning business process, business document and messaging aspects, the important properties change between publications, and the values for properties are often vaguely reported, for instance, whether business process descriptions are supported, whether the classification is based on existing specifications or just press releases of possible later usage. As an example, ECOM [45] comparison lists CPPA, MSG and BPSS as parts of RosettaNet usage, although no such evidence can be found in the RosettaNet specifications at the time. The transparency of the values is limited, as the specification versions used in the analyses are not always present and there are differences as the frameworks evolve. There is lack of cross-referencing in the studies, as many of the papers do not present related research.

Competition and co-operation between frameworks is a topic that is often handled in some detail. Many try to elaborate the situation and possible competitive parts. In general, it is not clear what should be included as an e-business framework? In addition, not all articles agree on values. There are different values for the same issues (starting year of a standard, does or does not include process definitions, competing or not). This has also been discussed by Kotok [92], who categorises 124 XML-based business vocabularies to nine frameworks, 38 functions and 77 verticals. Of the frameworks ebXML, RosettaNet, XML/EDI, cXML, eCO framework, BizTalk framework and OAGIS are mentioned but he does not go into further comparison. On the other hand, RosettaNet is often considered industry-specific, vertical framework, as it is strong in specific industries.

3.1.2 Papers on RosettaNet B2B integration experience

Although the number of existing integrations are high [35][36], there are few experience papers on B2B integrations using e-business frameworks [125]. Here scientifically reported implementation experiences on RosettaNet are drawn together in table 2.

Dogac et al. [43] present an implementation where an ebXML infrastructure is developed by exploiting UDDI registries and RosettaNet PIPs. This hybrid B2B infrastructure implementation includes tools for specifying the processes based on existing RosettaNet PIPs. UDDI registry is used to store ebXML documents and process descriptions. Dogac et al. have also developed a B2B server to provide mechanisms for secure messaging based on ebXML MS and workflow capabilities to keep track of the processes.

Ji et al. [74] describe RosettaNet integration concerning multiple PIPs for implementing third party logistics and vendor managed inventory (VMI) integrations. They propose a content-based document routing integrating a RosettaNet B2B system with an internal BPM system. They compare the processes needed for supplier-centric and customer-centric VMI to existing RosettaNet PIPs. This mapping reveals that sometimes two PIPs are needed to carry the information needed in one process step, and how one document needs to be answered by multiple smaller documents. The content-based solution of Ji el al. addresses these process heterogeneities. They do not provide details on the implementation but the system is said to be in production use and they discuss processes with 12 interactions and 10 different PIPs used to integrate these.

Khalaf [82] describes an implementation using BPEL together with RosettaNet PIPs. The objective is to allow the partners using a three-level approach to exchange details about their business processes covering the overall design, specialisation and implementation. The evaluation is done by presenting the solution to the RosettaNet board and the BPEL Technical Committee in OASIS. In the test setup, they had multiple servers running different instances representing different companies. The implementation used Web Services instead of RNIF to demonstrate easier agreement of choreography details. PIPs 3A2 and 3A4 were used in the demonstration.

Lu et al. [102] have studied the critical success factors of RosettaNet -based supply chain integration between Cisco and Xiao Tong. The benefits for Cisco through Xiao Tong's implementation of XML-based supply chain integration appeared in the form of more accurate information on the inventory, sales quality per product and faster processes. Earlier the information was transmitted in batches by hand. Cisco covered the 350000 USD software cost for Xiao Tong. RosettaNet and advanced back-end systems were also considered as critical success factors.

Preist et al. [135] describe a RosettaNet and EDI integration solution that utilises semantic technologies to handle the differences in EDI and RosettaNet. Their prototype illustrates the use of semantic descriptions to help partner discovery and have a running example of logistics supply chain.

Sayal et al. [140] present an HP Process Manager tool that supports RosettaNet PIPs and allows generating complete processes from PIPs by taking also internal integration to Workflow Management System needs into account. They concentrate on internal and public process mappings and assume that PIPs are used similarly. Their template-based approach makes it quicker to implement B2B integration. They use PIPs 3A1, 3A4 and 3A5 as the example order management process. Their approach expects the e-business frameworks to provide XML Metadata Interchange (XMI) -based process descriptions or else they need to be first manually generated.

Sundaram and Shim [149] present an infrastructure for B2B exchanges with RosettaNet. They have a three-tier client-server prototype that allows customers to send RosettaNet PIPs using a browser. Their prototype constructs RosettaNet PIP service contents. They claim to support all the PIPs and that this kind of solution would mean interoperability. There is no backend integration done and their prototype excludes RNIF functionality and the process aspects of RosettaNet considering times to answer.

Tambag and Cosar [150] describe a system utilising part from ebXML and RosettaNet. They describe their open-source implementation and their implementation utilises components by Dogac et al. [43].

Tao et al. [151] use RosettaNet as an example when they compare their internally developed data model for managing Work in Progress (WIP) information to the RosettaNet business dictionary and some unspecified PIPs WIP elements. They divide the mapped elements to “Exactly matched”, “Partially matched” and “Self-explicit style” from RNBD. However, they use the exactly matched against the RosettaNet message guidelines (MG) with the element “globalproductidentification”, which according to RNBD should be a GTIN number. This creates interoperability problems as element semantic descriptions are not adhered to. Tao et al. found all the elements they needed in 7B segment PIPs, but note that RosettaNet includes also many unnecessary elements for their scenario. For example, they report that RosettaNet ”Work Order” element has a 280-item hierarchical data type compared to 16 mandatory elements defined by the authors. The XML instance provided in the paper is not valid according to their own presented DTD, indicating that their solution has not been tested.

Different papers describe RosettaNet-based integration aspects. Table 2 classifies these papers concerning the frameworks used. The parts of the different e-business *frameworks used* in the implementation are listed first. Then whether the implementation covers *business processes*, *business documents* and *secure messaging* is described. *Requirements* describe whether the implementation is according to a certain case or whether it is based on general requirements. *Application area* handles the integrated processes. *Tools used* states what kind of systems/software is used. *Testing* and *evaluation* describes how the system is evaluated. *Backend integration* describes whether there is integration to other enterprise information systems. *Implementation described* states whether the system architecture and functionality is described to enable others to verify the details.

Table 2: B2B integration implementation experiences

Publication	Dogac et al. [43]	Ji et al. [74]	Khalaf [82]	Lu et al. [102]	Preist et al. [135]
Frameworks used	ebXML, RosettaNet PIPs	RosettaNet	RosettaNet (+ BPEL)	RosettaNet	RosettaNet and EDI
Process/ documents/ messaging	All	Process and Documents	Process, Web service	Not detailed	Process and documents
Requirements	General	Case	General	Case	General
Application area	General B2B infrastructure	Logistics and VMI	General B2B infrastructure	Order fulfilment	Logistics and discovery
Tools used	Open source	Not described	Not described	Commercia l	Open source
Testing/ evaluation	Not described	Not described	RosettaNet and OASIS experts	Not described	Scenario
Backend integration	No	Not described	No	Yes, ERP	No
Implementation described	Yes	No	Yes	No	Yes

Publication	Sayal et al. [140]	Sundaram and Shim [149]	Tambag and Cosar [150]	Tao et al. [151]
Frameworks used	RosettaNet	RosettaNet	ebXML, RosettaNet PIPs	RosettaNet
Process/ documents/ messaging	Process, documents	Documents	All	Process, Documents
Requirements	General	General	General	Case based
Application area	General B2B infrastructure	General B2B infrastructure	Order fulfilment	Work order management
Tools used	Commercial	Open source	Open source	Not described
Testing/ evaluation	Not described	Not described	Not described	Data model evaluated against RosettaNet data model
Backend integration	Yes, WfMS	No (Human interface)	No	Yes (WIP database)
Implementation described	Yes	Yes	Yes	Yes

All the implementations listed here are systems utilising at least partly RosettaNet PIPs. The secure messaging part of RNIF is not detailed in any of the publications. Two use a similar secure messaging specification from ebXML [43][150]. One paper focuses just on the PIP documents part [149], while a couple of papers are mostly focused on the technical details of internal processes integrations [82][140]. The specifics of interoperability within RosettaNet is handled in comparison to a specific part of PIP data models [151] and process instance content levels [74].

Most of the systems are based on general requirements, as the point of the article is some technical novelty of the implementation. Three papers [74][102][151] have specific cases of applications that have more specific requirements for the B2B integration.

The application areas for integration has been order fulfilment processes or the solutions are general purpose for all kinds of interactions. Ji et al. [74] target specific areas of logistics and Tao et al. focus on manufacturing work order information exchange [151]. Preist et al. [135] tackle also semantic partner discovery, while the infrastructures of Dogac et al. [43] and Tambag and Cosar [150] also address discovering business partners from ebXML registries. The general purpose platforms for all integrations are described in [43][82][140][149].

In addition to the papers listed here, there are also many papers describing systems using other e-business frameworks [11][17][84][126], such as ebXML and xCBL, but for space considerations, they have been left out. In addition, some just provide conceptual solutions to RosettaNet integration [163], and are not included in the comparison.

3.2 IT support for product development

There are many papers discussing IT support for collaborative product development.

Cutkosky et al. [34] describe an agent-based infrastructure, Madefast, for concurrent engineering in which the communication relies on Internet protocols. The participating applications communicate by translating internal concepts of applications to a shared language (grammar, vocabulary, and meaning). The system supports checking in/out documents and works similarly to web-based Product Data Management (PDM) systems. The benefits of using web technology include better user friendliness, greater accessibility and applicability, more effective linking, and easier formation of geographically diverse organisations. The same authors have previously presented a PACT system for collaborative engineering utilising agents and ontologies [33].

Chung and Lee [30] present a framework for collaborative design environment. The framework uses XML and Common Object Request Broker Architecture (CORBA) and can validate the correctness of the information.

Domazet et al. [44] present an infrastructure for collaboration based on an event-driven software component framework using the CORBA and Standard for the Exchange of Product model data (STEP). The modeling capabilities distributed over the Internet using CORBA facilitate collaboration between product designers, and STEP provides the common terminology. The infrastructure includes a rule management module.

Hameri and Puittinen [66] discuss two cases, in which a WWW-based solution for distributed engineering projects have been used. The case experiences report multiple benefits to projects. The solution enables integrating different phases of product life-cycle, information systems used and people contributing to various phases. When communication is electronic, monitoring of what is happening is easy. Hameri and Puittinen remind that 90% of all companies in the world are SMEs that are not eager to make large investments into proprietary software. An earlier paper [65] discusses the same system.

Kim et al. [85] present a Web Services for Collaborative Product Commerce (WSCPC) architecture to support service-oriented collaboration. WSCPC has a process server, web service calling module, cockpit, and in-house library, in order to support collaboration in product design. Kim et al. use the OWL language for semantic interface descriptions. Their further work is on developing formal pre-/post-conditions, similarly to what has already been defined in WSMO.

Pahng et al. [130] present a Distribution Object Modeling Environment (DOME) to support asynchronous collaboration. The environment can validate design changes between different modules automatically.

Rodriguez and Al-Ashaab [137] present a kdCPD system for collaborative product development. The system architecture is structured in a three-layered framework: information, application and end user layer. The proposed system does not aim to replace existing systems in companies but rather to be a support tool for communicating and sharing knowledge among the distributed partners functioning as a common portal to knowledge assets in different systems. The integration to databases and systems use CORBA.

Storga et al. [148] present a strategy, concept and architecture to support PDM during PD process, which utilises XML-based Web Services technologies SOAP and WSDL and STEP/XML integration. There solution is called Workflow Management Facility.

Wang et al. [164] present a Web/agent-based multidisciplinary design optimisation environment (WebBlow) for collaborative design. The same authors have published multiple papers on the use of agent technology for collaborative engineering [67] and a survey on collaborative manufacturing[169].

Zhang et al. [170] present Internet-based product information sharing and visualisation and its research challenges. They introduce also a system concept where CAD and STEP formats can be translated. For instance, taking an IGES file from the application can be translated to the STEP application protocol (AP) 203, which is further transformed to AP 209. The system acts as a portal with which the users interact. The system is integrated with the commercial Pro/Engineer application for IGES to STEP AP 203 translations.

In table 3, the main aspects of these systems is summarised. The properties listed for each paper are: *Requirements* for the system, *Integration type*, *Evaluations* made, *Standards applied*, *Backend integration* and *Implementation described*. *Requirements* indicate whether they are based on actual cases or generalised requirements. The values for *Integration type* are either “Portal” indicating web integration to multiple application or “Systems integration” for direct integration. *Standards applied* lists the standards used in the systems. *Backend integration* indicates whether the system has been integrated to other systems. The possible values are “no” or type of the systems to which integration has been presented. *Implementation described* has the values “No” and “Yes”. The value “yes” is given if the implementation is described in the text or using diagrams so that the implementations can be compared. The values for the evaluation are according to design research evaluation guidelines [72].

Table 3: Inter-company product development systems integrations					
Publication	Chung and Lee [30]	Cutkosky et al. [34]	Domazet et al. [44]	Hameri and Puittinen [66]	Kim et al. [85]
Requirements	General	General	General	Two case studies	General
Integration type	Systems integration	Portal	Shared datastore	Portal	Systems integration
Standards applied	XML, CORBA	MIME	CORBA, STEP, PDM enablers	No	XML, SOAP, WSDL, OWL
Backend integration	CORBA server	No	PDM, CAD, CAM	No	No
Implementation described	Yes	No	Yes	No	Yes
Evaluation	Scenario	No details	No details	Observational field study	Scenario
Publication	Pahng et al. [130]	Rodriguez and Al-Ashaab [137]	Storga et al. [148]	Wang et al. [164]	Zhang et al. [170]
Requirements	General	Three case companies	No details	Case	General
Integration type	Systems integration	Portal	Systems integration	Systems integration	Portal
Standards applied	CORBA	CORBA	STEP PDM scheme, XML, Web Services	XML	STEP
Backend integration	CORBA server	No	No	PDM	PDM
Implementation described	Yes	Yes	No	Yes	No
Evaluation	Scenario	Scenario.	No details	Descriptive	No details

Most of the papers are general-purpose architectures for collaboration, while three papers present case-specific requirements from real world needs. The portal-style web front-end is the integration style in four of the papers while five are systems integration -based. One system introduces a common datastore as a means of integration representing very deep and rigid integration.

CORBA is an often used technology for messaging, with Web Services getting popularity in most recent papers. The semantics of the document exchanged is mostly tackled by using the STEP standards or proprietary XML formats. No standard XML document formats are used in the papers. Most of the systems lack integrations to back-end systems. The back-end integrations described are to PDM systems and Enterprise Application Integration (EAI) type of CORBA systems.

Six papers describe implementations so that a similar system could be built to verify the results, in four of the papers this is not possible. Four papers use scenario-based evaluation and four papers lack evaluation altogether. Only one paper shows industrial validation of the system as whey has usage statistics by performing an observational field study on the system. One paper presents just initial prototype implementation without evaluation.

3.3 Semantic Web technologies in B2B integration

The potential benefits of increased automation using semantic technologies has been emphasised in many papers [49][50][51][77]. The following papers combine e-business frameworks and semantic technologies.

Anicic et al. [2] present how two XML Schema-based automotive standards, AIAG[5] and STAR[6], are translated from XML to OWL-based ontology using XSLT. They use a two-phase design and run-time approach. The paper focuses on the conceptual lifting of XML to the OWL language.

