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Knowledge-enabled Access of SMEs to the Electronic Market

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Accesso basato sulla conoscenza al mercato elettronico delle PMI

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Abstract

This thesis is addressed to describe the study carried out in the field of collaboration and information exchange between small organizations (companies and other businesses) possibly belonging to different sectors and located in different regions. The ultimate challenge is providing the intended organizations with easy and cheap web-based services enabling them to behave actively in the global electronic market by overcoming the present technological, cultural and linguistic barriers. This thesis is subdivided into three main sections:

1. Autonomic management of networked small factories

   This section describes the complex behavior of a small factory in a business ecosystem, time by time leader or supplier (or both) in one or more supply chains. A new operational environment, specifically addressed to assure fast reaction to customer orders, has been developed together with its supporting suite of software services and applications. The autonomic approach enables the intended networked small factories to perform distributed planning, individual scheduling and exception handling with no human intervention at run time, while every network member it put in the condition to customise at design time its behaviour with respect to the network.

2. Document exchange in logistics

   This section aims at showing the techniques that have been studied and developed to facilitate document exchange between collaborating companies in the logistic and transport field. It includes the process of construction and use of a multilingual Logistic Domain Ontology and a suite of software tools for format conversion and contents transformation of the exchanged logistic documents, and the mechanism to automatically import/export them from/to legacy systems. The ultimate aim is enabling the actors of the logistic chains, especially SMEs, to collaborate with each having overcome the interoperability and multilingual problem.

3. Adoption of the RFID technology by SMEs

   The last section is addressed to study and experimenting the conditions for a massive adoption of the RFID technology by wide SME communities for identifying and tracking the products on which they perform successive working stages or move to each other. As a by-product, this is intended to create new business opportunities for innovative RFID solution providers. This section describes an interesting pilot case coming from the European project RFID-ROI-SME. This pilot case provide the evidence of the tangible benefits the RFID technology can bring to different sectors and operational conditions.

Sommario

Lo scopo di questa tesi è descrivere gli studi che sono stati effettuati nel campo della collaborazione e scambio di informazioni tra aziende di piccole e medie dimensioni, possibilmente appartenenti a settori differenti e localizzate in regioni differenti. Lo scopo finale di questa lavoro è fornire a queste organizzazioni una serie di servizi web, economici di facile utilizzo che consentano loro di agire in maniera competitiva all'interno del mercato elettronico sorpassando le attuali barriere di tipo tecnologico, culturale e linguistico. La tesi è divisa in tre differenti sezioni:

1. Gestione autonomica delle reti di piccole imprese

   Questa sezione descrive il comportamento di una piccola azienda che opera in un ecosistema di aziende. Operando all'interno della rete, l'azienda può assumere di volta in volta il comportamento di azienda leader, azienda fornitrice, oppure entrambi. Al fine di facilitare l'operato di queste tipologie di aziende in particolare per assicurare una risposta veloce agli ordini dei clienti, è stato sviluppato un nuovo ambiente operativo composto da un'insieme di servizi e applicazioni software. L'approccio autonomico consente alla rete di aziende di poter utilizzare: pianificazione distribuita, schedulazione individuale e gestione delle eccezioni senza l'intervento umano consentendo al contempo ad ogni membro della rete è messo nelle condizioni di modificare il suo comportamento nei confronti della rete stessa.

2. Interscambio di documenti logistici

   Questa sezione mostrerà le tecniche che sono state studiate e create per facilitare lo scambio di documenti tra aziende collaboratrici nel campo della logistica e del trasporto. Questo include tra le altre cose: il processo di costruzione e uso di una Ontologia Logistica con supporto multilingue, una collezione di strumenti software per garantire le opportune conversioni di formato and trasformazione di contenuti dei documenti logistici scambiati, una serie di funzionalità per l'impor-

tazione e l'esportazione automatica dei documenti da/verso i sistemi informativi aziendali esistenti.

3. Adozione della tecnologia RFID da parte delle PMI

   L'ultima sezione della tesi riguarda lo studio e le sperimentazioni sull'adozione massiva della tecnologia RFID da parte di PMI per l'identificazione e il tracciamento dei prodotti che sono sottoposti a successive movimentazioni e fasi di lavorazione. In questa sezione viene descritto un interessante casi di studio derivato dal progetto europeo RFID-ROI-SME. Questo caso pilota fornisce la prova degli effetti tangibili che la tecnologia RFID può portare alle aziende che operano in settori differenti.

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Introduction

As a matter of fact, from the global electronic market perspective SMEs do not exist as a unique (uniform) category. On the one side there are well-structured medium-sized companies having skills and resources to optimise their behaviour and play an active role. On the other side there are small companies with few resources and no possibility to divert them from their core business. While the former often lead supply chains and impose their digital models, the latter must adapt to the models of their main customers and can hardly uptake autonomous ICT and eBusiness solutions.

There are several good reasons to focus the attention of electronic business studies, and the related analysis of collaboration problems, on the category of small companies [7]. Among them it is worth recalling the following:

- Playing a fundamental role in the European economy. Small companies overcome in number the 90% of the European companies and account for more than 60% of employment and GDP. They are the solid backbone of the European economic fabric and, obviously, there is no electronic market without their active and massive participation.

- Belonging to all the industrial sectors. Even in traditional sectors, such as building or footwear, it is possible to identify larger companies that are very well positioned in the electronic market and smaller ones that, although exporting most of their production, are not equipped with adequate communication and collaboration supports.

- Neglected by the principal ICT developments. ICT-based innovation is mainly addressed to medium-large companies while small companies are normally disregarded because of their limited budgets. Simple and cheap ICT solutions, suited to them, only come from local developers that, however, cannot introduce real breakthroughs.

- Showing limited interest to standardisation. Adopting standards in knowledge representation and exchange can facilitate communication and collaboration. However it implies higher costs and a substantial

revision of enterprise and business processes, which are not really understandable and affordable to most small companies.

In general it is costly and difficult to create novel enterprise relations to address new business opportunities in a timely manner. In particular SMEs, due to their lack of ICT solutions, have a great need for adaptable collaboration tools to better cope with the changing business environment. In addition, the globalisation process has often required the development of proprietary, expensive and close software solutions which are sometimes imposed to SMEs without bringing real advantages to them [17]. Finally, an SME can actively participate in the global Electronic Market only when it is enabled to exchange electronic business documents with its partners [2].