Brambilla et al. [9] present a prototype solution based on the WSML-language to SWS-challenge[7] scenario. The system uses a software engineering approach to solve the scenario and utilises a commercial visual modelling tool. On top of the commercial tools, Brambilla et al. have built translators that generate applications and services in the WSML language. They have built software that can run on conventional web technology and at the same time is ready to become part of a WSMX.

Dogac et al. [42] present a Artemis system to semantically enriched Web Services in the healthcare domain. They discuss how healthcare data defined by healthcare standards, such as Health Level Seven (HL7)[8], can be formally represented and how these formal representations are used for defining semantic Web Services. In the architecture, a clear distinction is made between formally describing the functional Web Service interface and the application data themselves.

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[5] http://www.aiag.org/
[6] http://www.starstandard.org/
[7] http://sws-challenge.org/
[8] http://hl7.org

Foxvog and Bussler [53][54] describe how EDI X12 can be presented using WSML, OWL and CycL[9] ontology languages. The papers focus on issues encountered when building a general-purpose B2B ontology, but does not provide an architecture or implementation.

Preist et al. [135] present a prototype solution covering all phases of a B2B integration life-cycle, starting from discovering potential partners to performing integrations including mediations. The paper also addresses translating messages to RDF but provides no details. The demonstrator uses XML, RDF and OWL-DL and the authors emphasise that the solution is not a deployed application. There are no back-end integration or security aspects addressed. The authors expect integration via semantic descriptions to become an important industrial technique in the near future.

Trastour et al. [154][155] augment RosettaNet PIPs with partner-specific DARPA Agent Markup Language and Ontology Inference Layer (DAML+OIL)[10] constraints and use agent technologies to automatically propose modifications if the partners use messages differently. DAML+OIL is a language that was used as the basis of OWL. The same Nile system is also partly discussed in [134].

Table 4 summarises the papers by listing the *e-business frameworks*, *semantic technologies, tools and systems used*, *backend integration*, *implementation described* and *evaluation*.

[9] http://www.cyc.com/cycdoc/ref/cycl-syntax.html
[10] http://www.daml.org/

Table 4: B2B integration with semantic technologies			
Publication	Anicic et al. [2]	Brambilla et al. [9]	Dogac et al. [42]
E-business framework used	AIAG, STAR	RosettaNet (as in SWS-Challenge[11])	HL7, ebXML registry
Semantic technologies	OWL-DL	WSML	OWL
Tools/systems used	Racer reasoner, XSLT	WebML[12], WSML, XSLT	MAFRA [104], JXTA[13], Protégé OWL plugin[14], Jena[15], ebXMLrr[16]
Back-end integration	No	SWS Challenge back-end systems	UDDI server
Implementation described	Yes	Yes	Yes
Evaluation	Descriptive	Black and white box testing on a simulated scenario	Descriptive prototype
Publication	Foxvog and Bussler [54]	Preist et al. [135]	Trastour et al. [154][155]
E-business framework	EDI X12	RosettaNet PIPs, EDI EDIFACT	RosettaNet PIPs
Semantic technologies	CycL, WSML	RDF, OWL-DL,	RDF, DAML+OIL
Tools/systems used	No details	Racer reasoner, Jena	OILed, Racer
Back-end integration	No	No	No
Implementation described	Yes	Yes	Yes
Evaluation	Descriptive	Descriptive scenario	Descriptive

RosettaNet is the most popular e-business framework to be semantically described. RosettaNet PIPs have been used in three of the six papers. There is one paper for both EDI X12 and EDIFACT and one concentrates on automotive industry standards, and a further one in healthcare standards. Three papers tackle problems using inter-standard semantics.

[11] http://sws-challenge.org/
[12] http://www.webml.org/
[13] http://www.jxta.org/
[14] http://protege.stanford.edu/plugins/owl/
[15] http://jena.sourceforge.net/
[16] http://ebxmlrr.sourceforge.net/

The semantic technologies used are mostly OWL or its predecessor DAML+OIL, which are present in five papers. Two uses WSML, while one case also used CycL descriptions. Additional tools and technologies were also mentioned in many papers, for instance, the Racer reasoner is used in three cases.

Back-end integrations are not typically presented in the papers. Brambilla et al. [9] provide integration to SWS-Challenge services. Dogac et al. [42] integrates UDDI servers, but all other papers use web pages to simulate back-end processes.

From evaluation perspective, Brambilla et al. [9] provide most testing details having both white box and black box testing with externally provided scenarios. Dogac et al. [42] describe system functionality details, while Preist et al. [135] only present a scenario of prototype functionality. The other papers just describe the general solutions but do not provide any real details on the solutions. All papers use formal technologies and thus mathematical proof that such solutions can be done is proven.

Common to all the papers is that the solutions are still academic prototypes and there are no industrial solutions. The SWS-challenge is a step to this direction, but the challenge is simplified from real PIPs and also lacks RNIF-related security details.

4 E-business framework comparison and role in B2B integration

This chapter summarises the main aspects of publications III and IV and related work concerning this thesis. The role of XML in e-business frameworks in B2B integrations is discussed first and then the standardisation of e-business frameworks is presented. Finally, the analyses are compared to related work and the answers to the research questions concerning e-business frameworks are summarised.

4.1 XML-based e-business frameworks

Several initiatives support supply-chain integration by using XML. The basic XML technologies enable straightforward exchange of data as XML documents between the trading partners in a supply chain. In this chapter, the motivation and need to standardise the use of XML technologies in B2B integrations is clarified. A shared understanding of business documents and business processes is necessary for B2B integration, and XML technologies alone do not solve all these issues. When XML was introduced, it was said to replace EDI standards by enabling more efficient B2B communication [58]. However, EDI or XML are only useful in syntactic interpretation, but a standard for e-business is necessary in semantic interpretation on the use of these technologies [127].

To operate across organisational boundaries, the trading partners must have a shared understanding of the ways of doing business. The trading partners have to know what information should be shared, in what processes and how to do it securely [127]. The e-business frameworks define a standard interface between the trading partners and their heterogeneous information systems, internal processes and internal terminologies. The frameworks often combine other standards, specifications and classifications.

The e-business frameworks cover business and technical aspects of business documents, business processes and messaging, but all frameworks are not limited to specifying these issues. The following list outlines the basic interoperability issues:

- *Business document* issues are about what information to share. The framework contains a vocabulary that describes the structures and parts of the business documents, and defines the meanings of the terms used in these documents. For example, if trading partner X sends a purchase order to trading partner Y, this business document includes elements for the customer's name, the supplier's name, the product name and the ordered quantity, as well as an attribute for measurement units.

- *Business process* issues are about when to share information. The frameworks take different approaches to these issues. The rough process approach explains in which order to exchange particular business documents. The detailed process approach describes the purpose of particular business processes and the trading partners' roles in them. It also defines what kinds of business documents are necessary and in which order to exchange them. The generic process approach deals with neither particular business processes nor exchange of particular business documents, but provides a way to model details of the business process. For example, if Company Y receives a purchase order from X, Y sends a purchase order response to X.
- *Messaging issues* are about how to share information. This also includes how to handle basic exceptions, such as message loss. Since the transmitted message is an envelope consisting of headers, attachments and business document content, the framework defines the headers, as well as the allowed standards for the encryptions and transportations. For example, if companies X and Y exchange purchase orders and purchase order responses, they use HTTPS for secure transport of the business documents. They can also use digital certificates to authenticate the trading partners and encrypt the contents.

An e-business framework is based on XML, if it utilises XML [127]. The e-business framework instructs how the XML is used in the business documents or gives schemas to validate the business documents. Additional dictionaries or other such guidelines are often used to document the semantics and sometimes the constraints that cannot be defined with the schemas used. For documenting process details, XML is not always used, but textual descriptions or graphical representations are provided. XML is also used in messaging, in which the e-business framework specifies the allowed structure and semantics of the headers with schemas. There is a major difference between EDI- and XML-based e-business frameworks. The EDI-based e-business frameworks provide the business document specification that determines how to represent the business documents in EDI. These e-business frameworks do not deal with business processes or guide the messaging aspects similarly.

Business documents and business processes are important in B2B integration. However, the many different frameworks using XML have caused a problem of semantic interoperability [98]. There is a lack of a common vocabulary for the terms used in business documents. The current state means that an XML element with exactly the same term can mean different things in different business documents. This makes transformations between the frameworks difficult. The use of XML to standardise business processes has been a dynamic area of standardisation and standards. For instance, the Business Process Modelling Language (BPML) provide a meta-language for the modelling of business processes, but it was discontinued and eventually evolved to the Business Process Modelling Notation (BPMN) providing standard graphical notation to describe business processes. The Business Process Execution Language (BPEL) has gained more support among vendors and users. The messaging differences are generally quite small and can lose their significance in the future [127]. For instance, the RosettaNet Multiple Messaging Services specification, published in 2006, defines how RosettaNet PIPs can be sent using ebXML Messaging Services, Web Services or Application Statement (AS) 2 specification.

The basic XML technologies enable straightforward exchange of data as XML documents between the trading partners' systems. XML is useful in syntactic interpretation, but insufficient in semantic interpretation. E-business frameworks are necessary for standardising how XML is used to define business documents, business processes and messaging in supply-chain integration. The purpose of e-business frameworks is to support interoperability by making standard interfaces that offer scalability benefits. The business partners can change their business applications as long as they use the standard interfaces, which is important in the development and operation of information systems. However, the large number and quick evolution of frameworks and basic technologies cause new problems because complete transformations between frameworks are not always possible.

4.2 Example process

In order to illustrate the role of e-business frameworks in B2B integration, an example business scenario is presented here. The scenario represents the support from a 'typical' e-business framework and it concerns a manufacturer and a supplier. The manufacturer needs product parts from suppliers on time with low costs and therefore the manufacturer periodically requests quotes from different suppliers to find best value deals. The suppliers answer to the quotes and the manufacturer can purchase the parts according to the best quote. There is a lot of information that needs to be transferred securely between the manufacturer's resource planning system and the suppliers' order management systems. This information exchange between the manufacturer and the supplier concerning one supplier is presented in Figure 6.

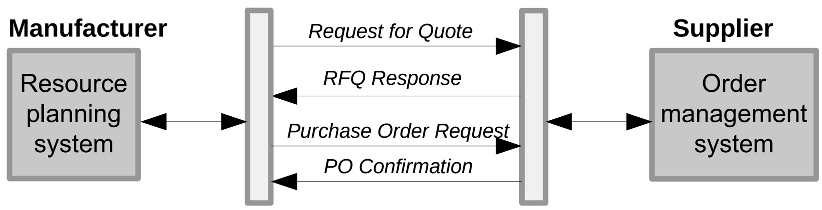

Figure 6 Quoting and purchasing business process.

E-business frameworks can assist in integrating the information systems participating in the above scenario in many ways.

- E-business frameworks define the exact details of the business documents for exchanging order management information. There is typically a schema that defines the structure and allowable contents for the business documents, and a dictionary to assist in establishing common semantics of the product, its pricing, availability and shipment information between the manufacturer and the supplier. An excerpt of a Request for Quote (RFQ) business document instance from RosettaNet is provided in Listing 1[17].

- E-business frameworks define the business process for exchanging forecasting information. In the example, the manufacturer sends a RFQ business document, the contract manufacturer must reply to it by sending a RFQ Response business document to the Manufacturer within the specified time-frame. Typically, the business processes are defined in the form of UML (Universal Modeling Language) diagrams and textual descriptions. However, some e-business frameworks can be generic in this aspect, and do not define any particular business processes, but only offer languages to represent business process details. For instance, ebXML BPSS can carry the public choreography details so that machine-readable XML can be used to carry information that is currently in only human-readable UML diagrams and descriptions.

- E-business frameworks define the messaging mechanism that is required to exchange the RFQ and PO business documents. The messaging mechanism covers the ways how to package and secure the business documents, what transport protocols, such as HTTP, are used and how to guarantee security and ensure that the transport was successful. This enables legally binding transactions over the Internet or other networks.

By standardising the order management business documents, the business process, and the messaging mechanism, the e-business frameworks can shorten the time to

[17] See http://www.soberit.hut.fi/pkotinur/Technical_appendix/PIP3A1_Quote.xml for full example.

agree on integration details and enable integration with other business partners with small additional work. In addition, without e-business frameworks the integration is very tight so that any change in the systems would reflect on the integration. When using e-business frameworks, internal changes do not matter as long as the use of the e-business framework stays the same. This means that partners can change the information systems without causing the B2B integration to break. This has been discussed in connection with automotive industry collaboration [88].

```
<?xml version=”1.0” encoding=”UTF−8”?>
<!DOCTYPE Pip3A1QuoteRequest SYSTEM ” 3A1 MS V02 01 QuoteRequest.dtd”>
<Pip3A1QuoteRequest>
 <GlobalDocumentFunctionCode>Request</GlobalDocumentFunctionCode>
 <Quote>
   <GlobalQuoteTypeCode>Bid for Buy </GlobalQuoteTypeCode>
   <QuoteLineItem>
     <comments><FreeFormText>Looking for best price for ComponentX (GTIN
12345678901234) for the delivery date specified</FreeFormText></comments>
      <GlobalProductUnitOfMeasureCode>Piece </GlobalProductUnitOfMeasureCode>
     <isSubstituteProductAcceptable>
       <AffirmationIndicator>Yes</AffirmationIndicator>
     </isSubstituteProductAcceptable>
     <LineNumber>1</LineNumber>
      <ProductIdentification><GlobalProductIdentifier>12345678901234
      </GlobalProductIdentifier></ProductIdentification>
     <requestedQuantity><QuoteQuantity>
       <QuantityTransportationSchedule>
         <GlobalTransportEventCode>Dock</GlobalTransportEventCode>
         <QuantitySchedule>
           <DateStamp>31062006</DateStamp>
           <ProductQuantity>200</ProductQuantity>
         </QuantitySchedule>
       </QuantityTransportationSchedule>
     </QuoteQuantity></requestedQuantity>
     <shipTo><PartnerLocationDescription>
       <BusinessDescription><businessName>
           <FreeFormText>Galway plant</FreeFormText>
         </businessName>
       </BusinessDescription>
       <GlobalPartnerClassificationCode>Manufacturer
       </GlobalPartnerClassificationCode>
       <PhysicalLocation><PhysicalAddress>
         <addressLine1><FreeFormText>IDA Business park</FreeFormText>
         </addressLine1>
         <addressLine2><FreeFormText>Lower Dangan</FreeFormText>
         </addressLine2>
         <cityName><FreeFormText>Galway</FreeFormText></cityName>
         <GlobalCountryCode>IE</GlobalCountryCode>
       </PhysicalAddress></PhysicalLocation>
     </PartnerLocationDescription></shipTo>
   </QuoteLineItem>
```

Listing 1. Excerpt of a Request For Quote business document

4.3 Key results on the standardisation of e-business frameworks

The standardisation processes of different XML-based standards for B2B integration have been studied for this thesis. The purpose of e-business frameworks is to enable efficient business interactions between business partners. Although the literature contains a number of papers on standards or standardisation, there seem to be very few papers studying both e-business frameworks and their standardisation systematically. The present study focuses on 12 XML-based e-business frameworks, analysing them with respect to seven variables [128].

The analysis indicates two commonalities. Most XML-based e-business frameworks are standardised in formal organisations that can be regarded as committees. All e-business frameworks are limitedly open so that they cannot be modified or extended in proprietary directions.