Then, a major challenge for many small companies in the next few years is the need to become credible actors in the electronic market, or disappear. While in the traditional market they use to rely upon steady relations with local partners, in the expanding electronic market they risk to be left aside unless they extend their knowledge base and adopt advanced collaboration means. This calls for gaining visibility with respect to potential customers, developing ability to involve suppliers and partners and exchange knowledge with them, and qualifying themselves to collaborate with companies belonging to different sectors and established in different countries.

To this purpose SMEs must be enabled to easily access such an eBusiness space and leave it if no more convenient, save their previous investments in ICT, and be properly supported by tailored business models and suited ICT functions. These ICT functions have likely to take the form of an operational environment hiding the complexity of the underlying technology and be provided to small companies by their reference intermediary organisation, e.g. chambers of commerce or entrepreneurial associations.

This rationale is behind a number of recent EU project aimed at defining the collaboration needs of SMEs, in particular it is work recalling two of them:

- IST-FP6-502512 SEEMSEED Study, evaluate and explore in the domain of the single European electronic market

  Started in January 2004, this project was aimed at meeting the requests from the European Commission to carry out a detailed analysis of the cultural, organisational, legal and technological framework needed to realise a real Single European Electronic Market (SEEM) as fundamental part of the devised Single European Information Space (SEIS). The project ended with the development of a detailed "roadmap to SEEM implementation" that was successively published as a book [20].

- IST-FP6-26476 SEAMLESS Small enterprises accessing the electronic market of the enlarged Europe by a small service infrastructure.

  This RTD project, belonging to the Digital Business Ecosystem cluster promoted by the European Commission, studied the set of basic services that can enable small companies to exchange business documents with partners in an interoperable and multilingual environment [8, 36, 23]. In conclusion of the project, June 2008, the identified services were prototyped as an ICT platform to behave as proof-of-concept and be used to demonstrate the potential of the intended ICT market.

Starting from the outcomes of these projects three new Eu projects were started with the objective to go deeper into critical aspects of the devised themes.

- FP7 243554 eBEST Empowering Business Ecosystems of Small Service Enterprises to Face the Economic Crisis

  This project started in December 2009 lasting 24 monts aims at showing the associated companies the benefits of been involved into a vital and rational business environment where collaborations are frequent and dynamic; at the same time companies remain independent and autonomous but contribute all together to the evolution of their ecosystem as a whole.

- 1CE036P2 INTERREG Central Europe KASSETTS Knowledge-enabled access of central Europe SMEs to efficient transnational transport solutions.

  This project, started in October 2008 and lasting 36 months, aims at exploiting the SEEM concept and the SEAMLESS achievements in the transports and logistics field. Its main objective is establishing a network of logistic intermediaries (brokers) in different European regions, starting from seven nodes already under construction. Each intermediary provides the associated companies with access to optimised transport solutions and the possibility to exchange logistic documents to improve collaboration between SMEs.

- CIP 25043 Rfid-Roi-Sme Pilot RFID Deployments and ROI Studies for SME using Open Source Middleware and Tools

  Rfid Roi Sme is a en Eu project lasting 24 months started in October 2009 lasting 24 months whose main goal of RFID-ROI-SME is to deploy and coordinate 12 European pilots targeting multiple sectors

across different Eu countries aimed at assisting European SMEs in understanding the potential benefits of the adoption of RFID technology. RFID-ROI-SME adopts an SMEs for the SMEs approach i.e. innovative SME solution providers will be deploying pilots for SME end-users.

This thesis reports on the studies carried out in the frame of these projects and on the achieved results.

The research, aimed ad study and prototyping in the field of collaboration and cooperation between SMEs to help them playing an active role in the electronic market, has been divided into three important main topics discussed in the following chapter.

- The first chapter *Autonomic management of networked small factories* present a new approach and a set of software tools developed to help SMEs build and maintain relationship within a business ecosystem.
- *Business document exchange in logistics* presents an innovative solution to provide SMEs with an efficient business document exchange interoperability environment.
- *Adoption of RFID technology by SME* aims at showing the way by which the RFID technology can help improving collaboration and comakership between SMEs belonging to the same supply chain.

Chapter 1

Autonomic management of networked small factories

This chapter presents a new operational environment, specifically conceived for networked small companies, supported by an advanced suite of software services and applications. The ultimate aim is enabling the intended clusters of small companies to perform distributed planning and individual scheduling activities with the purpose of making them more reactive to triggering events and possible perturbations. The proposed model and supporting functions are developed in the frame of the EU-funded FP7 SME 243554 eBEST project, led by entrepreneurial associations from six European countries. The eBEST approach is validated by a number of pilot cases providing interesting feed-back to improve the solution.

Observatories of European SME Associations are expecting a dramatic future for their smaller associates, especially service companies. The probable negative trend of the next five years (2009-2013) could determine the closure of up to 40% must first show to the associated companies that they all belong to a sectoral/regional business ecosystem where their fortunes are strictly interrelated. Then it must leverage on difficulties to induce positive behaviours by favouring explicit and fair collaboration and competition based on shared rules, promotion of best practices and increased cohesion.

A number of studies have been carried out at the European level [16] in the last years on the degree of ICT adoption at small companies, and all of them show an unsatisfactory situation in most of the EU27 countries, especially in Central, South-East and South Europe. This happens although an increasing number of companies have access to Internet, with extending broad-band coverage. As confirmed by the recent European Interoperability Roadmaps [18, 32], two main barriers to ICT uptake are the lack of collaboration services available at reasonable conditions and the need for small companies to change

their present ICT tools.

Today the market of services is typically local but new business opportunities could be exploited e.g. by offering technical assistance in the region to a foreign machine tool vendor or offering an integrated bundle of textile services to external buyers. The concepts of holonic business system and virtual enterprise were promoted in the last years, then small service companies normally know the potential of joining forces to obtain a result which is greater than the sum of their individual results.

One of the most important challenge to deal with is moving the associated companies from a situation where they struggle with each other to survive, towards a vital and rational business environment where collaborations are frequent and dynamic, and companies remain independent and autonomous but contribute all together to the evolution of their ecosystem as a whole. Opening the business ecosystems to the widest electronic market is also useful to achieve higher business objectives.

But because of their limited activity scope they are not in condition to undertake alone the change and remove the present cultural barriers.

1.1 The eBEST project

The eBEST project strategic objective is to push the target companies to adopt beneficial behaviours and open themselves to collaborate with other complementary and even competing companies, providing them suited ICT applications and functions that are absolutely necessary to support this approach and make it becomes operational in a reasonably short time.

1.1.1 Project objectives

Within the framework of the eBEST project the associated company can set-up, experiment and promote the adoption of new collaboration practices within each business ecosystem and across the ecosystem borders, taking advantage of a shared knowledge, an agreed corpus of rules and codes of practice, and a suite of ICT tools to support the intended ecosystem dynamics.

The target companies typically operate by offering to the market their qualified resources, especially skilled personnel and specialised equipment. Their main strength points are high quality of service and intrinsic flexibility and adaptation to market conditions. Their main weakness points are limited investment capability and poor use of ICT tools (especially for eBusiness).

In periods of economic growth service companies proliferate to meet the increasing demand by larger companies that prefer to focus on their core business and outsource service activities. Service companies work in competition with each other to find new customers and maintain the old ones, sometimes using unfair methods (dumping, grey labour and so on).

In periods of economic crisis the demand decreases and this affects in particular those companies supplying services to a limited number of customers and those unable to adapt to the change. In order to survive, service companies need to:

- find new customers
- optimise the use of their own limited resources,
- save effort from market competition
- increase competitiveness

The eBEST project main objectives are:

- Presenting worldwide the individual offers of service companies as well as the integrated offer of the ecosystem as a whole, by exploiting multilingual ontologies and taxonomies.
- Adopting trust-building mechanisms, codes of practice, work assignment rules and performance evaluation criteria to guide the fair coopetition of the target companies.
- Providing the target companies with easily accessible ICT applications and functions to enable collaboration and communication within and outside the ecosystem.
- Validating and improving in real-life conditions the functional coverage and user acceptance of the proposed approach, methodology and ICT functions.
- Deploying the project results to the largest audience so as to reach a critical mass of user companies in the shortest possible time after project completion.
- Spotting opportunities to improve sustainable technological innovation and collaboration within ecosystem by promoting the community concept and practice.

The eBEST project addresses small companies providing services to other businesses, often by subcontracting, in different industrial sectors. In general the intended service companies perform added-value activities in the intermediate phases of the value chain and/or in the repair and maintenance phases. Examples relevant to the project are:

- Textile sector: prototyping (of textile or knitted goods), weaving, finishing, ironing.
- Construction sector: heating, hydraulic and electrical plants, painting, maintenance.
- Mechanical sector: surface treatment, machining, assembling, repair, maintenance.
- ICT and media sector: setting-up and maintenance of voice and data networks, printing.

1.1.2 Collaboration practices

By examining in detail the project objectives, the first critical aspect to face is promoting new collaboration practices to make the business ecosystem and its member companies gain competitiveness in the global (electronic) market. This implies the definition of a collaboration framework that each ecosystem will interpret and adapt to the specific contextual conditions.

Collaboration habits and needs

Although generically perceived, the collaboration potential of small service companies belonging to a business ecosystem is not known in the required detail. It certainly depends on variable factors such as industrial sector, company nature and size, local economic fabric, norms and regulations. Of course, the reference association is in the best position to understand habits and needs of the associated companies. However, further investigations are required to assess in depth the specific situations. This knowledge is the first measurable result of the eBEST project. It consists of business and technical specifications to be taken as basis, on the one side, for the definition of the devised collaboration framework and, on the other side, for the expression of requirements on the ICT applications and functions to develop.

Trusted operational scenarios

The ways how the intended companies can interact and collaborate within and across the boundaries of their business ecosystems – on a full trust and confidence basis, including regulatory and contractual issues – are formalised and represented as main operational scenarios. These scenarios constitute the eBEST project detailed vision and perspective, and represent another of its measurable results. The scenarios are defined starting from habits and needs and taking into account the information and docs the companies are used to exchange. However, they are not limited to express what presently happens (or is considered a possible improvement), but are intended to imagine the eBEST environment where the new practices are finally adopted to provide the target companies with other business opportunities .

New organisation and business models

The third component of the eBEST collaboration framework deals with understanding which medium-term changes could (should) be introduced by a full deployment and use of the eBEST approach. It means in the first place studying the impact of the collaboration practices and ICT support tools on the work organisation of the target companies, and on the associations themselves. This will lead to define business models suited to benefit of the dynamic collaboration opportunities offered by the innovative environment, representing another measurable result of the eBEST project. They will provide the basis for a wide deployment of the proposed methodology and ICT support tools at each of the involved business ecosystems and towards other candidate ecosystems.

1.2 State-of-the-art & innovation Area

In order to pursue the vision of small companies playing an active role in the global electronic market it is necessary to innovate in a number of fields in a short period. This is feasible only if the research is based on a huge amount of background knowledge. Part of this knowledge comes out from three important RTD project that offer a basis for the developed research:

- IST-FP5-20276 PROVE SME. Web-based tools supporting operation of SME networks, with particular attention to enable customers and suppliers in sharing information on order progress. Part of these tools were engineered into the KET EE (Extended Enterprise) commercial product.

- IST-FP5-25125 SOSS. Web platform to help matching demand and offer of small services for home, person and leisure at the metropolitan scale. The SOSS project led to the definition of easy but effective mechanisms to represent the intended services and their supply conditions.

- IST-FP6-26476 SEAMLESS. Platform of web applications and services to support partner search as well as negotiation and collaboration between small companies acting in different sectors and European regions. The SEAMLESS technology is very simple to adopt and use and ensures automatic format conversion and content translation of the exchanged documents. Then, the technical work of the eBEST project is more focused on adapting, integrating and engineering already prototyped solutions rather than starting from scratch to study and design new solutions. The expected solutions belong to two main categories, namely an innovative collaboration framework and the ICT platform that can support its adoption and operation, as detailed in the following.

Let's now focus on the international state-of-the-art in three important innovation fields (namely collaboration model, service oriented architecture and semantic interoperability) and represents the (limited) extent to which the research findings are practically adopted in the (few) existing solutions.

1.2.1 Collaboration model

A growing corpus of literature has examined in the last fifteen years the formation of inter-firm linkages, the dynamics of relationships among network participants, and the effects of collaboration on firm performance and development. However, because of the polarisation of current studies on some specific dimensions, many issues are still insufficiently explored. First, the literature focuses on RTD collaboration and overlooks the strategic alliances aimed at improving already existing businesses.

This bias is partly due to the effectiveness of networks in reducing uncertainty for participants in risky projects that often motivate RTD alliances. And in regimes of rapid technological change networks prove to be a better source of innovation than individual organisations.