Since there are differences between e-business frameworks, they do not compete in all respects, but often cooperate with each other. The most intense competition between e-business frameworks occurs in the business document specifications and the least intensive in the messaging specifications. In addition, two regularities have been found. Cross-industry e-business frameworks are less comprehensive than industry-specific e-business frameworks. Vendors tend to drive the standardisation of cross-industry e-business frameworks and users the standardisation of industry-specific e-business frameworks. Therefore, the vendors seem to emphasise a wider use and the users a deeper use. These findings differ to some extent from those in the literature, which have not emphasised the users' role in the standardisation of e-business frameworks.

4.4 Positioning to related work

The analysis of this research is mostly related to Medjahed et al. [112], which can be considered the paper with most impact according to the citation reports. They use the terms *content*, *business process,* and *communication* for the layers branded *business document*, *business process,* and *messaging* in this study. In comparison to other papers, the present study has been more thorough in classifying details on the business document, the business process and the secure messaging. In addition, the collaborative and co-operative aspects have been more deeply analysed to point out such aspects. More transparency in the analysis has been provided by stating the version information the analysis is based on. Overall, the roles of e-business frameworks can now be considered to be understood well. In addition, there are no longer new e-business frameworks coming up, and many standardisation efforts have discontinued.

The standardisation process has been considered as well. The analysis of standardisation has been said to be too scarce in Information Systems literature [103]. Recently, with the special issue on Standardisation in MIS Quarterly [103], there have been some papers discussing different aspects of standardisation processes. Nickersson and zur Muehlen [123] have done an extensive review of 12 years of choreography language standardisation processes, in which standards organisations have changed, but largely the same people have been working on advancing the field. Chen and Forman [26] discuss a case of router and switch vendors have introduced proprietary extensions to open standards causing switching costs to buyers. The observations in this study on vendors looking for wider markets is supported by recent related research on standardisation [26][123]

4.5 Summary and conclusions

The most important standardised issues are *business documents, business processes* and *messaging.* XML-based e-business frameworks guide the use of XML to specify these issues. Business documents define the structure and semantics of the business information carried, such as how dates are encoded and what the dates are. Business processes define the choreography of business document exchange, associated times to answer and things related to changing the exchanged information later. Messaging defines secure communication of business documents, the headers needed in the message, security details and the receipt of delivery.

In the area of B2B integration standards, having end-users driving the standardisation have the effect that the framework covers all business document, business process and messaging aspects. User-centric e-business frameworks tend to be industry-specific. Vendor-driven standardisation results in solutions that are more general and often just concentrating only on business documents or business processes.

Different e-business frameworks provide different level of support for defining business documents, processes or messaging. If the definition is generic, these can be utilised to provide specific solutions. The competition is between different generic solutions to the same issue. Similarly the different specific solutions are alternatives to each other and thus compete. There are many alternative to provide a source for business documents used in B2B integration by different e-business frameworks.

E-business frameworks assist in practical B2B integration by introducing a common vocabulary for business documents and common choreography for the process. In addition, the support for messaging means that not everything needs to be agreed on in the smallest technology detail. They also hold the promise of extensibility of the solution to multiple partners and avoiding exponential growth in integrations to support. Furthermore, e-business frameworks isolate the solutions from changes in information systems.

5 B2B integration implementations using RosettaNet

This chapter presents a practical B2B integration implementation using RosettaNet to product development (PD) systems integration and is based on publications I and II. The experiences are compared to related research and case study on existing integration approaches to identify special needs for integration support for PD projects is presented. Finally, the answers to the research questions are summarised.

5.1 Systems integration to support networked PD

This chapter follows the design research steps [158]. First, general motivation for integration of product data management (PDM) systems is introduced. Next, the requirements for the integration solution rising from case studies of networked PD are summarised. The suggestions reported here are an integration architecture and prototype implementation of B2B integration supporting PD interactions. The B2B integration of networked PD information using XML-based e-business frameworks has not been reported before.

PDM systems facilitate the PD process in one company by providing up-to-date information to all the product designers who need it [101]. The same type of support needs to be extended to cover the whole product development network [7]. With integrated systems, the transactions leave trace to the information systems that enable better transparency and controllability of what is happening in the projects [65]. Eloranta et al. [46] present the analogy between that an unused part in a work-in-progress inventory and a document waiting for approval from a user. Both include work and value, which is not exploited to the extent it could be. In addition, the business processes share fundamentally the same phases and problems whether they are re-engineering, new PD or order fulfilment processes.

With B2B integration using an e-business framework, the information delivery could become faster, less error-prone and more transparent than in manual processes of using e-mail. With a B2B integration approach, the end-users in companies could use their own systems, which they know how to use, and still be able to collaborate with other partners. In addition, the integration could resemble integrations done in order fulfilment processes, in which there are many integration experiences. In the case network of the present study [7][89], PD documents are exchanged in projects even several times a day [7][89].

Documents synchronise the processes within the companies of the network. Thus, document exchange in a network should itself be considered and treated as a systematic process. This process can be triggered by a predefined schedule or an event within one company (e.g. a new version of a document becomes available). If any changes to the schedule should occur, these changes should be communicated to all relevant companies automatically. These repetitive information delivery processes can be automated with the help of system-to-system integration. Figure 7 presents the change processes needed in distributed product development, where first an engineering change is requested (ECR) and after getting the responses, the engineering change order (ECO) can confirm the change.

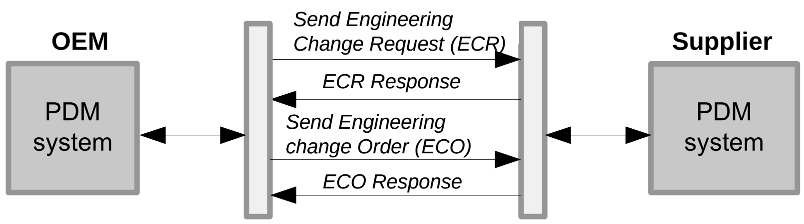

Figure 7 Information delivery in networked product development

The motivation to create an IT artifact integrating PDM systems with e-business frameworks was to know whether such a system is feasible to build and to gain feedback on the suitability of the chosen e-business framework. Thus, the preset criterion for the evaluation of the developed artifact was proof-of-concept.

5.1.1 Motivation for selecting RosettaNet

As the starting point for selecting suitable e-business frameworks for comparison in early 2002, the documentation and specifications of several e-business frameworks were analysed including the BizTalk framework, commerce XML (cXML) and the eCo framework (eCO). The analyses further concentrated on the five most promising frameworks, which were ebXML, RosettaNet, OAGIS, Product Definition eXchange (PDX) and Standard for the Exchange of Product Model Data (STEP).

The RosettaNet e-business framework was chosen as the basis for the prototype system, as it covers all the needed features considering business documents, processes and messaging. Although especially the product data related standards PDX and STEP contain significantly more detailed specifications for representing product data, they lack definitions for processes and secure messaging. RosettaNet has even had PIP2D cluster of standards reserved for collaborative design and engineering [89][139].

5.1.2 The system architecture and functionality

The solution architecture of the present study emphasises modularity and flexibility. This means that for example the PDM system used can be easily exchanged. The prototype system consists of five architectural components, as shown in Figure 8.

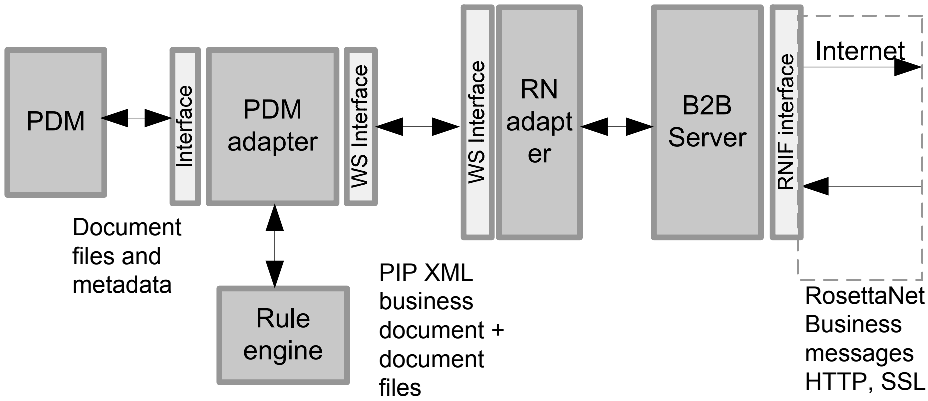

Figure 8 System Architecture

The PDM system is a repository for design documents and their metadata. It notifies the PDM adapter of changes in its contents.

The PDM adapter is connected to the rule engine and has interfaces to the PDM system and the RN adapter. It notifies the rule engine of events in the PDM system, retrieves design documents and metadata from the PDM system, and sends them to the RN adapter. There is an internal data-model in the PDM adapter, which acts as intermediary in transforming PDM data to a specific PIP [75].

The Rule engine has a user interface for defining document delivery rules for the design documents, for example, a rule saying that updates to a specified design document must be sent to a specified trading partner. The rule engine also evaluates these rules each time there are changes in the PDM system. For more details, see [76].

The RN adapter is connected to the RosettaNet messaging server and has an interface to the PDM adapter. Based on the design documents it receives from the PDM adapter, it adds RosettaNet-specific delivery information to them.

The RosettaNet messaging server constructs RosettaNet business messages from the documents received by the RN adapter. It controls the exchange of business messages with trading partners, based on the RNIF 2.0 specification.

For details on the components and their implementation, see [90].

5.1.3 Web Interface option for RosettaNet processes

Small and Medium-sized Enterprises (SME) are important and cannot be totally excluded. System-to-system integration is not the most favourable option to small companies, which may lack the back-end systems altogether. Thus, a software project to establish a portal for SME users was carried out. The portal enables the SME users to conduct same operations manually as PDM users do with integration. The users interact RosettaNet PIPs using web forms to answer messages. The portal takes care of the processes and can automate inputting the repetitive information needed in PIP business documents. The portal application can validate the manually typed information against schemas and visualise process steps by showing the time left for sending a response to requests with specific times to answer. Figure 9 shows a screenshot of the user interface localised to Finnish users. The user only inputs the relevant values for the interaction. By inputting the information and pressing “send”, the system constructs a valid PIP response document to the request.

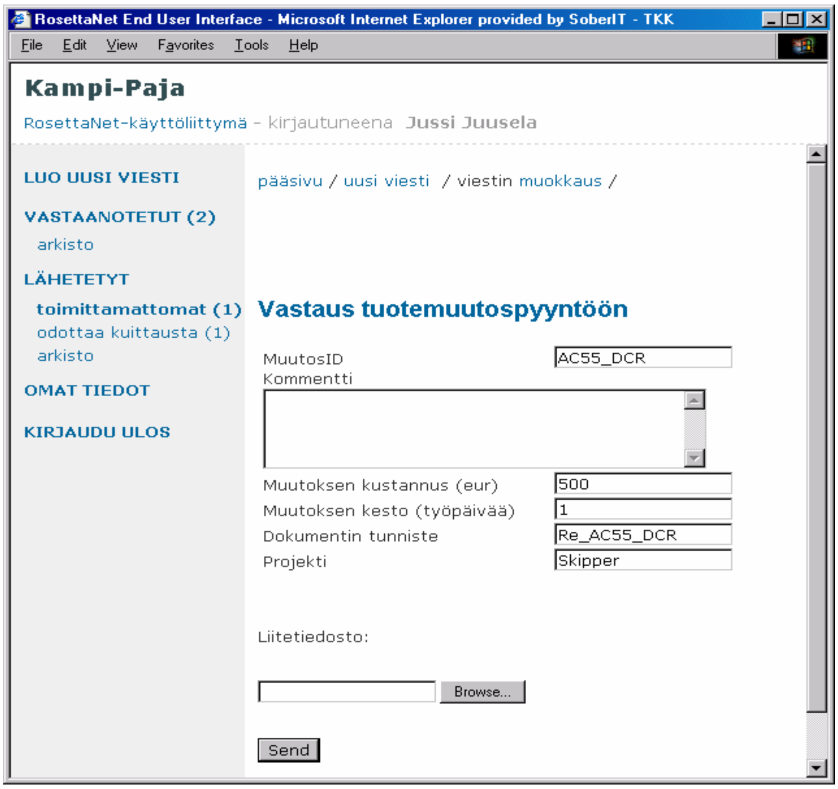

Figure 9 Screenshot of SME user interface for B2B integration

5.1.4 Implementation effort

The prototype implementation effort was significant, even though existing tools and systems were used. Considering the systems integration as in figure 8, two student groups used 700 hours implementing the PDM adapter and the rule engine. The

PDM configuration took 100 hours. The RN adapter implementation took in 80 hours, and the RosettaNet messaging server configuration took 40 hours. Integration of the different components, testing, and other additional work took about 80 hours, so altogether the implementation of the prototype system implementation took about 1000 hours. This only includes the actual implementation time, excluding getting to know the systems used. An industrial implementation would naturally require more time, as the system is only a prototype. As this implementation is for design document delivery only, it is a considerable effort. In addition, a student software project of roughly 500 hours was carried out dedicated to the solution of developing the SME interface.

5.2 Evaluation of the prototype solution

The evaluation procedure is described below according to the guidelines from Hevner et al. [72].

5.2.1 Evaluation of the PDM integration solution

As the goal of constructing the PDM integration solution was feasibility and learning, the evaluation concentrated primarily on descriptive and experimental methods.

The proof-of-concept prototype shows that PDM integration is possible with e-business frameworks. The end-to-end solution was tested in an environment that simulates two partner companies. There were two instances of PDM servers with different database schemas to represent two different companies. A design document update in one EDMS server led to the construction of a complete RosettaNet business message according to the PIPs 2A1, 2A10 and 2C5[18]. The business message was sent to the other PDM server, where the design document was saved correctly. The scenarios used in the simulated experiments were design document exchange and engineering change processes. The scenarios were presented to company representatives in two public seminars in May 2003 and April 2004, showing the utility of PDM system integration in PD networks. The PDM and integration experts in the public seminars gave positive feedback of the prototype system. In the second public seminar, the test setting had partners using both PDM systems and SMEs using the Web interface.

[18] See: http://www.soberit.hut.fi/pkotinur/Technical_appendix/ for examples.

The whole prototype and individual pieces have been white-box tested with regard to big message sizes, in which attachments over 10 megabytes caused problems. External RNIF interfaces were tested concerning the external RosettaNet messaging interface with the Softatest company, running also a BizTalk server and with the custom built integration solution in [153]. The tests between BizTalk servers revealed no problems. But tests with the custom built integration solution [153] revealed multiple interoperability problems related to interpreting the RNIF specification guidelines.

5.2.2 Architectural evaluation of the prototype systems

There are many papers on reference architectures, such as Computer Integrated Manufacturing Open Systems Architecture (CIMOSA) and Purdue Enterprise Reference Architecture (PERA) for enterprise integration [22][27][55]. The reference architectures do not include information on how the integration is realised in the enterprise and it is hard to find papers describing some companies' experiences of really using these [55]. For the present prototype solutions, they were too general.

Several publications present software architectures supporting e-business which utilise XML [3][4][14][19][24][93][112][133][140][144][149]. However, these architectures are often very abstract, and in many cases they are just suggestions without proof-of-concept implementations. In related work, the present solutions are positioned to the ones listed in table 2.