The second polarisation is on the type of actors examined in empirical studies. The available evidence focuses on alliances among large players or on local networks of socially and economically interlaced actors such as small and medium enterprises (SMEs) in industrial districts. On the contrary, empirical evidence on voluntary collaboration among SMEs is still comparably reduced. Voluntary networks, defined as "a collection of relationships

that binds a group of independent organisations together", represent a special form of strategic alliances whose distinctive characters are the long-term nature of the commitment, the agreement upon compatible goals, the collaboration to achieve otherwise precluded benefits, and the independence of the participating members. SMEs could derive substantial benefits from participating in networks aimed at improving already existing business, achieving economies of scale and rationalising existing processes.

However, networking among SMEs may be hampered by threats such as the risk of opportunistic behaviour or the lack of qualified skills to manage the complexity of an inter-organisational cooperation.

A comprehensive state-of-the-art representation in this field comes from examining rationale, approach and results of the recent, well-known, EU funded FP6 IP project 506958 ECOLEAD "European Collaborative Networked Organization Leadership Initiative". Its main limitations are here briefly recalled:

- It focuses on steadily networked organisations, whose size and nature allow diverting skilled internal resources to manage the complex problems arising from a systemic orientation to networking.

- It imposes the full use of the ECOLEAD-prototyped collaborative business ICT infrastructure so that all the transactions within the collaborative network must be digital and via computer networks.

- Although claiming the ECOLEAD solution is affordable to SMEs it requires deep changes in the networked organisations on the way they operate, both at intra- and inter-enterprise levels.

Voluntary collaboration

The eBEST project is clearly addressed to realise the conditions for voluntary collaboration (or networking) among small companies not belonging to the same supply chain or industrial district, a situation that is poorly studied in the literature and experimented in practice.

This condition will be characterised by the following guidelines:

- Every company is free to enter and leave the organisation at any time with no restraints. When registering it has available a private workspace and the functions for internal planning and external relations. When leaving it can save its data and export them to the legacy system, if existing.

- Every registered company accepts and shares with the other members a set of simple rules (that can be customised in the different ecosystems) for fair coopetition according to the "equal rights model"

- Every company is free to decide (and modify) the quality of its collaboration with the other ecosystem members. It can use the new organisation just to gain visibility, it can occasionally search for partners, it can participate in or even lead one or more company clusters.

- When participating in a cluster every company remains free to dynamically define and update the service capacity it shares with the partners. This satisfies its willingness to collaborate in full autonomy, and the possibility for the cluster to show a stronger image to potential customers.

Trust building

The success of a collaboration model is strongly conditioned by the possibility to create the needed level of trust within the business ecosystem and in relation with the external world. Then trust building assumes a quite critical role and will receive particular attention that will lead to specific innovation as detailed in the following points:

- Every company shell feel confident that its transactions are not intercepted or modified, sellers and buyers own the identity they claim, the transactional mechanisms is secure and legal. Possible barriers are absence of trust marks, disputes, lack of information about partners and contracts.

- Fundamental is the intermediary role of SME Associations that will behave as trusted channels for mutual identification and reputation between parties sharing common goals and values, and will be direct or indirect providers of the technology.

- A further help comes from sharing the knowledge base made of a common data model and vocabulary that was proved to be potentially effective by the already-cited SEAMLESS project.

- Finally, the impact of the trust services created for the the whole platform, especially related to identification, reputation and document translation, shall be tested at the wide scale to ascertain if they are suited to overcome the traditional distrust that is found in existing business networks.

1.2.2 Service oriented architecture

Service Oriented Architecture (SOA) is a broad research area that is demonstrating important benefits and advantages in enterprise applications, eBusiness and service networking. The SOA approach attracts industry attention by providing a flexible and cost effective way to re-use functions captured in loosely coupled business-oriented services and develop new ones.

Although several SOA definitions have been provided in recent years, the only OASIS organisation is developing a reference model that can be applied to both business domains and technology. According to this model "SOA is a paradigm for organizing and utilising distributed capabilities that may be under the control of different ownership domains". A number of service orientation characteristics – open architecture and standard based, modularity and scalability, flexibility and reusability of services – make the SOA approach a suitable option for advanced provision of ICT solutions including order acquisition, planning services, document exchange, that are typically dynamic, multi-actor, multi-service evolving conditions.

Recent research projects have faced the question of how to exploit the SOA concept and technology to provide companies, especially SMEs, with ICT services suited to meet distributed business process requirements. Three of them, funded by the EC and grouped into the Digital Ecosystem project cluster, perfectly summarises the state-of-the-art in this field:

- The first is the FP6 IP project 507953 DBE "Digital Business Ecosystem" that studied and prototyped a new open-source distributed SOA infrastructure enabling software producer SMEs to fast develop software services making companies belonging to business ecosystems go digital.

- The FP6 STP project 027178 VISP "Virtual ISP of the Future" is in turn intended to develop a software platform enabling a cluster of SMEs to operate as a single business entity for the production of tailored Internet Service Provider solutions adapted to local business needs.

- Finally, the FP6 STP project 026476 SEAMLESS "Small Enterprises Accessing the Electronic Market of the Enlarged Europe by a Smart Service Infrastructure" is the only one focusing on software services enabling small enterprises to run dynamic collaborations in the electronic market.

In synthesis, much attention is normally devoted to introduce new tools for SOA implementation, e.g. for service composition and execution environment, and very often the ultimate aim is supporting the work of software

developer or provider SMEs. The weak point remains the still poor development of actual software services, especially for small companies, if compared with the huge effort spent on technology.

In order to fully it's important to provide small service companies with a very new combination of ICT functions normally available only to larger companies. This means that the emphasis is on the SOA concept and the operational aspect of the service platform, rather than on SOA technology and implementation tools.

Conceptual viewpoint

It is interesting to observe that the business structure of an ecosystem populated by collaborating service companies is itself a service oriented architecture. As a matter of fact, every company can be seen as an autonomous server executing a variety of labour-intensive (non-ICT) services under customer or partner requests expressed by exchanged messages and documents. The SOA metaphor extends to other aspects such as the possibility, for the intended companies, to carry out synchronous and/or asynchronous operations in relation to the received requests, to change the service execution mode while keeping the service interface, to combine their services into compound initiatives whose execution requires a suited orchestration capability. The interdependence between a distributed business model and the supporting service oriented architecture is strongly emphasised by the business process management community. The eBEST approach is indeed an original materialisation of this stimulating intuition, and will give experimental evidence to the conceptual components shared by business architecture and service oriented architecture. In fact, the design of the eBEST platform will take this possibility in due consideration since it helps modelling the collaboration context and specifying in detail the needed support functions. The service development cycle – business modelling, service specification, development – was proposed but never used at a significant scale, like it will happen with eBEST.

Operational viewpoint

It is typical for a distributed collaborative business environment to involve several business entities at the same time and provide each of them with a combination of ICT functions covering the identified needs. More precisely, the collaboration scenario will include ICT functions that besides executing user requests can communicate and interact with each other. Then, from the user viewpoint the eBEST platform will show a suite of software applications

realised on top of layer of ICT services including networking, communication, storage and document translation functions. Innovation factor for such applications is ease of use and the capacity to hide the underlying complex technology according to a Software-as-a-Service approach, the paradigm of Future Internet. In synthesis, the eBEST project is intended to realise a full and consistent development of the SOA model in a real and practical case, exploit the flexibility of the web technology to create a layer of primitive functions, build easy user-oriented applications on top of them, and make the access to the service layer easy to further, future application developers. Consequently, the project will become a living example for the promotion of an advanced open-source software development and provision model, in the perspective of a future autonomous development and customisation of the eBEST platform by the single partner association as well as by other associations that will decide to follow by adopting and adapting the proposed solution.

1.2.3 Semantic interoperability

This third innovation area is justified by the intention to provide the eBEST platform with a technology assuring the possibility, for the user companies, to import/export business documents from/to their own information (legacy) systems and to exchange documents with customer and partners characterised by different data models and languages. More precisely:

- Import/export. Every document moved from the legacy system of a user company to the eBEST platform, and vice versa, will undergo an automatic transformation process from the origin data model to the destination data model.

- Document exchange. Every document exchanged through the eBEST platform with a customer or a partner will undergo a similar transformations process plus the automatic translation of contents between the origin and destination languages, if different.

This requires the construction of a Service Sector Ontology – a reference data model and multilingual vocabulary for that specific application domain – and its use to "annotate" (or "map") the concepts of every interesting legacy systems and to cross-reference the terms from the origin language to English as "lingua franca" up to the destination language.

The generic WordNet lexicon, the UNSPSC and the eCl@ss product/service standard taxonomies, the UBL data model for business documents, all them represent good starting points for the construction of the

Service Sector Ontology. What is needed is a strong focus on the only concepts and terms that are actually used for communication and doc exchange in the devised collaboration environment.

Interesting examples of domain ontologies aimed at supporting collaboration between small companies are the global ontology developed in the frame of the already-mentioned SEAMLESS project, to integrate the textile and building & construction sectors, and the studies on semantic modelling and document exchange in the logistics and transport sector.

Although the document processing steps ensuring the required level of interoperability are well known, very few examples of business document transformations, including simultaneous structure conversion and contents translation, exist to be taken as reference. And the challenge is made even more critical by the need to hide the process complexity under an easy and simple user application.

The eBEST project will contribute to the advancement of knowledge and technology in the field of semantic interoperability with two main actions, respectively addressed to the joint construction of the service sector ontology and to the practical implementation and deployment of a so-far experimental approach to document structure conversion and contents translation. *Service sector ontology* The service sector ontology is a multilingual data model and vocabulary specifically oriented to facilitate coopetition in the service sector. At the time being there are no published examples of service sector ontologies. The eBEST project will work on the experience gained in the SOSS and SEAMLESS projects and deliver, together with the ontology, the needed functionality for ontology construction and evolution:

- RTD performers in the eBEST consortium will start identifying the service-related concepts and terms in standard taxonomies and in the basic suite of business documents to be exchanged by the intended companies, and realise with them the core service sector ontology.

- This core ontology will be made of two main parts: the reference data model for the eBEST business documents and an embryo of vocabulary (terms and definitions, in English as lingua franca) expressing the fundamental domain knowledge.

- After that, every user will be asked to translate such terms into its own language and propose further terms to cover missing concepts. The result will be a spontaneous growth of the ontology, regulated by RTD performer, up to the achievement of a steady condition.

Document transformation

In the eBEST perspective document transformation means the simultaneous execution of document structure conversion (from / to the eBEST reference data model) and document contents translation (from / to the reference English vocabulary). Once again the solution will be inspired to a preliminary experiment carried out in the frame of the already-cited SEAMLESS project.

The significant technological progress that will be introduced by the eBEST project is in engineering the experimented techniques and transforming them into efficient ICT services with a very high degree of transformation success and the possibility to be easily adapted to other kinds of business documents than those taken as fundamental. More precisely:

- The editing operation of (proprietary) data models and their mapping onto the eBEST reference data model will overcome the difficulties arising from representation in research-related languages – such as OWL – by introducing easy drag & drop user interfaces.
- The run-time document transformation function will be automatic and completely transparent to the sender (receiver) user who will maintain its own legacy system and be relieved by the need to know the data model and language of the receiver (sender) user.

Semantic interoperability and Document transformation will be widely discussed in chapter 2.

1.3 Business ecosystem architecture

The eBEST model applies to every business ecosystem whose companies are aggregated by a geographic, linguistic, sectoral or associative criterion, or a combination of them. Within the ecosystem companies form steady collaborative networks (called clusters) made of complementary, and sometimes even competing, nodes. In each of these networks companies maintain their full individual autonomy; at the same time they aim at showing a unique image of their cluster to potential customers.

Then, from the functional viewpoint the cluster can be seen as a network of nodes distributed on the Internet that publish services and exchange information among them and with external customers. In detail, eBEST realises two main kinds of nodes, namely company node and cluster node:

- Company node. This provides the functions needed by every single company in the network. The company node holds its own data and