Wang and Song [163] have compared architectures supporting RosettaNet, and in their analyses the present implementation is compared together with two commercial systems and the solution by Sayal et al. [140] and Tikkala et al. [153]. They list advantages, disadvantages and the technologies used in the solutions summarising different papers. They do not discuss the precedence of the different architectures.

5.3 Discussion on the prototype implementation

5.3.1 Experiences on RosettaNet

The available software tools and the available information of RosettaNet implementations helped in designing and setting up the prototype implementations. The RosettaNet standards are understandable and quite well documented. Especially RNIF messaging seems well thought out, although the practical implementations can still be non-standard.

RosettaNet does not even try to standardise the content and structure of a CAD file exchanged as attachment, but treat them as binary files. This obviously means that the tools used for viewing and modifying these documents in the company network must be compatible. The RosettaNet solution for networked PD helps to transport the files in a controlled and secure way as in the requirements.

There were several problems with the use of RosettaNet. The existing PIPs were not defined with PD in mind. As a result, the definitions available in current PIPs did not provide sufficient support for most of the document metadata wished to be exchanged in business documents. So far, PIP2C5 “Notify of Engineering Change Order” with change request documents, initially PIP2A1 “Product Information Notification” has been used, and later the newer versions of PIP 2A1 “Distribute Product Catalog Information” for new document delivery. Later the 2A1 PIPs were replaced by 2A10 “Distribute Design Engineering Information”, which was released after the solution using PIP 2A1 had been implemented. The first PIPs enabled meaningful carrying of only roughly 30% of the internal data model information. PIP 2A10 increased this to 85%, but for some of the attributes of the internal data model this meant only a close but not precise match to the term. For example with the PIP business document, the message guidelines for the contents of “objectName” and “Supplier” were not followed strictly. Those elements were used to carry the name of the exchanged document and the document creator information. In the remaining 15%, a match for some attributes could not be found in the PIPs. To carry the document metadata identified in the internal data model, PIPs freeFormText elements had to be misused not to lose information. Misusing the standard obviously affects the interoperability of the system.

In addition, some of the information in the PIP service contents needs to be better defined to avoid misinterpretations. An example of needed extensions is the *life cycle status* for documents. As companies define the life cycle statuses such as “pending, ready, approved, obsolete” in different ways, RosettaNet should provide clear definitions for these kinds of enumerated lists to avoid misinterpretations. For example whether a document should be ready before it can be approved or vice versa. For more discussion and details on the data model, see [75][90].

Technically the use of both DTDs and MGs for business document validation is problematic. If the implementers ignore the MGs and use just DTDs, the validations do not find the problems, and the partners need to manually agree on details how to use certain elements. Use of XML Schemas in most recent PIPs has helped in this. This validation issue came up also in tests between the commercial server product in the present prototype and the B2B messaging solution [153]. The commercial product produced RNIF headers valid according to the DTD:s but not valid according the MG and thus violated the RNIF specification. The use of just the XML Schema would have cured the RNIF header validation problems. However, for all PIP business document validation needs even the XML Schema is not expressive enough [36].

The more recent PIP specifications tended to be better than the older ones, such as PIPs 2C5 and the 2A1 used in the beginning. The need of resources for the implementation might also have been smaller if implementation guidelines had existed, such as the ones available in RosettaNet for collaborative forecasting processes. In the present study, suggestions for processes have been made on the basis of the case requirements and implementation guidelines for them[19]. Example PIPs were also run in the prototype. As of July 2007, the PIPs for collaborative design (PIP 2D) are still not available, but there are new PIPs under standardisation to support product change processes.

Overall, what became evident in building and testing the solution is that just following an e-business framework does not guarantee interoperability. There is need for more exact implementation guidelines to provide details how the specific aspects are done in this case with our suggested RosettaNet style processes. These include the decision on, what change is big enough to start informing partners on business process issues. The current business document guidelines can be interpreted differently and the validation can be more or less strict. Thus more specific guidelines of what are needed by partners are needed and how the data mappings are done. Currently this is a manual process. Even supporting same RNIF version is not enough, as different software solutions can still interpret the specifications differently. Similar problems are expected to exist with other e-business frameworks as well. As RosettaNet is still an active e-business framework, the selection to base the solution on RosettaNet seems to have been a good one, as the selection could have been on an e-business framework that would not be further developed. Now companies often use RosettaNet already in other B2B integration needs, so it has made sense to build on those specifications.

5.3.2 Prototype system architecture and implementation

The numerous architecture papers in the academic literature did not provide clear basis for solution. It was necessary to define a specific architecture to support the case requirements and incorporate possibilities to change implementation details easily. The implementation was very educating in terms of the interoperability issues

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[19] see http://www.soberit.hut.fi/netsetup/PIP/

encountered. The amount of possible problems in practical integration is bigger than it was expected.

The developed architecture can be considered successful. To add support for a new PIP in the prototype system takes less than two days. Building a new XSLT takes about a day. The modification needed for the system components takes altogether less than one day. To add a new partner or PIP to the prototype system requires minor modifications to the PDM system, the PDM adapter, the RN adapter and the RosettaNet messaging server. Similarly, to add support for different PIPs in the B2B messaging solution is easy.

One issue that the evaluations revealed was that the transfer of large files as attachments is a potential problem. RNIF recommends BASE-64 encoding, which increases the message size by one third. PIPs allow typically only two hours to acknowledge the RosettaNet business messages, which is challenging, as the network delivery and server encodings may take a lot of time. In thorough tests with B2B messaging solution of Tikkala et al. [153], also the system memory gave maximum limits for business message sizes, which can differ between solutions. Vaugham-Nichols [160] discusses problems XML faces with large data files and security. The security approaches suggested by Vaugham-Nichols are addressed in RNIF. However, the large data files and the operations with them are clear concerns that are also shared according to our experiences during the present study. Naturally, the problems can be solved by sending a link to the file with a PIP and introducing other channel to download the bid attachments separately, but this again adds complexity to the solutions.

Overall, the PDM systems integration effort including especially back-end integration took a lot of time. The investigation and planning took more time than just the implementation. This included many details on how exactly the process goes through different components, where to implement a certain piece of logic, how end-users interact with the system and how the back-end interface will work. For example considering an incoming document from a partner, “what to use as a username?”, as normally all documents take the user login information, but now the update comes through integration. In addition, suitable standards and tools had to be selected for different parts of the needed functionality. The large number of contributing individuals also contributed to the relatively big effort as a lot of communication was needed. As the architecture emphasised modularity and platform independence, it also took more effort. The PDM adapter was implemented in Java, while the RN Adapter was implemented with .Net technologies.

The implementation technologies, such as XML Schema validation, also introduce limitations. The internal data model needs complex validation rules if reuse is wanted. Some elements mandatory for design document exchange are only optional for EC documents. The XML Schema is not expressive enough for such constraints. If the validation strictness in slackened, the solution is more flexible to reusability. This is however a double-edged sword, as the stricter the validation, the more certain it is that erroneous content is detected. Thus, currently a lot of tests and agreements on specific details in implementation are still needed.

5.3.3 Expected business benefits

As PD related B2B integration is not common practise nowadays, its potential business benefits are important to consider. As indicated by the case study [7] and the requirements for IT support [89] , the B2B integrations have potential to quicken the inter-company processes and reduce errors that exist in current manual collaborations. This is an issue especially in products, where the price erosion is quick and getting the product early into the market is very important. Furthermore, business process optimisation is currently hard as the projects run on e-mails and phone calls and it is hard to assess afterwards the performance of the PD projects. Integrated PD processes would automatically bring controllability to projects, as the experiences with portals indicate [66].

The B2B integration would be also good from the usability aspect, as then the designers would not need to learn to use multiple systems differing in usage logic and terminology. Integration using e-business frameworks can benefit from other B2B integrations according to the same frameworks. If the companies use RosettaNet already, the same messaging infrastructure and standard terminology can be used. However, as e-business frameworks currently lack proper definitions for PD integration needs, further standardisation is needed. This calls for companies to initiate such standardisation effort in RosettaNet, as RosettaNet standardisation takes place through member organisations willing to take those standards into the use.

5.4 Positioning to related work

Chapter 3 presented research on B2B integration implementations using e-business frameworks and integrations supporting networked product development. Here, the work is positioned to those papers. This positioning extends the related work compared to publications [89][90] by including related work that had not been found at the time of the publications.

5.4.1 Related work on B2B integration implementation experiences

Table 5 positions the present study to related work on B2B integration implementation experiences. Both solutions in this work used RosettaNet. The PDM integration solution concerns processes, documents and messaging and is built on case requirements. Its application area is PD collaboration and the implementation uses both open-source and commercial tools. Evaluation is conducted and back-end integration is provided to a PDM system. The implementation details are described to offer enough information for other researchers to be able to build similar solution and arrive at similar conclusions.

The author of this thesis participated also in putting together a generic RosettaNet messaging solution [153] implemented to run on open source and commercial J2EE platforms. Evaluation of performance and interoperability testing was emphasised in this solution.

Table 5: B2B integration implementation experiences with RosettaNet

Publication	Kotinurmi et al. [90]	Tikkala et al. [153]	Other papers [43][74][82] [102][135][140][149][150][151]
Frameworks used	RosettaNet	RosettaNet	RosettaNet in all. Also ebXML in 2 papers and EDI in one.
Process/ documents/ messaging	All	Document validation and messaging	Only 2 papers address secure messaging. 4 discuss only PIP business documents.
Requirements	Case	General	6 based on generalised requirements and 3 based on cases
Application area	Product development	General	Order management most typical. Also general-purpose papers
Tools used	Open source and commercial (Microsoft BizTalk)	Open source, also run on commercial J2EE server	Open source tools used in 4 papers, 2 commercial systems and 3 papers do not provide details
Testing/ evaluation	Yes. Descriptive and experimental.	Extensive. Analytical, testing and experimental	No tests reported in 6 out of 9 occasions. No chance to compare performance with these papers.
Backend integration	Yes, EDMS system for PDM	No	No integration to back-end systems in 6 papers. Integrations done not detailed
Implementation described	Yes	Yes	7 out of 9 papers describe implementation

RosettaNet PIPs are present in all the solutions, while RNIF is not used in related papers. In two papers where the secure messaging functionality is present, ebXML messaging is used. Considering process integration, Khalaf [82] and Sayal el al. [140] introduce model-based solutions to business processes. The requirements are mostly general, while only three papers had specific cases to base the solution requirements on. The application areas are often order management related or then the systems solutions are general purpose. Tools are not always reported but mostly open source tools were used. Evaluation is often not conducted at all, but then again some papers have really good evaluation, as in [82]. Overall, there is no evaluation to support in-depth comparison on the performance or scalability of the different solutions. Only one related paper [151] analyses the suitability of RosettaNet for the solution in hand regarding business document details, but this also have problems of misusing RosettaNet message guidelines considering product identifiers used. Back-end integration is largely neglegted and only one paper brings up that the quality of their internal ERP system was a factor to make the integration [102]. Overall, the repeatability of the solutions is weak, as very few details are generally provided on the implementations. Compared to related work on B2B integration using e-business frameworks, this thesis presents solution implementations that are more detailed in documentation and testing.

5.4.2 Related work on product development systems integrations

Table 6 positions the experiences in PDM systems integration to related work on integrated systems supporting PD. The present solution got its requirements from an industrial case [7][89]. RosettaNet PIPs and RNIF were used for external communications and internal communication used XML and Web Services. The proof-of-concept prototype was integrated with a PDM system, called EDMS. There was also integration to commercial B2B server product, Microsoft BizTalk. The implementation details and evaluated the solution implementing and demonstrating descriptive scenarios and using experimental methods.

Table 6: Inter-company product development systems integrations		
Publication	Kotinurmi et al. [90]	Other papers [30][34][44][66][85][130][137][148][164][170]
Requirements	Case study.	3 papers have case studies, 6 general requirements and one does not go into detail
Integration type	Systems integration	4 papers present portal-style integrations, 5 are Systems integrations and one has a shared datastore.
Standards applied	RosettaNet PIPs, RNIF, XML, Web Services	4 papers use CORBA, STEP is used in three papers, 2 use web service technologies and 4 XML. One paper applies also semantic technologies
Backend integration	PDM system. Also BizTalk B2B server product	5 papers provide no integration, 2 integrate with a CORBA server, and 3 with PDM
Implementation described	Yes	6 papers clearly describe the implementations, 4 do not provide details
Evaluation	Descriptive scenarios and experimental methods	Five papers have scenario evaluation, one has been observed in real projects, 2 do not provide details

Compared to related work, the most obvious issue is that nobody else has so far used e-business frameworks to support PD processes. Instead, CORBA and STEP are often used. CORBA is an older technology to Web Services, doing similar issues. In general, supporting distributed PD is considered very important but systems integrations have not been reported in real use. Only portal solutions have real world use experiences.

5.5 Set-up of B2B integration in practical setting

The lessons learned from our prototype solution to PD integration raised questions on how to put such solutions into practical use. As PD projects typically last only a few months, it became apparent that the integration set-up should be fast. Also according to other authors [23][140][154], implementation times are currently measured in months. This is clearly infeasible for a PD project that may last only a few months. The present approach was to interview B2B integration teams in partner companies to learn from current B2B integration projects and have opinions of PDM integration feasibility in PD projects.

5.5.1 Case interviews

Interviews were performed in the NetSetup research project companies to understand their current B2B integration projects and the times needed for set-up. Case studies provide a rich methodology for studying the organisational context in which the technology resides, and case studies are good for answering questions like how and why [5][168]. To enable triangulation, the same questions were asked from different people and the available documentation was used on B2B integrations. The goal was to understand the existing B2B integration processes.

Semi-structured interviews were conducted in three companies, which all had experience with networked PD projects and B2B integrations using EDI and XML. One company still used primarily EDI, while two others used increasingly RosettaNet, and the use of EDI was not growing significantly any more. The size of the companies varied from one thousand to tens of thousands employees. The two bigger companies also had multiple factory locations. Altogether 18 people responsible for B2B integrations or PDM systems integrations were interviewed. All the interviews took between 1-2 hours and they were taped and transcribed. The questions[20] included PDM-specific questions and going through previous experiences on B2B integration projects and their length. The results were validated by presenting them to the company representatives in a workshop.

5.5.2 Results

Current B2B integrations can be divided to first-time integrations and mass deployments. First-time integrations take a new business document into use. They are usually rather complicated and require considerable amount of time and effort. The reasons for this include building the back-end system integrations, modifying the internal processes to match the requirements, and agreeing on the business document details. The first-time integrations can take from a couple of months to more than a year to build. "*It is easily at least a 0.5-1 year project when integrations started from scratch*". According to the integration experiences of the researchers and the conducted interviews, the following steps in a typical B2B integration process were identified:

1. Agree on overall business process with the partner(s). For example, the process from quoting to paying the supplier would consist of quote negotiation, sending purchase orders, possible changing or cancelling something and finally handling the payment processes. This includes rough planning of the overall process choreography.
2. Agree on the detailed design of the integration solution. Design the specifics of the internal process and the common public process. For example the pre-

[20] See http://www.soberit.hut.fi/pkotinur/Technical_appendix/interviews.pdf for the basic questions

conditions for initiating the processes and splitting the exchanged information into business documents. This includes also the private process details on how they interact with back-end applications and the public process choreography. Agree on the business document details to make sure the information is understood and used similarly.