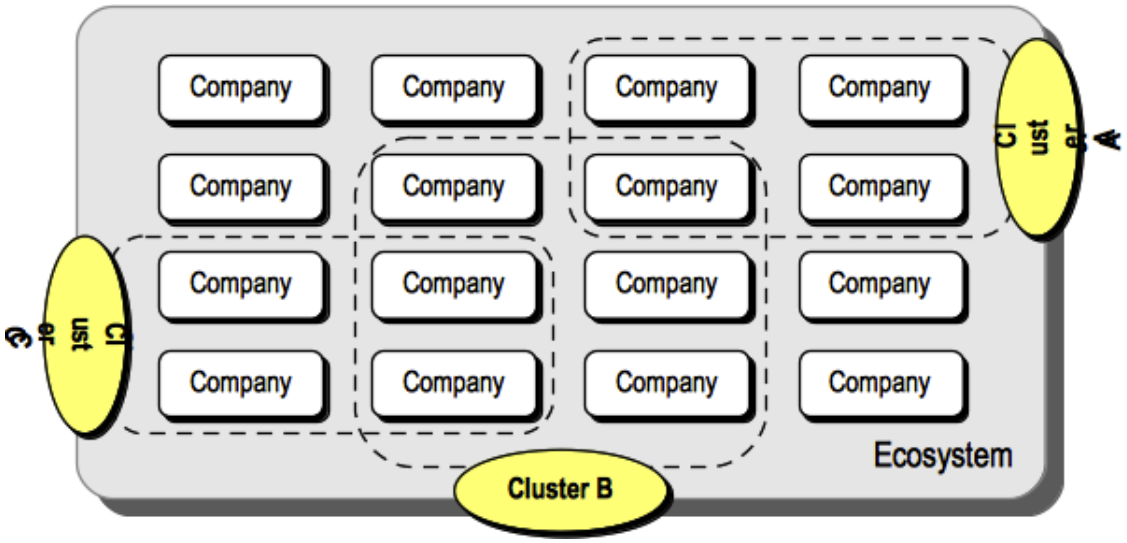

Figure 1.1: eBEST model overview with company and cluster nodes

exposes services and applications for using such data and exchanging them with the other nodes in the cluster.

- Cluster node. This provides the functions needed to present the cluster as a unique entity. They include the integrated offer of the cluster and the possibility for customer to register at that cluster and issue requests for quotation and orders.

Figure 1.1 shows this model, including the possibility for a company of belonging to two or more different clusters. Besides presenting its network to external customers the cluster node supports the communication between networks thus enabling candidate partner discovery and cluster-to-cluster collaboration.

Two company nodes do collaborate directly (that is, without passing by the cluster node) if belonging to the same network. Instead, if they are in different networks they must first discover each other by passing through the respective cluster nodes. In other words, the cluster node is also enabled to broadcast (delegate) partner search queries to the other cluster nodes until the needed information is collected to establish a direct communication between the two company nodes.

Concerning the technology, the eBEST communication infrastructure is based on a SOAP layer working on top of a P2P layer. The P2P layer is intended to provide services for discovery and announcement of nodes. To this purpose it links all the companies of a cluster seen as nodes and, if any,

the other cluster nodes so as to maintain the general system architecture open. Thus nodes know each other, directly or by cluster nodes, and are informed at run-time of which nodes are on and which are off.

1.4 Software platform

The fast and full adoption of the new collaboration practices calls for developing a suite of ICT tools to be made available to the target companies by their associations.

The final product of the eBEST project is then a software platform (available as functions of a web-based platform) and the knowledge to use it at best in different operational conditions. This is indeed the result expected by the participating SME-AGs and SMEs, for which they will pay the contracted RTD performers. In fact the eBEST platform will meet all the above-identified objectives in an easily adaptable and simply usable way.

1.4.1 Platform architecture

The figure 1.2 shows the eBEST platform architecture. The platform will normally be installed at the SME-AG (or at its reference ICT service provider) and made accessible to the associated companies after their registration as users. It is worth recalling that user companies are of two types depending on whether they behave individually or as lead of one or more clusters:

- Individual user companies. They use the eBEST platform functions to improve their organisational capacity and optimise the use of internal resources. These individual functions are sufficiently beneficial to the user companies to justify alone their adhesion to the eBEST system.

- Cluster lead user companies. Besides behaving as individual user companies, cluster leads need further functions to coordinate and govern the collaboration activities. A company can lead a cluster and be led in another cluster. The access to the coordination functions is an additional and valuable reason for cluster leads to adhere to the eBEST system.

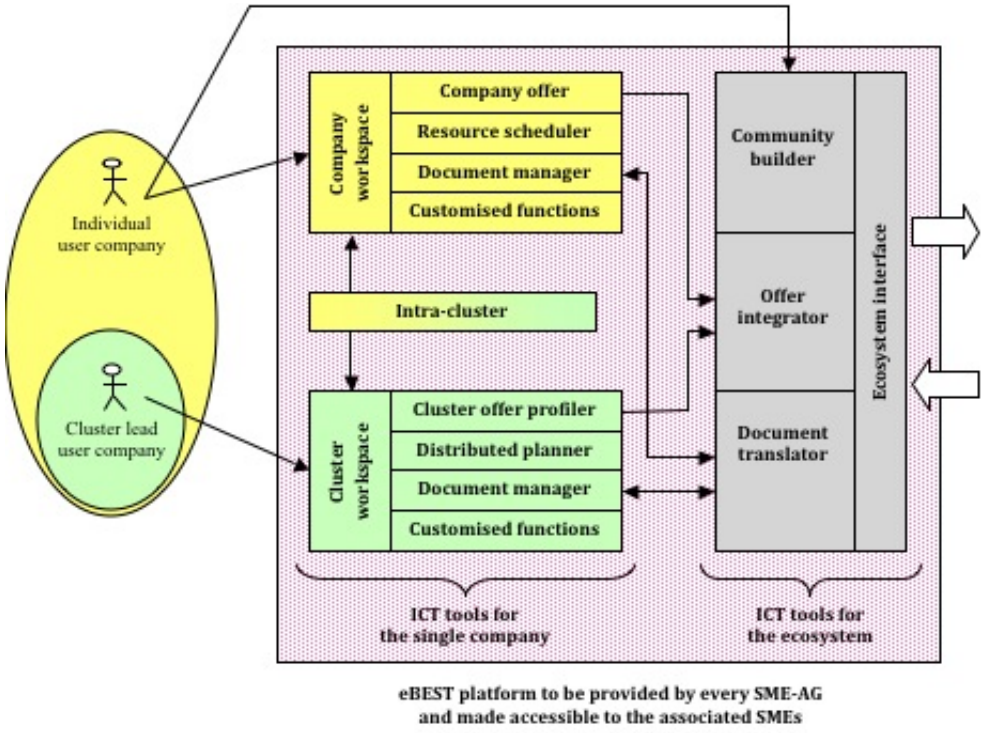

Figure 1.2: eBEST software platform

Some comments:

- As soon as a company registers as platform user it has immediate access to its protected workspace and to the functions corresponding to its role (individual user, cluster lead). These services will be invoiced by the SME-AG likely as a monthly fee.
- When behaving as cluster lead the user company plans tasks and assigns them to the selected partners (sub-contractors). This is done through the intra-cluster communication functions, which will be used in turn by those partner that lead themselves a lower-level cluster.
- The ICT tools for the single company can include customised functions. These are additional functions that every SME-AG can ask for to its supporting RTD performer, or to third parties after project completion, in order to cope with the peculiar needs of that ecosystem.
- The ICT tools for the ecosystem intended as a whole are very powerful but complex. However, their complexity is hidden to the user companies under the easy user interface of the visible ICT tool so as to

facilitate user acceptance of the eBEST platform. In addition to the eBEST software platform the RTD performers will provide the SME-AGs with the knowledge needed to facilitate its exploitation. This knowledge is made of three main components:

- Knowledge to promote the adoption of the eBEST solution at the associated companies and at other (linked) associations. This is mainly constituted by dissemination materials and, particularly, by the documentation of good practices and pilot experiments.