3. Implementation includes making the integration to back-end information systems. This includes implementing the private process as well as making the necessary data mappings between the back-end systems data models and business document specifications.
4. Testing that everything interoperates. This includes testing that secure communication of business documents works and that exceptions are properly handled.

This process is almost analogous to the systems development process by Nunamaker and Chen [124]. They have an additional step 2 to develop a system architecture, which normally is not needed as the general integration architecture is already known. This process is needed for first-time integrations, adding new partners can concentrate on just making the necessary extensions.

Mass deployment cases are straightforward B2B integrations on business processes that have been integrated already with at least one partner. The work needed to add new partners is smaller and the effort is from days to a few weeks. Typically, only steps 3 and 4 are needed. The implementation usually needs just extending some data mappings for partner specific information. The role of testing is more important considering the overall time. The mass deployment cases take from a few days to weeks with the partners.

B2B integration towards customer companies was uniformly thought to be much more difficult than to suppliers. The reason for this was that despite using RosettaNet or EDI for the integration, companies typically used them slightly differently. This caused a need to align the differences in the use of the e-business frameworks by, for instance, designing rules using conversion tables and XSLT to transform the differences. "*For the biggest problem the cure would be to have fewer versions of business messages. Now there are even many versions for the same customer*." Typically, companies in the customer role can demand that their suppliers do this work.

The existing integration did not have any project-specific issues. In general, most of the integration is continuous. Forecasting, order fulfilment and payment processes are typical processes to be integrated. Material composition processes are first PDM-related B2B integrations. The interviewees considered the integration of PD processes important, but in the near future B2B integration priority was still more on other processes that had good standards ready or under active development.

5.5.3 Product development processes

The PDM experts were asked to describe the differences between the ongoing PD projects in their companies. Typically each PD location had their own way of working, they had for instance different processes for engineering change (EC) management. The back-end information systems supporting the processes could also vary. Another difference was that a PD project could be working either on a totally new product or the new product could be based on an existing product. Projects based on existing products were typically smaller and shorter in duration than PD projects developing new products from scratch, which were overall considered much more complex and dynamic. The number of partners in the networked PD projects varied.

Supporting PD processes requires flexibility in the integrations. The process execution times can vary and the change process strictness may need to be varied. This project specific B2B integration work needs to be taken into account when planning B2B integrations for PD. Otherwise, there is risk that the B2B integration would not fully support the project-oriented nature [94].

Currently, the private PD processes are not mature for B2B integration. This problem is not technical but rather the private processes and the internal use of PDM systems needs to be more consistent. "*We have one global process, but process can be interpreted in many ways, the consistency needs to be improved*". This combined with the experiences of the suitability of existing PIPs, a wide use of B2B integration to support PD is a future issue. Therefore, the hope of getting stronger market-tests [80] on B2B integrations for PD projects has not yet succeeded.

Considering the overall implementation times, it is not feasible to set up systems integration for a PD project that is just starting. The first-time integration effort needs to be done earlier and should consider the flexibility needed to support project-specific aspects. This solution might be similar to the functionality of the *rule engine* of the present study [76][90].

The results are in line with other studies. A study of Swedish companies [28] on collaborative PD shows that the adoption of networked collaboration has been limited as companies have focused on internal efficiency rather than on the involvement of external parties. Further, research on Virtual Enterprises (VE) has the same goal of fast set-up of integration [118]. VEs are created by several independent organisations to cooperate on a specific business opportunity for a brief time that then dissolve when the operational phase for the business opportunity has been completed. E-business frameworks are expected to have an impact on the development of support software for VE and other collaborative networks [20][25][118], but they do not address the question of how this is accomplished fast.

5.6 Summary and conclusions

The general support from RosettaNet fits the requirements for B2B integration solutions needed to support networked product development (PD). The e-business frameworks defining common processes, commonly understood business documents and secure messaging support the interoperability and for the present purposes, and RosettaNet seemed the best framework to follow. RosettaNet PIPs are suitable and they address the semantics of business documents. The RosettaNet Implementation Framework (RNIF) addresses security concerns.

However, the implementation experiences brought up multiple interoperability concerns in the practical B2B integrations. The existing RosettaNet PIPs lack suitable data models for document management interactions. Not all the required document metadata is standardised by RosettaNet and overall there are lots of interoperability problems still when using the standard business documents. Just supporting the same standard process does not mean that the solutions will easily interoperate, as there are so many choices that need to be made in the implementation phase. Furthermore, the RNIF supports attachments but is not very efficient with large files that might require special considerations.

The internal PD processes are challenging.. What changes are communicated to partners and how the support is set up for new PD projects? In traditional integrations, the set up is done once and requires minimal maintenance. With distributed PD, some project-specific integration is needed and more complex rules are required in when the inter-company processes needs to be started. In organisations, the way of working is then affected.

The processes and semantic aspects of data mappings are time-consuming activities in current implementation processes. They can require changes in back-end information systems and end-user training and can thus be long projects. Learning is a factor. The first-time integrations differ significantly from the process of extending integration to new partners. A new process integration effort is currently measured in months and the negotiation power position affects the outcomes, as the buyer can often dictate specific integration details. For quick PD project integration, the first-time integration needs to be built first and then the project-specific integration can be set up fast for future collaborative PD projects.

6 Semantic technologies for B2B integration

This chapter presents experiences of using semantic technologies to support B2B integration and is based on publications V and VI. The solution set-up and run time operation is described and discussion includes expected benefits of using semantic technologies. The experiences are compared to related research and conclusions presented.

6.1 Motivation to apply semantic technologies

Due to the flexibility of the e-business frameworks regarding message details and message ordering, considerable effort is required to ensure that the B2B integration details of two partners match [154] and thus the B2B integrations suffer from long set up times and high costs [35][135]. The shortcomings of e-business frameworks, such as RosettaNet, are that they solve interoperability challenges only partly [35][36]:

- The schema languages lack expressive power to capture all necessary constraints and do not make all document semantics explicit in the current specifications
- Partners can use the same PIP messages differently as the messages contain many optional elements, which the partners can support differently.

When the number of partners increases, such limitations become increasingly important. Since resolving heterogeneities on a case-by-case basis is expensive, the use of partners is limited and B2B integrations do not support competitive arrangements easily. Similarly, the integration of more complex processes needs faster solutions, as discussed above with the case of product development processes.

Semantic technologies and semantic Web Services (SWS) have been proposed to achieve more dynamic partnerships [16] and constitute one of the most promising research directions to improve the integration of applications within and across enterprises. The SWS approach based on for example OWL-S [108] or the Web Service Modeling Ontology (WSMO) [138] enable annotation of B2B integration interfaces with semantic information. This allows automated or semi-automated mediation of heterogeneity. In addition, SWS enables powerful discovery, composition, and selection capabilities of services [162].

The SWS solution in this chapter is based on the Web Service Modelling eXecution environment (WSMX) [62]. WSMX is a reference implementation of the WSMO and operates with the Web Service Modeling Language (WSML). The chapter proceeds by presenting a solution of applying SWS technologies to RosettaNet integration and also involving partners using EDI. The author of the thesis has also participated in implementations according to the SWS-Challenge scenario, which represent more simple use case. The SWS-Challenge implementation is further described in [68][69][161].

It is assumed that SWS technologies are introduced to B2B integration stepwise rather than all at once. The scenario focuses on the purchasing domain as those standard processes and messages have been used in industrial implementation. Similar to the motivation by Khalaf [82], with so called double action PIPs, the most complex of the RosettaNet patterns are used and that covers other patterns as well.

6.2 Solution description

This subchapter summarises key aspects of a semantic B2B gateway solution to B2B integration. In the scenario, buyer’s internal use of SWS technologies enables it to integrate with heterogeneous suppliers that support different e-business frameworks.

An organisation A manufactures electronic devices. For a device, organisation A needs to procure specific components that can be delivered by approved suppliers, referred here as partners B and C. In the current situation, there is no competition for purchasing per delivery basis. In this proposed scenario, organisation A first submits Requests For Quotes (RFQ) for the components to all its suppliers. After the responses, it selects the best quote and initiates the Purchase Order (PO) process with the selected partner. Figure 11 presents the overall need for integration.

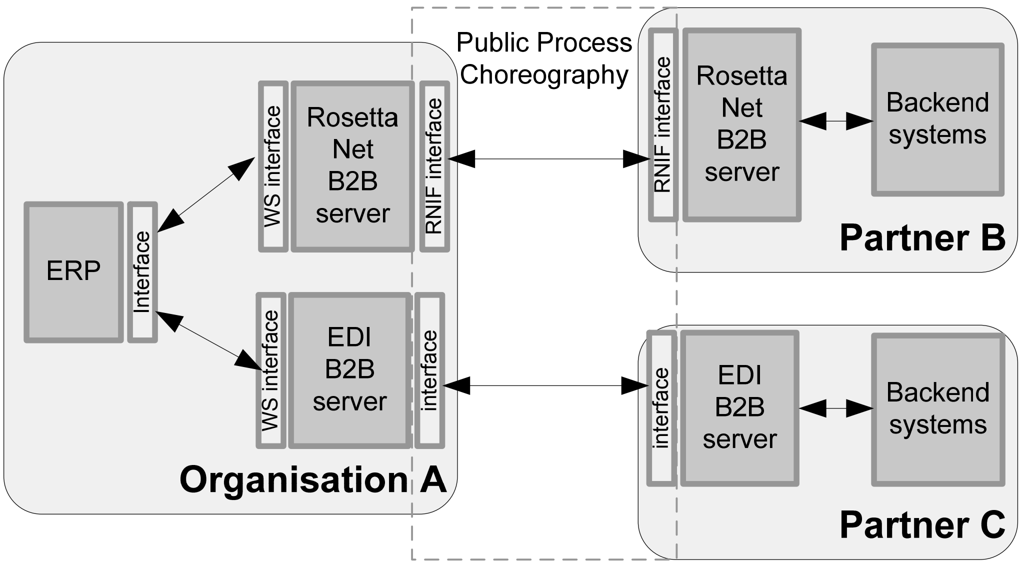

Figure 11 Scenario of integration

Considering the integrations, the following heterogeneities exist with the partners according to general B2B integration levels [112][127]

- Business document interoperation is the ability to understand the exchanged documents. RosettaNet PIPs define standard inter-company process choreographies and the related schemas for the business documents. Partner B uses the *PIP 3A1 Request for Quote* and *3A4 Request Purchase order* business documents according to the message guidelines provided by RosettaNet. Both PIPs contain request and response messages. Partner C uses EDI X12 messages and expects the *840 Request for Quotation* for quotes and *850 Purchase Order* for orders. The quotes are responded with *879 Price Information* and the purchase orders by *855 Purchase Order Acknowledgment* business documents. These PIP and EDI X12 documents use different terms and identifiers in referring to the same concepts.

- Business process interoperation is the ability of companies to exchange messages in the right sequence and timing. Partner B complies with PIP 3A1 and 3A4 standard choreographies. This means that the partner's response arrives within 24 hours of sending the requests or they answer with pending and provide their answer later with a different PIP. For every PIP message sent, there is a receipt acknowledgment for delivery. Partner C with EDI X12 has not such fixed response times between different messages, as this is not dictated by EDI X12. In this case, partner C has agreed to answer the quotes and purchase orders in the same 24 hours. In addition, the EDI choreography differs since the receipt acknowledgment message is not always used.

- Messaging level interoperation for secure communication. Partner B uses the RNIF 2.0 for secure communication and the message contents are in XML. RNIF guides how the messages are sent and acknowledged and how digital signatures are used. With partner C the communication is achieved via a Value Added Network (VAN) operator, which takes care of the communication between the companies. Alternatively, they could use Applicability Statement 2 (AS2) for EDI messaging.

Figure 12 shows the process interactions showing the role of PIP documents in the interactions considering the overall process of first quoting and then purchasing using BPMN notation.

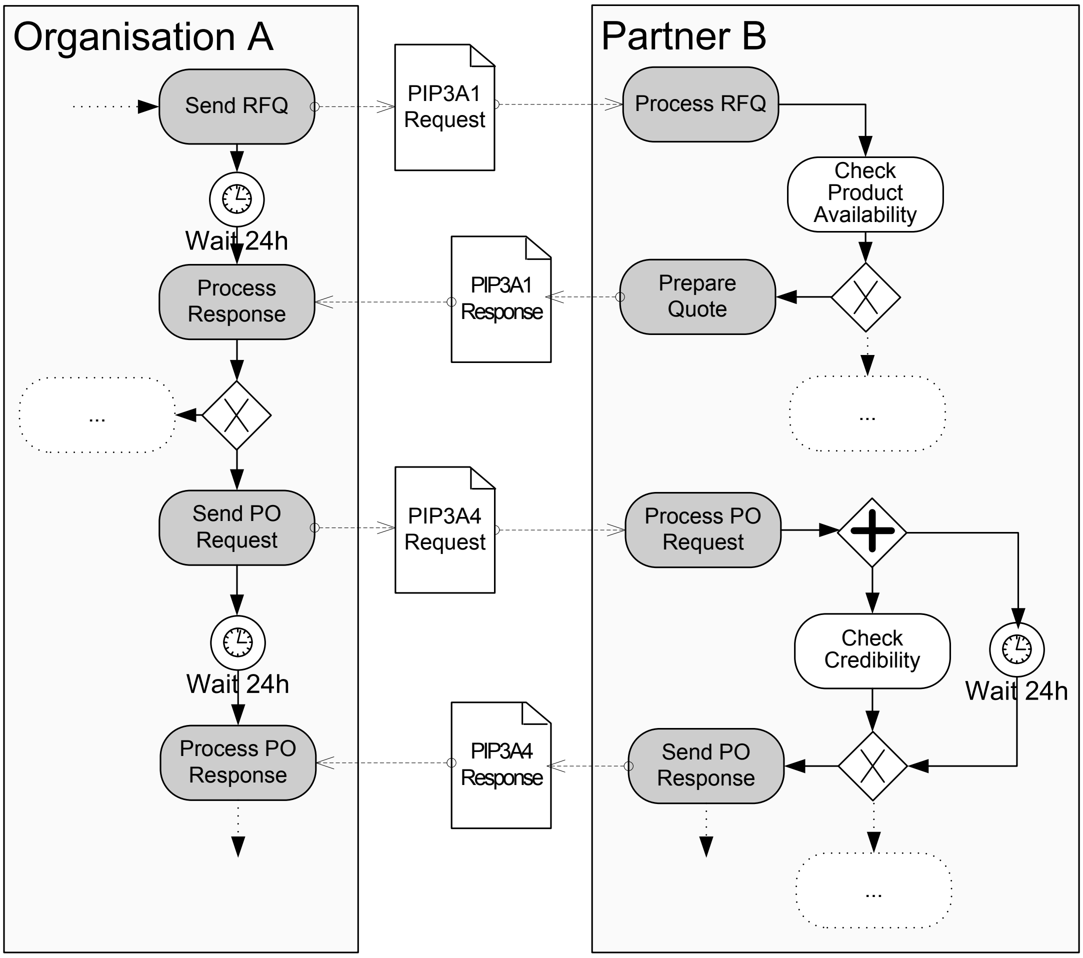

Figure 12 RFQ and PO processes

Table 7 shows excerpts of responses for quotes concerning only a very small part of the business document contents, as there are several hundred fields and enumerations both in RosettaNet and EDI messages.