- Knowledge to start-up and operate the eBEST platform at the single SME-AG. It includes manuals and technical documentation of the platform, instructions for third-party developers, the domain ontology and training materials for trainers and trainees.

- Knowledge to advice the user companies on how to take the maximum benefits from the eBEST functions (and invoice for this support). It includes analysis guidelines as well as proposals for the new suited organisational and business models.

1.4.2 ICT tools for the single company

- Self-profiling and service offer coding. Every user company defines its own profile in terms of general data (nature, size, turnover, location, etc.). Moreover, it can classify and code its own offer of services by exploiting a simple but effective model linking the company activity to a service taxonomy and specifying the offered services in terms of families, options and supply conditions.

- Management of company clusters. Some companies can decide to establish a steady collaboration by joining forces and work capacities and offering to the market compound services. The cluster lead company is provided with functions to coordinate the cluster, e.g. by splitting up the incoming quotation requests or orders into the tasks to be assigned for execution to the member companies.

- Answering requests for quotation. When a request for quotation is received the company performs an infinite capacity planning of the implied activities to compute the quotation. If the request for quotation comes from a cluster lead it will be its task to merge together the quotations generated by the member companies into a unique document to be eventually sent to the customer.

- Order acquisition and scheduling of resources. When an order is received the company performs a finite capacity planning of the implied activities according to the actual state of resources (manpower, equipment) and schedules their use. If the internal resources are not sufficient the company tries to subcontract activities to business partners by triggering a similar (nested) contracting process.

- Exception handling and re-planning. Whenever an exception occurs during plan execution (e.g. order cancellation, activity delay, loss of materials) the plan must be stopped and the remaining activities re-planned with the main aims of damping down the perturbation and optimising the use of internal and external (subcontracted) resources.

- Activity logging and performance evaluation. While performing the scheduled activities and exchanging business documents, the company can log their occurrence (e.g. just occurrence type and time) so as to collect performance measures. A set of statistical functions is made available to derive efficiency indications on which basis e.g. cost and led time estimations can be periodically revised.

- Business document import/export. Each company can use the eBEST tools as a sort of basic ERP system by storing its data and documents in the assigned workspace. If the company is already provided with a legacy system it could migrate business documents to/from the eBEST platform by a proper import/export tool assuring the automatic transformation of document formats and contents.

1.4.3 ICT tools for the ecosystem

- Registration on the eBEST platform. A company can become member of a business ecosystem by simply registering on its eBEST platform. Then it can participate in setting up one or more clusters that have in turn to be registered on the platform. As soon as each company or cluster is registered it has full access to the platform workspace and functions, and remains free to leave with no restraints.

- Partner search within and outside the ecosystem. Every registered company can search for potential partners within the business ecosystem by expressing queries on the desired profile data, service offers and (dynamically changing) supply conditions. In presence of other ecosystems the query is forwarded to them and the incoming results are merged into a unique list of candidate partners.

- Individual and integrated offers. The eBEST platform assures an effective external visibility by a proper (multilingual) user interface showing an integrated view of the entire ecosystem offer and the possibility, for the potential customer, to go deeper into the specific offer of a single company or cluster and then submit requests for quotation.

- Business document conversion and translation. A number of business documents are exchanged with customer and between partners. While the latter are facilitated by the adoption of a common document model, the former introduce problems of structure conversion (like for import/export) and language translation. This problem is overcome by a specific document transformation service.

- Constitution and operation of the ecosystem community. The deployment of the eBEST approach requires the possibility for the ecosystem members to exchange opinions and knowledge, identify and negotiate collaboration opportunities, compare conditions. The project will provide the needed functionality which is expected to take advantage of the social networking model. It is worth observing that the proposed functions are a schematic example of the suite of ICT tools the eBEST platform will provide. The real functions to develop will be designed for meeting the practical company needs represented by the partner associations and will take into account the possibility to have different collaboration models in the different geographical and operational contexts.

1.5 Implemented software modules

As already described the eBEST project general objectives are attracting customers to work with the clustered companies, facilitating companies to collaborate with each other, and enabling associations to foster the devised innovation. To this purpose the project develops three interlinked software environments as depicted in figure 1.3:

- Ecosystem shaping. It offers the functions that every association can employ to promote the constitution and characterise new company clusters, and improve their image over time, out of the ecosystem of its members.

- Collaboration framework. It offers the functions that the single cluster can use to seize business opportunities, possibly identified by the asso-

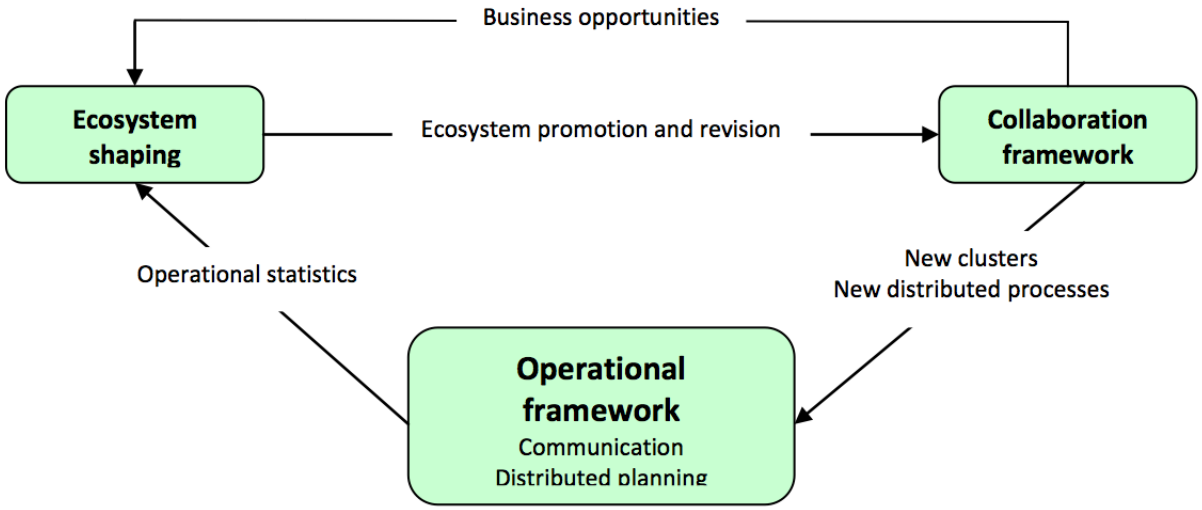

Figure 1.3: eBEST model overview with company and cluster nodes

ciation, and to prepare itself by designing the corresponding distributed processes.