Table 7. Excerpts of heterogeneous responses to quotes

Partner	Standard used	Identifier scheme and Identifier	Price / Number of Units
Partner B	RosettaNet	GTIN 12345678901234	198 USD / 204 Pieces
Partner C	EDI X12	EN 4567890123123	120 GBP / 200 Pc

EDI Codes: EN = (European Article Number) EAN, PC = Piece.

For the buyer, in order to decide on the best quote, homogenisation of the responses is needed. This includes changing all currencies to the one the buyer uses internally to enable the comparison of unit prices. In addition, as there are often multiple product identifications for the same product, the buyer needs to be able to match the identifiers accordingly. The standards support many ways to refer to even the same products, including global standards for product identification, such as Global Trade Identification Number (GTIN). The purpose of these examples of showing how SWS technologies and RosettaNet can be conceptually combined and what are issues that the SWS technologies enable better than the current specifications.

6.2.1 Solution Architecture

The semantic B2B gateway of the present study relies on four components: *knowledge base*, *choreography engine*, *adapter framework* and *reasoner* as depicted in figure 13. The architecture is based on the WSMO framework, and the WSMX system is used in the implementation. Here, the integration is presented in detail concerning Partner B, which uses RosettaNet. WSMO is mostly targeted towards a dynamic discovery of providers, achieved by matching the description of a requester's goal with the description of a provider's service capability. However, the solution omits the WSMO ontology parts concerned with dynamic discovery (goal and capability) of SWS, but operates on the WSMO service interface, a description of the communication patterns according to which a service requester consumes the functionality of the service. The discovery of business partners is conducted when the infrastructure is set up and it is based on well-established and long-running business relations.

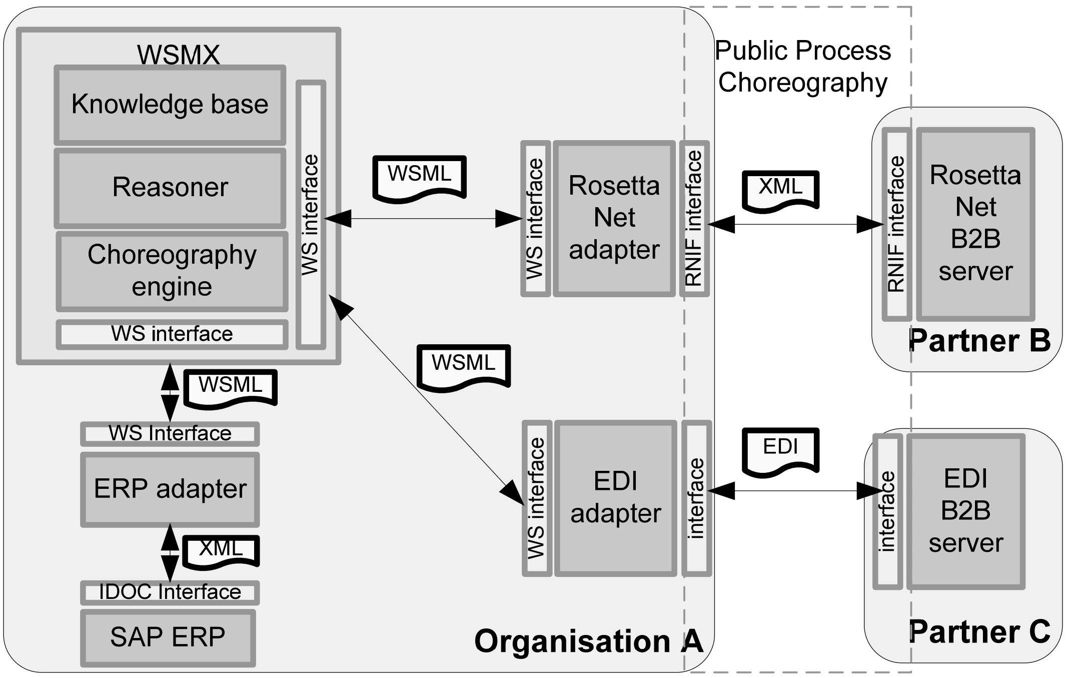

Figure 13 Overview on integration solution architecture

Knowledge Base. The knowledge base contains the generic and collaboration-specific knowledge required for resolving the heterogeneities in the collaboration.

Specifically, these are the ontologies, the domain specific rules and the choreography specifications. The knowledge base is further populated at run-time with ontology instances generated for every incoming business document.

Choreography Engine. The semantic B2B gateway manages the full life-cycle of the collaboration. The collaboration described in the PIP is expressed as a WSMO choreography and its execution is managed by the choreography engine (provided by WSMX). The engine sends and receives the exchanged business documents and updates the state of the choreography according to the message content.

WSMO choreographies are modelled as Abstract State Machines and are processed with standard algorithms during the runtime. The current state in the execution is represented by ontology instances. According to the instance data, a transition rule is selected from the rule base within a choreography. The rule is interpreted and the ontology instance is modified accordingly. It is the responsibility of the choreography engine to maintain the state of a process instance and to take the correct action when that state is updated. For example, the message received from a service provider updates the state of a choreography instance.

Adapter Framework. The adapter framework provides transformation functionality for every non-WSML message sent to the B2B gateway. Adapters are necessary for lifting and lowering syntactical to semantic representations, namely XML or EDI instances in the business documents sent from the partners to WSML ontology instances. Furthermore, application adapters are necessary to connect the B2B gateway to the back-end applications of the requester.

The adapters act as the actual service provider for the semantic B2B gateway. The service interface of the adapter is used by the gateway to invoke the provider functionality. Thus, the adapter is responsible for executing the correct endpoint of the partner B2B server. The adapters only perform data manipulation, and their interface behaviour replicates the behaviour of the underlying partner service.

Reasoner. The reasoner is required to perform query answering operations on the knowledge base, including the collaboration instance data during the execution. The reasoner has to handle WSML and should have built-in predicates for handling basic data-types, basic arithmetic functions and basic comparison operators.

6.2.2 Ontologies

The generic RosettaNet ontology that underlies all further description sis presented. The choreography ontology details are excluded here, but are elaborated in [63].

Based on its requirements, organisation A has to create or ideally reuse domain ontologies. In the example in this study, a purchasing ontology is used for a formal description of the RFQ and PO process messages. Creating these domain ontologies requires an expert who first understands specific e-business scenarios, and second, has knowledge about ontology languages to be able to capture the information in the business documents semantically. Since we are still far from an industry-wide recognised formal ontology, organisation A in the example needs to define the ontology itself. It is assumed that organisation A is not in a position to dictate its proprietary ontology to its partners. In this case, the ontology is based on RosettaNet PIPs and dictionaries that can already be regarded as a light-weight ontology.

Apart from translating the schema specifications to the richer and formal ontology language WSML, it is also necessary to model the constraints on the semantics of the business documents. The ontology includes constraints that are not expressible in DTD or XML Schema and that capture the implicit knowledge provided in the RosettaNet MG and accompanying documentation. The ontology has been modelled according to PIP3A1 business documents, containing concepts such as *PartnerDescription* or *PhysicalAddress*, and their attributes. These concepts can be straightforwardly expressed in WSML and are not discussed here. The full ontology can be found on-line[21]. Here, the focus is on the richer constraints, which cannot be expressed with the technology used within the current RosettaNet specifications.

Listing 2 shows examples of implicit knowledge captured in the purchasing ontology in WSML using the non-XML syntax for more compact readability. The numbers represent line numbers in the ontology file. For example, the RosettaNet business dictionary has a list of more than 300 possible values for the units of measurements, with the logical relationships between values unspecified. Here, these logical relations have been made explicit and these axiomatisations have been included in the ontology.

[21] http://m3pe.org/ontologies/rosettaNet/coreelements.wsml

```
axiom resolveMeasurementUnitType
  definedBy
    forall ?x(?x[globalProductUnitOfMeasurementCode hasValue ”
      dozen”] memberOf quoteLineItem implies ?x[
      globalProductUnitOfMeasurementCode hasValue ”12”]).
    forall ?y(?y[globalProductUnitOfMeasurementCode hasValue ”10− pack”]
      memberOf quoteLineItem implies ?y[globalProductUnitOfMeasurementCode
      hasValue ”10”]).

relation poundKilo (ofType productQuantity, ofType productQuantity)
nfp
  dc#relation hasValue poundKiloDependency
endnfp

axiom poundKiloDependency
  definedBy
    forall ?x,?y (
      poundKilo(?x,?y) equivalent
      ?x memberOf productQuantity and
      ?x[globalProductUnitOfMeasureCode hasValue ”Kilogram”]
        memberOf quoteLineItem and
      ?y memberOf productQuantity and
      ?y[globalProductUnitOfMeasureCode hasValue ”Pound”]
        memberOf quoteLineItem and
      ?x = wsml#numericDivide(?y,?x,0.45359237)).
```

Listing 2 Example of definitional facts

The first axiom *resolveMeasurementUnitType* in Listing 2 shows how the measurement units defined with a natural language text in the RosettaNet PIPs can be resolved to its corresponding numerical value. The second part of the listing defines a function used to relate a kilogram value to its equivalent pound value. As such, organisation A can query the knowledge base and retrieve instances data of different partners with homogenised values for the measurement units.

New partner integrations can require the setup of additional domain specific rules to capture any data heterogeneity that is not resolved by the definitional facts in the domain ontology. These domain specific rules (conversion relations in this case) define how attribute values in the different WSML instances can be transformed.

The adapters transform all non-WSML messages sent to the WSMX and they lift and lower between syntactical and semantical representations. Two types of adapters can be identified: *B2B adapters* that map between RosettaNet or EDI business documents and WSML and *application adapters*, such as the ERP Adapter, that map between (possibly proprietary) message schemas of the backend applications and WSML. The adapters operate on transformation rules expressed for instance in XSLT [31]. A short example of a XML document fragment and resulting WSML instance is shown in Listing 3.

```
<QuantitySchedule>
    <ProductQuantity>204
    </ProductQuantity>
</QuantitySchedule>
<GlobalProductUnitOfMeasureCode>
  dozen
</GlobalProductUnitOfMeasureCode>
<SubstituteProductReference>
  <GlobalProductSubstitutionReasonCode>
      Better product
  </GlobalProductSubstitutionReasonCode>
</SubstituteProductReference>
<totalPrice>
  <FinancialAmount>
    <GlobalCurrencyCode>USD
    </GlobalCurrencyCode>
    <MonetaryAmount>198
    </MonetaryAmount>
  </FinancialAmount>
</totalPrice>
```

```
instance QuoteLineItem1  memberOf
    rfq#quoteLineItem
   rfq#globalProductUnitOfMeasurementCode
    hasValue "dozen"
instance quantitySchedule1 memberOf
   core#quantitySchedule
 core#productQuantity hasValue "204"
instance substituteProductReference1 memberOf
   core#substituteProductReference
core#GlobalProductSubstitutionReasonCode
   hasValue "Better product"
instance totalPrice1 memberOf core#totalPrice
   core#financialAmount
    hasValue FinancialAmountTot
instance FinancialAmountTot memberOf
    core#FinancialAmount
   core#globalCurrencyCode hasValue USD
   core#monetaryAmount hasValue "198"
```

Listing 3 XML Instance and WSML instance after translation

6.2.3 Collaboration run-time phase

After the set-up phase is completed, WSMX is ready for running the processes. Here the execution process is described according to the scenario: (1) Converting back-end message to a WSMX goal, (2) Discovery of the possible suppliers capable of fulfilling this request, and negotiating with the discovered suppliers using request for quotes (RFQ) to get the pricing and delivery details, (3) Selection of the best supplier, (4) Invocation of the Purchase Order (PO) process with the selected supplier, and finally (5) Returning the answer to the back-end ERP system. The sequence diagram for the run-time behaviour is depicted in Figure 14.

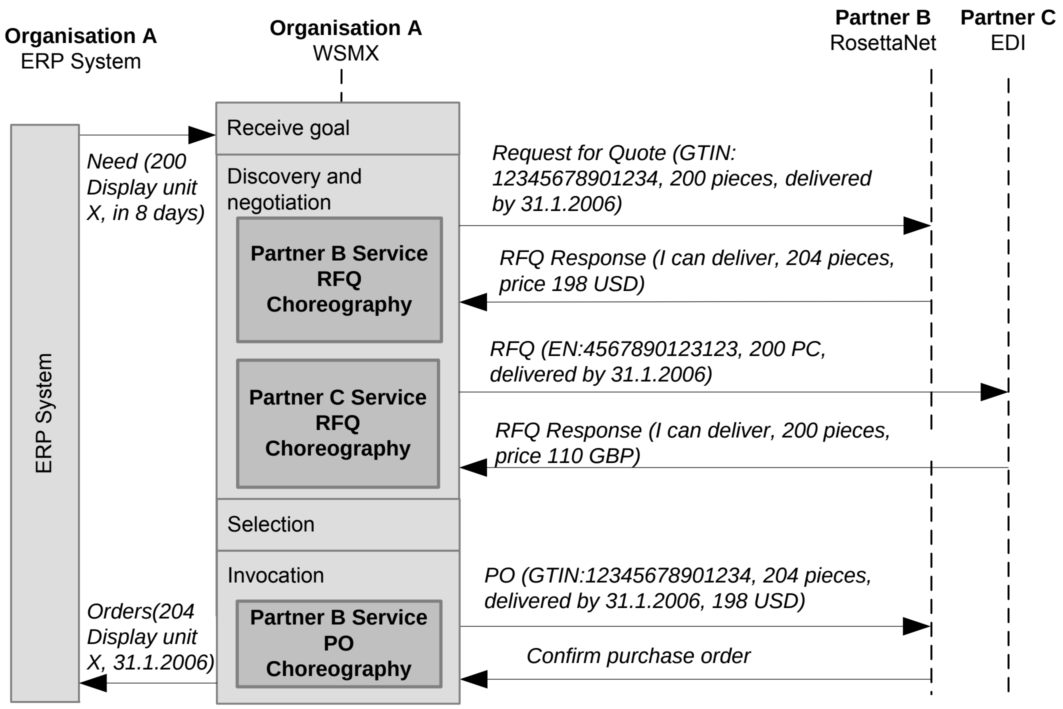

Figure 14 Run-time behaviour

- *Converting back-end message to WSMX goal*. Organisation A's ERP system sends out a request in its proprietary format, such as SAP IDOC, to the ERP adapter. The request is to get 200 display units delivered to the plant within 8 days. The adapter translates this to a goal in WSML and sends it to WSMX.

- *Discovery and negotiation*. The execution process starts by invoking the WSMX discovery component. All services in the repository matching the request are found. In the present case, the partners B and C are discovered as potential suppliers. During the discovery, data mediation rules can be executed to resolve differences in the ontologies used for the goal and the service descriptions. As discovery operates on abstract description of services, the next step is to find out whether each discovered service can deliver the required product within the given time and give a price for that. In this example, negotiations are performed with partners B and C by sending RFQ documents, and the partners answer these with RFQ responses. Data and process mapping rules are implemented in the adapters, which handle the differences between the RosettaNet and X12 message choreographies. Responses coming in RosettaNet PIP 3A1 and EDI X12 879 messages are translated to WSML and sent to WSMX. Here, the mediation handles the differences between the currencies, date representations and identifications used and can use the terms specific to RosettaNet or EDI X12.

- *Selection*. Based on the information provided by the quotes, the best partner is selected. In this scenario, this is done simply according to the cheapest price. In the present scenario, partner B has a cheaper quote and is selected. Alternatively, this can be a semi-automated process, where a user makes the selection from a list of quote responses.

- *Invocation*. The PO process starts with partner B using PIP3A4. The concrete interactions between WSMX and partner B happen analogically to the case of the RFQ choreography.
- *Returning answer*. After the invocation returns the PO response, the necessary data mediation for the product identifiers and currencies expected by organisation A's ERP is done. Then the result is sent back to the ERP adapter as expected by the ERP system.

6.2.4 Implementation status

It took us roughly 200 hours to build the ontologies, choreographies and axioms, but this is still just a conceptual implementation. The Web Services Modeling Toolkit (WSMT)[22] was used in building the examples. However, as parts of WSMX architecture and WSMT are under development, implementing a running implementation would have needed additional resources.

6.3 Evaluation

The evaluation conducted for the RosettaNet integration using semantic technologies according to design research guidelines [72] is described in this subchapter. The examples given in the original articles show how RosettaNet and semantic technologies can be combined.

The quoting and purchasing scenario is mainly evaluated by constructing a scenario and the related instances. In this study, WSML instances of the XML files are generated as well as the choreographies and axioms to tackle the heterogeneities. As parts of the WSMX architecture is still under development, there is no full implementation of the use case. There is implementation of a simpler use case that have been through peer-review and test cases, but with a simpler use case and the development team had participants in the WSMX system development. The SWS-Challenge[23] implementation has been evaluated according to the criteria defined by the SWS Challenge [161]. The black-box testing is done, as the solution passed the

[22] http://sourceforge.net/projects/wsmt
[23] http://sws-challenge.org

tests provided by the SWS-Challenge organisers. The other participants of the SWS Challenge provided white-box testing as well.

The needed formal models of the solution are presented, and thus logically constructing such a solution is possible, provided enough implementation resources. In this respect, the evaluation is analogous to the example design research paper [159] in Hevner et al. [72].

6.4 Discussion

Experiences with the semantic solutions are summarised and the potential business benefits of using SWS technologies are discussed in this subchapter.

6.4.1 Architecture and implementation issues

The contribution of the present study is the concept of integrating WSMX with RosettaNet and pointing out how SWS can help to support particularly RosettaNet. There are many challenges related to ontologising RosettaNet specifications as RosettaNet evolves. The introduction of XML Schema PIPs has brought some major changes to RosettaNet specifications. The element naming has changed, and supporting the same PIP in DTD and XML Schema formats requires separate mappings. This involves additional work in defining the necessary mapping rules for different message versions. Having RosettaNet specifications in the current non-ontology language means that developers currently need to do this lifting to ontologies. Hopefully RosettaNet will adopt an ontology language to formally specify PIP business documents, as has been suggested by other scholars as well [155].

The present approach requires a lot of work in setting up the SWS architecture. Adapters need to be developed for every e-business framework and mappings are needed with the different business documents used. However, after ontologising one PIP process, adding support for other PIPs can reuse a lot of the existing work. Furthermore, the behaviour of the RosettaNet adapter concerning RNIF is identical in all RosettaNet PIPs and thus needs to be defined just once. So far, the conversations in valid RosettaNet messages have been defined and the domain ontology representing the concepts in the example scenario created. The current ontology contains the information carried in those business documents rather than all concepts in the RosettaNet PIPs. Although only specific RosettaNet PIPs have been used, the results are applicable to other PIPs. The ontology built for PIP3A1 and PIP3A4 include common elements present in every PIP message. It is a time-consuming engineering task to encompass all messages in RosettaNet in the ontology, but it is a one-time effort. Since such a comprehensive ontology has not been defined yet, the ontology can be extended on a case-by-case basis.

The SWS-Challenge implementation [68] represents an implemented but simpler use case, as the RNIF messaging does not need to be addressed in the challenge, and RosettaNet business documents have been simplified by the SWS-Challenge organisers. This means that so far dynamic currency conversions or measurement unit modifications are not needed. However, SWS-Challenge provides valuable input and a comparison platform for solutions built with different partially competing semantic technologies. It shows how more adaptive B2B integration solutions can be built.

The SWS implementation platform, such as WSMX, provides an alternative to traditional EAI systems. WSMX can be thought as a semantic SOA that provides similar functionality to existing EAI/SOA systems for integrating to heterogeneous services. The difference is that WSMX is open-source and not based on proprietary technologies. However, WSMX is still a research prototype under development and lacks features of respective commercial applications.

Currently, implementing a SWS solution in an industrial setting is still hard. The technologies and tools are under development, which means that they are changing. For instance handling multiple identifiers for the same product is possible with standard database technologies as well, but supporting such heterogeneity involves some cost. In general, the semantic solution would be most beneficial to companies facing lots of heterogeneity without a position to dictate how everything should be done. If a company is in a position to dictate, then the problems of heterogeneity are more on their partners. Preist et al. [135] state the ideal approach to integration would be to have all internal systems re-engineered to communicate with each other using semantic technologies data in a shared enterprise knowledge base. They acknowledge that this is unlikely to be acceptable in the short term and thus their solution also utilises existing e-business frameworks.

Furthermore, current evaluations have not addressed performance and scalability issues with semantic solutions. Lifting and lowering are extra steps, and complex reasoning and mediations can have performance issues. As some existing PIP instances have been reported to be even hundreds of megabytes big [35], scalability and performance are obvious concerns.

6.4.2 Expected benefits

As discussed by Preist et al. [135], the results of this work demonstrate the feasibility of SWS approach to B2B integration problems, and the use of dynamic integration via semantic descriptions is expected to become an important industrial technique in the near future.

The current long set-up of integration leads to business models with simple processes, in which long term rigid partnerships are established between organisations. There is, for example, no competition for getting multiple quotes, as the default partner is selected directly for purchasing using long-term contracts. This is partly because there is too much overhead to manage multiple partner specific quoting and purchasing integrations. The present solutions show, how more heterogeneity can be accepted to support competitive arrangements.

The quoting and purchasing scenario highlights the problems currently observed in RosettaNet collaborations. For example, having suppliers from different countries brings heterogeneities, as the partners are likely to use different currencies, different measurement units or different packaging units. The benefits of resolving heterogeneities for the buyer result from decreased costs of purchasing as the best value deals can be selected on the basis of the best quotes. The suppliers benefit from being able to integrate to the buyer more easily without having to make potentially costly changes to their current integration interfaces. The solution relies upon a formalised RosettaNet ontology including axiomatised knowledge and rules to resolve data heterogeneities. Further, by using stronger technologies, the specifications could become simpler and some unnecessary textual constraints could be readily expressed. Such an issue also emerged in out efforts making suggestions for standard PIP style processes. If a value of an enumeration causes constraints on other business document elements, these have to be currently resolved by loosening the automatic validation requirements and adding textual guidelines to provide such issues not supported by DTD or XML Schema technologies.

The study showed how to capture definitional facts such as the relation between pounds and kilograms, by defining the functions in the ontology related to units of measurement. These relations are not specified by RosettaNet. The solutions provided have potential use in a significant portion of the more than hundred RosettaNet PIP business documents, of which roughly half contain currency and measurement unit information. According to McComb [109], more than half of the 300 billion dollars annually spent on systems integration is spent on resolving semantic issues. So automating even a part of this makes a big difference.

6.5 Positioning to related Work

In the literature section, research on B2B integration with semantic technologies was presented. Here, this work is positioned to those papers.

The semantic technology solution presented in this study aims at extending RosettaNet integrations to handle heterogeneities better. Further, the implementation represented in SWS-Challenge is compared. WSMX architecture and WSML language are applied in the solutions and WSMT is used in constructing the ontologies, and XSLT is used in translating XML to WSML. Both solutions address back-end integration, integration details are given and the complete examples are available in the Internet. Evaluation has been done around the scenarios.

Table 7: B2B integration with semantic technologies

Publication	Quoting and purchasing solution [63][91]	SWS-Challenge implementation [68][69]	Other papers [2][9][42] [54][135][154][155]
E-business framework used	RosettaNet PIPs, RNIF	Simplified RosettaNet PIP	RosettaNet PIPs *3, HL7, ebXML registry, EDI X12 and EDIFACT, AIAG, STAR
Semantic technologies	WSML	WSML	OWL*3, WSML*2, RDF*2, DAML+OIL, CycL
Tools/systems used	WSMX, WSMT, XSLT	WSMX, WSMT, XSLT	Racer *3, Jena*2, XSLT*2, many individually mentioned
Back-end integration	No, only planned to SAP IDOCs	SWS Challenge back-end systems	SWS Challenge back-end systems, UDDI server, no details in four
Implementation described	Yes	Yes	All describe implementation details
Evaluation	Descriptive scenario	Black and white box testing on a simulated scenario	5 descriptive scenarios, one of which have clearly a functional prototype. One SWS-challenge evaluation.

RosettaNet is a popular example for semantic technologies, but the solutions ignore secure messaging solutions and do not provide concrete examples on benefits on the PIP schema level. More details on how certain parts of typical PIP documents can benefit from SWS are shown here. Semantic technologies mediate between different standards in many cases [2][42][135]. There are multiple tools and systems used with Racer, Jena and XSLT been used in multiple solutions. Lifting and lowering to the ontological level is often done with XSLT. Back-end integration is not commonly addressed, only in the case of SWS-Challenge, but overall implementation details have been presented, so that in principle others could verify the details. However, real running examples with extensive testing are missing.

Similar to other related work [2][135][155], we use semantic technologies together with current technologies to highlight the benefits of using stronger semantic languages. This is meant to show the potential benefits of SWS technologies and to show how existing B2B integrations can be enhanced with semantic technologies. Regarding the current RosettaNet business documents specifications, the current DTD and XML Schema languages have limited support for information reuse through reference, rules, and external imports. The business documents specifications contain a high amount of repetition since all implicit information is stated explicitly. These repetitions make the schemas long and complex to interpret.

6.6 Summary and conclusions

The scenario on combining RosettaNet and semantic Web Services (SWS) have been presented to address interoperability challenges between partners. The RosettaNet specifications can be represented with SWS technologies and the SWS technologies can capture information that is only human readable in the current specifications. It has been show how to formalise the existing specification using stronger SWS technologies making it possible to provide explicit relationships between values.

The scenarios present how more heterogeneity can be accepted in PIP business documents, and how stricter validation can be accomplished. Support for automated matching of interfaces can significantly shorten the implementation times and lessen the need to point-to-point transformations.

A solution was described, how existing e-business frameworks can be used together with a system using SWS technologies. The solution accepts the current B2B integration technologies, but shows how the existing business documents can be lifted to formal ontology languages.

7 Technical interoperability in B2B integration

Technological development supports goals of easy integration of business partners. There are many XML technologies to define business processes, business document schemas and application interfaces and this makes integrations easier. However, just XML is not enough. In addition, recent technical development around acronyms such as Service-Oriented Architectures (SOA), Business Process Management (BPM) and Web Services are starting to have an impact on companies' internal enterprise architectures, offering a promise of making application more accessible and processes more model-driven. Furthermore, semantic technologies have emerged to provide means for computers or programs to understand more of the actual content enabling higher degree of automation.

Since the widely referenced paper on B2B integration by Medjahed et al. [112], new technologies have emerged. Medjahed et al. [111][113] further discuss composing Web Services, but do not really tackle how semantic technologies affect B2B integrations.

7.1 Typical B2B integration

A typical current B2B integration architecture to integrate information systems is presented in Figure 15. The back-end systems often do not have Web Service interfaces but offer some custom interfaces. The Enterprise Application Integration (EAI) systems have many adapters available for connecting to different back-end information systems. They support Web Service technologies and have tools for modelling and execution of processes and making business document transformations between bank-end application data-models to business document standards. The functionality of a B2B server often comes as a B2B adapter to EAI products and they offer support for packing and securing the business documents for messaging. However, the commercial tools often use proprietary technologies or have proprietary extensions in the solutions. The information flow is typically XML.

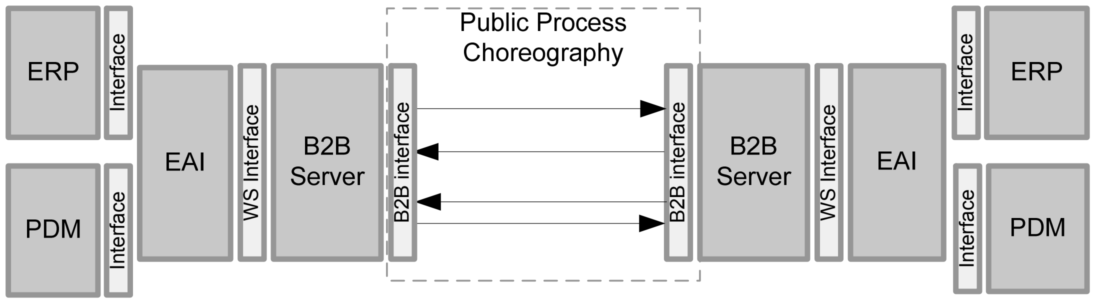

Figure 15 General architecture of B2B integration

The public processes use XML or EDI. The technologies and software tools to create integration solutions have matured. The internal processes can be modelled using business process languages that can be even translated to executable processes. The the messages are described using XML Schemas, the needed data transformations use often XSLT, and the integration end-points use Web Service technologies. These details need to match exactly, including all the details on process steps and business document contents.

However, building B2B integrations take a considerable amount of resources. The prototype development of the present study already took hundreds of man-hours. Lu et al. [102] reported that the Rosettaet integration cost for a Chinese company amounted to 350,000 USD, which CISCO covered fully.

7.2 The role of e-business frameworks

The role of e-business frameworks is to support interoperability by defining standard interfaces between companies specifying common processes, semantics of the business documents and security details. The business partners can change their back-end applications, but as long as the standard interface stays the same, the B2B integration can stay the same foe the partner. This loosely coupled nature along with extensibility is one of the major benefits over point-to-point integrations, which break with system upgrades [88].

However, agreements are still needed on the specifics of the processes, business documents and messaging. Regarding processes the roles of partners, the sequence of business documents exchanged and the overall process frequency needs to be agreed upon. For instance, in some cases the engineering change (EC) request and response cycles need to be one week and in others one day. This sets different requirements to internal processes, as the users typically need to produce the EC responses. E-business frameworks help here by providing building blocks for such processes.

The details on business documents need to be defined as well. E-business frameworks offer shared semantics for the contents of the business document. The use of voluntary elements in business documents and agreements on known enumerated options are needed to agree on details. In addition, agreement on what identifiers are used for companies, locations, products and documents is still needed, as there are many options there as well.

Messaging details include defining actual integration end-points and agreeing on optional issues considering for instance security methods. With RosettaNet and ebXML messaging there are lists of products that have passed third party interoperability tests, which help to ensure that the products are compliant with the specifications.

E-business frameworks, such as RosettaNet, still have interoperability challenges in practical implementations. Software products can interpret the specifications, such as RNIF, differently [153] and the semantic support might not match the actual requirements [75][90][151]. The DTD and XML Schema languages lack expressive power to capture all necessary constraints and do not make all document semantics explicit [91]. Enforcing more complex rules is lacking in the current specifications [36]. Furthermore, companies can use the same PIP differently, as the business documents contain many optional elements, and companies can support different parts of the RosettaNet dictionaries in the enumerated values.

7.3 The role of semantic technologies

Semantic technologies do not have yet any role in current B2B integrations. However, the use of semantic technologies and ontologies have been suggested for easy integration of information systems [49][70][138]. Just introducing stronger technologies to encode B2B integration details is not enough. Having a formal language to present business document content is not enough as there is still need for the partners to commit to the ontologies described in these languages. The basic problem of agreeing on terminology is similar to using DTD or XML Schemas. So far, there are no industry-widely used formal ontologies available and thus e-business frameworks, such as RosettaNet, represent current best efforts on domain specific ontologies to support B2B integration.

Semantic technologies have more representative power than the current XML technologies. This enable stronger reasoning capabilities and means that more textual constraints can be readily presented. There are many papers on using semantic technologies to support and enhance interoperability in B2B integrations. These include describing EDI X12 messages in formal languages [53][54] and using formal languages to bridge heterogeneous automotive standards [2]. There are also many papers complementing RosettaNet with semantics [9][63][69][91][135][154][155]. The more expressive languages support for information reuse through reference, rules, and external imports. The use of more expressive languages have potential to create the business document definitions simpler and thus the unnecessary optionality can be avoided.

The numerous publications on semantic integrations show that conceptually, B2B integrations using semantic technologies can be made. However, a lot of implementation effort is needed to implement all the ideas in practice. Furthermore, special skills are still needed for working with semantic technologies – the traditional XML technologies and current EAI products are more known among practitioners in organisations. The publications present only prototype solutions with limited evaluations and there are no practical implementations yet in companies. Considering the evaluation guidelines of design research [72], further testing is needed to evaluate scalability and performance, as has been done with RosettaNet technologies in Tikkala et al. [153]. Ultimately, it should be shown as in strong market test [80] that semantic solutions have measurable benefits over traditional technologies. This is a long road as many companies are just making their first traditional B2B integrations and portal solutions still represent the typical solutions, as discussed in Schemm et al. [141].

Considering the integration process, the semantic technologies enable more automated agreement, provided that the interfaces are semantically described [154]. The testing can be also partly avoided, as formal checking can logically make sure that there are no deadlocks or livelocks in the processes [159].

7.4 The role of BPM and SOA

The technologies around the acronyms Business Process Management (BPM) and Service-Oriented Architecture (SOA) are gaining popularity. The technologies offer more automation for B2B integration. BPM technologies and tools provide a model-driven software development, where the diagrams meant for business people can be directly used in the actual implementation effort. This is not the case yet with existing RosettaNet diagrams. The SOA technologies help to access information systems easier and there is often a registry to help applications to integrate as the calling application does not require knowing all the details on the service that answers the request.

Considering the present solution to integrate PDM systems in chapter 5, the solution has some SOA features as Web Service technologies have been used. However, the

Web Services are tightly coupled to exact Web Service interfaces and changing a server causes need to change the code. In addition, the internal processes are not described in any BPM languages but are hard-coded in program code or use application-specific technologies. If the same prototype would be done again with the latest tools and technologies, the solution could be made more model-driven and implementation effort could be saved.

The BPM or SOA technologies do not compete with e-business frameworks, as they do not provide semantics for business documents or give details for public processes. They promise help making the technical integration part and offer technologies to make cross-platform and tool interoperability easier.

7.5 Discussion on B2B integration standardisation

Currently B2B integration standardisation seems to be dominated by a large number of standard developing organisations, from which many are industry-specific. The use of semantic technologies in standardisation is so far non-existent. Prominent e-business frameworks, such as RosettaNet, ebXML, OAGIS or UBL, do not use semantic technologies or tools. Still, it is recommended that standardisation should start using semantic technologies [2][155]. Many current research efforts aim to provide a bridge between current standards with weak semantics and the formal languages. However, there is call for more industrial strength formal ontologies that go beyond academic prototypes [71][155] and in general applying and improving the existing semantic technologies in real-life cases [152].

Not all standardisation issues are technological. The importance of social interactions and presence of different stakeholders is very important for the quality of the results. A meeting between partners to agree on B2B integration is still needed and providing support for these is also important. However, this thesis has concentrated on the technical aspects that could be better specified to provide flexibility for the integration.

7.6 Summary and conclusions

This thesis has discussed the role of e-business frameworks for interoperability. They provide extensible solutions to agree on business processes, business documents, and secure messaging. They make the integrations loosely-coupled with particular enterprise systems and provide common terminology and process interactions between organisations.

Nevertheless, XML standards have still interoperability issues that the use of semantic technologies can solve. The main interoperability stems from the current need to have everything match syntactically, as the e-business frameworks do not provide specifications that would enable logical matching more flexible in slight heterogeneities.

8 Discussion and conclusions

In this chapter, the main contributions of this thesis are summarised and the relevance to practise and research validity and reliability issues are discussed. Finally, topics for further research is presented.

8.1 Summary of the contributions

This thesis contributes to interoperability issues in B2B integrations. The role of different technologies and e-business frameworks in B2B integrations has been explored. Further, how e-business frameworks can support product development process integrations have been discussed. This is new areas of B2B integration. Further, the role of semantic technologies enabling more flexibility and faster integration of new partners is discussed.

For any given integration, there needs to be agreement on the processes and semantics of the exchanged information and physical connection between the integrated systems with good enough security. E-business frameworks set standards and specification to help define these issues for the necessary processes. Different technologies help in this process by giving means to represent the business processes, and documents, and provide secure connectivity. The study has analysed the current technologies used in B2B integration and presented the potential of semantic technologies to address shortcomings of the current technologies. For establishing common understanding, a technology such as XML, XML Schema, OWL or WSML is not enough. Whatever language is used to present the business document contents, a common agreement is needed on the details. Current e-business frameworks, such as RosettaNet, provide only human-understandable semantics and leave many logical relationships for the burden of application developers. This causes interoperability problems in B2B integrations.

The study has presented a design and implementation of a prototype system for supporting networked product development processes. This is a new area for B2B integration using e-business frameworks. The experiences with the implementation and use indicate that RosettaNet is feasible for this purpose. However, there are potential problems regarding the level of support offered by RosettaNet. The RosettaNet specifications for the common processes and the related business document should support the product development information exchange better, by ensuring common understanding of important terms and providing better guidelines for the use. As business document definitions currently make it possible to misuse the standard, two implementations of the same RosettaNet process are not necessarily compatible. Hence, the aim of industry-wide cost-effective B2B integration using e-business frameworks may be compromised. In addition, the project-oriented nature of product development processes brings special requirements for integrations. There is pressure to make B2B integration set up times short. This work should provide guidelines and interoperability lessons that can be considered when organisations are ready for such solutions. Currently there seems to be more urgent processes to fix first that have wider user potential.

Considering the role of semantic technologies for B2B integration, this study has presented B2B integration combined with semantic Web Service (SWS) technologies. This shows potential benefits of SWS technologies to existing B2B integration, particularly with RosettaNet. It was shown how using SWS technologies, currently only human-readable relationships in RosettaNet specifications can be made explicit. This enables accepting more syntactical heterogeneity in B2B integration details.

8.2 Practical relevance of the thesis

Hevner et al. [72] stress the utility of the designed artifacts, as well as the fact that they should be interesting, applicable and current to practitioners at the time of the publication. There is call for more industrial relevance in information systems research [5][37] and frames of reference which are intuitively meaningful to practitioners to organise complex phenomena [5]. Considering the various e-business frameworks for B2B integration, it has been shown how they relate to each other. The results should help practitioners to better understand the role of different e-business frameworks and technologies in setting up practical B2B integration solutions.

Related to systems integration supporting product development, an implementation that provides a basis for constructing such solutions has been presented. The experiences can provide a basis for real solutions and feedback on standardisation of processes suitable for such collaboration. The experiences on project-specific support should also provide a checklist for integrating such processes. Building an artifact for an important task first is said to have utility as itself [106]. The study has shown that it is possible to develop systems integration solutions for supporting networked product development. The prototype presented with its architecture and use of internal data model with well-specified internal semantics, helps to map different standards-based business documents to the solution. This reduces lock-in for a certain e-business framework or solutions vendor.

The experiences in technical interoperability issues show, particularly with RosettaNet standards, possible interoperability problems. Supporting the same standard process does not indicate easy interoperability, as current B2B integrations require an exact match on specific details. There are many such details in the standard business documents. The study has shown how semantic technologies enable designing interfaces that accept more heterogeneity in the measurement units or currencies used. Such solutions should be useful with different e-business frameworks as well. The role of semantics and standards are important to the Service-Oriented Achitecture (SOA) vision of adaptive, reusable services that are easily discovered and used, also across companies. Basic Web Service descriptions support only interoperability at the syntax level. Structural and semantic heterogeneity between messages exchanged by Web Services are far more complex and crucial to interoperability [117]. The e-business frameworks, such as RosettaNet, provide commonly understood document semantics and process choreographies and are important part in SOAs. Further, SWS technologies provide support for more complex interoperability solutions as well as better support for discovering and composing services. However, the solutions only tackle technological issues on B2B integrations. The organisational issues in general can be more significant in practical B2B integrations.

Regarding market tests of different solutions [80], there is data on EDI integration supporting strong market test claims [116]. The use of RosettaNet e-business frameworks in general supports strong market tests [102][121] but for other e-business frameworks this is not necessarily the case. Semantic technologies for B2B integration in general are still in the phase of approaching weak market tests, as there are no publicly reported industrial usage experiences.

Considering the artifacts of the present study, the product data management (PDM) integration solution and the SWS solutions can be evaluated on these criteria. The PDM integration solution has received positive response from companies participating in the projects but they are not yet used anywhere for such product development collaboration. So far, the B2B integrations are still related to order fulfilment processes. In RosettaNet, the first PDM-system related integrations seem to be material composition and product change. This applies also to semantic technologies to B2B integration. The semantic solutions have not been used in reported production implementation. The use of such technologies still requires special skills, and the supporting tools and technologies are still maturing.

However, despite the weak market tests, the research outputs have practical utility. They show the relationships between different technologies and e-business frameworks and display prototype solutions. To get this to industrial use network effects are also needed [142] as integration needs partners capable of such efforts.

8.3 Scientific rigor

For design research, scientific rigor in constructing and evaluating the artifacts is important [72]. To validate and verify the results, transparency has been aimed to provide traceability for the results. The following sub-chapters discuss this more on detail.

8.3.1 Literature study

The systematic approach was used in the literature study and the process was documented. The articles found with the systematic approach were compared to those collected earlier with less formal approaches of random searching. The important articles and quite a few new ones were found. There is ambiguity in the use of terms in literature, as for example RosettaNet is sometimes called an e-business framework, e-commerce framework, B2B protocol, Inter-Organizations System (ISO) standard, B2B interaction standard and standard. This was taken into account in the literature study. Therefore, the literature can be considered to have been thorough.

There is always room for improvement. The title and abstract of a paper might not have provided enough hints on the contents and important articles may have been omitted. In addition, for space limitations, it is not possible to position the work to all possible related research papers and the things that are compared are not always the main points in the publications.

8.3.2 E-business frameworks

The speed of change makes studying e-business frameworks challenging. For example, the BizTalk Framework was officially closed down in 2002, e-speak was discontinued and eCo has been inactive for years, whereas the first full version of UBL was published only in 2004. Moreover, new versions of some e-business frameworks emerge nearly on a monthly basis. Therefore, many of the studies on e-business frameworks are already outdated.

At the time of the analyses, effort has been put to provide transparency. Therefore, others can come to the same conclusions based on the given specifications. Naturally, there has been and there will be further development on the e-business frameworks studied. So, it has to be accepted that the results of this study will be old in a few years.

8.3.3 RosettaNet implementation experiences

The requirements and solution details have been documented to enable others to verify the results by building similar systems. The solutions have also been evaluated with appropriate means. Naturally, there could still be more evaluation of the artifacts, especially in real-life settings, to gain observational analysis on the solutions. The efforts used can be considered very significant in hours spent on designing, building and evaluating these solutions. Getting wider user experiences requires partners, who are equally ready. Companies will not build something just for the future, but will require the partners to be ready as well. For instance, the readiness of the existing information systems was reported to be motivation, for selecting a particular partner for B2B integration among alternatives [102].

Regarding the interoperability problems found, similar problems can be expected with other frameworks as well. At least with EDI standards, the general problem is the same considering the measurement unit value relations not provided. But implementations for EDI have not been provided in this study. For wider generalisations, more research efforts are needed to generalise results to other e-business frameworks.

8.3.4 Semantic solutions

The semantic solutions have been built on formal models and some implementation experiences have been gained. The ontologies and solutions have been made public to help others to evaluate and reuse the solutions. They are still limited to mostly a couple of RosettaNet PIPs but the process of extending the solutions has been discussed. More efforts are needed to further build and evaluate the solutions.

8.3.5 Use of design research

The design research guidelines [72] have been used in this work and for most part, they have fitted the needs of the study well. However, the evaluation part is confusing and lacks guidelines on what evaluation methods are appropriate. There is no clear distinction on what implementing a prototype is, because scenario-based evaluation can be with or without actual implementation, and the different evaluation methods make a long list. “This is how we built it so it works” -evaluation does not fit any category. In this regard Kasanen [80] is better in defining the market-tests for artifacts. Overall, implementation details or evaluations do not seem very important to get papers published currently. In general, there should be more open information to support others following the existing work.

8.4 Pointers for future research

Considering the research on XML-based e-business frameworks, adoption and benefit studies are still quite limited. It is not yet proven, whether they enable better integration of SME companies. Currently the collaboration set-up still seems a very long and expensive process. Making the B2B integration process faster is an important topic for future research. This probably needs both technological solutions increasing the automation, and organisational solutions covering best practise processes on how to reach collaboration agreements through social interaction.

Regarding further research on PDM integration, I agree with the research issues proposed by Zhang et al. [169]. They propose the application of Web Services and Semantic Web to solve such problems as integrating legacy systems from various service providers. They also want active collaboration with industrial partners to deploy research solutions in industrial settings. Additionally, setting up product development projects quickly needs further research. It would be useful to target more research on the integration of project-based processes to propose solutions to handle these differences. The different project-specific aspects should be identified better so that the B2B integrations would be agile for changes needed in different projects. As this project specificity is not necessarily only a product development related concept, it would be good to gain more experiences in other B2B integrations that are organised in projects.

Currently, the semantic technologies have a very limited impact on the standardisation of e-business frameworks. Using semantic technologies have potential to better support interoperability than the current standard specifications do. Therefore, the standardisation should better support interoperability and use of semantic technologies in the specifications could enable this. More experience on semantic technologies is needed for establishing guidelines how to best extend the current XML-based specifications. Similar validation can be provided with XML Schema or ontology languages and best practices need to be established, what is the best way to combine technologies.

To have standards developing organisations to use semantic technologies, introducing tools and solutions to standardisation bodies is needed. Before the e-business frameworks provide their specifications using semantic technologies, the technologies have most potential use internally with organisations that need to manage a lot of heterogeneities. Considering the definitions on existing e-business frameworks, efforts are needed to demonstrate semantic mappings between different frameworks that now standardise the same business documents differently. There is also a call for industry-strength ontologies that go beyond academic prototypes and the ways to automate ontologising of the existing specifications [71]. In doing this, reuse of existing ontologies is needed to avoid situation with multiple e-business frameworks defining similar document differently. Common ontological building blocks for many situations, such as time ontology, location ontology and measurement unit ontologies should be used when appropriate. In general the relation of things that do not change often should be encoded formally in an ontology. This thesis has been an attempt to provide basis for such efforts.

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