- Operational framework. It provides customers, companies and company clusters with a suite of operational functions enabling them to communicate, plan the distributed processes and schedule the internal resources.

My research activity has been focused onto the realization of the operational framework. In order to understand them it is worth underlying since now that a target company may belong to two categories depending on whether it leads a cluster or is a supplier member:

- Cluster leader. It needs functions to coordinate and govern the collaboration activities of the cluster members, including cluster offer presentation, customer order acquisition, distributed process planning and monitoring, distributed exception handling.

- Supplier. It needs functions to optimise the use of its internal resources in the cluster context, including quotation preparation, leader order acquisition, scheduling of internal resources, internal exception handling.

Of course, the operational framework takes into account that a company can be at the same time leader and supplier member of a certain cluster,

or even it can lead a cluster and be led in another cluster. Moreover, the eBEST software platform must interoperate (meaning: import/export business documents) with the information systems already existing at the cluster member companies so as to safeguard their previous investments in ICT and minimise the expected resistance to change.

1.6 Collaboration scenario

Imagine a business ecosystem grouping small companies that are specialized in complementary manufacturing activities as producers, subcontractors or suppliers and are used to participate in several supply chains. Imagine now that one of them is reached by a customer order (similarly for a request for quotation). This event will trigger a succession of consequent actions that is worth recalling here briefly:

- The receiving company must activate its supply chain, if any, as leader (see Figure 1.4 left). To this purpose it will carry out a planning activity to decide which tasks are better performed internally, which are conveniently assigned to partners and which are the preferred partners in those specific cases.

- According to this plan the leader company will communicate the assigned task to each of the involved partners. If one partner is leading in turn a supply chain it will carry out a similar planning activity with the involvement of further partners to fulfill the received task (see Figure 1.4 right).

- The result of this distributed planning process is the configuration of the working supply chain for that customer order. The configuration will be static if partners are predefined for every task to assign; it will be dynamic if partners are selected within constellations of competing companies [4].

- As last step each involved company, including leaders, will undertake a scheduling activity for the tasks to perform internally in order to allocate and book the required resources on routings and phases. This is also the step for each company to determine lead time and cost of the assigned task.

The propagation of the distributed planning process across the ecosystem is intended to select the suited supply chain members to fulfill that specific

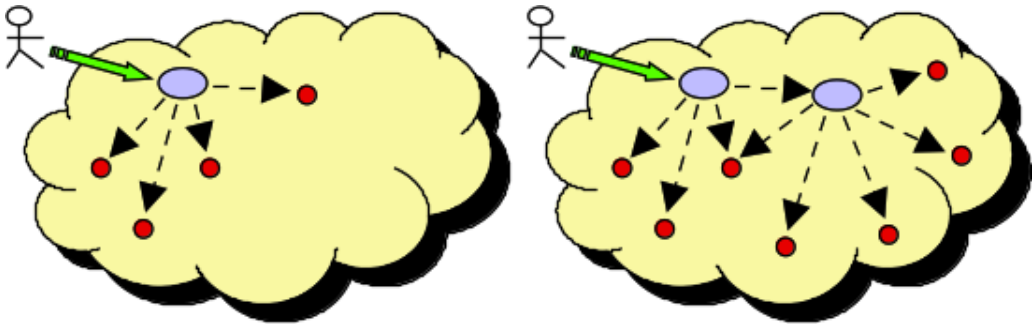

Figure 1.4: A company in the business ecosystem is reached by a customer order. As a consequence it activates its supply chain (left) by sending the proper requests to its members. Every member with its own supply chain will activate it in turn (right).

customer order and commit them to participate in the forthcoming execution of the planned and scheduled tasks. The process will end when all the devised activities will be successfully covered and this will produce proper changes on the work calendars of the allocated internal resources at each selected partner.

Later, during order execution, the distributed plan will be put in action and the tasks progressively carried out by the selected companies. Transports will be performed whenever the materials need to be worked in different locations. Should a task be affected by problems (delay, loss of materials) this will trigger a replanning effort for damping down the perturbation while propagating it to the other partners.

1.6.1 Autonomic approach

Before introducing the proposed autonomic solution to distributed planning and scheduling problem it is worth introduce the autonomic approach.

The Autonomic Computing Initiative (ACI) was launched by IBM in 2001 [24] as a self-management capability for facing the rapidly growing complexity of distributed computing. The essence of autonomic computing is automating low-level management tasks. The adjective is taken from the autonomic nervous system of the human body that controls important functions without any conscious intervention.

More recently, the Autonomic Network Architecture (ANA) integrated project co-funded by the European Commission [15] moved the focus to network organization based on the application of the autonomic principle. The

ultimate goal was the dynamic adaptation and re-organization of the network according to the working, economical and social needs of the users. The project results confirmed the application potential of such novel network architecture. In an autonomic system the human operator takes on a new role: he does not control the system directly, instead he defines general policies and rules that serve as an input for the self-management process. For this process the ACI defines the following four functional areas:

- Self-Configuration. This means automatic configuration of a subset of nodes in a certain zone of the network. This function is then strongly localized and includes the addition of nodes as well as the creation and cancellation of relations between nodes in order to meet the defined requirements.
- Self-Optimization. This means automatic allocation of resources in the single node to ensure an optimal functioning with respect its expected behaviour. The optimization algorithm is driven by performance objectives set during the self-configuration phase and by policies set by the node responsible.
- Self-Healing. This means automatic discovery and correction of faults. Self-healing methods are triggered by events or exceptions occurring in a single node or by changing requirements. Normally self-healing propagates through the network and impacts on configuration and optimization.
- Self-Protection. This means proactive identification of and protection from defaulting conditions or intentional attacks. Since in networked small factories the main cause of faults is the negative behaviour of certain nodes, self-protection is mostly based on evaluation of past performances.

1.6.2 Distributed planning

Instantiating the supply chain to fulfill the operational needs triggered by a customer request is a complex task to which much research effort has been devoted in the last years from the methodological [38] and implementation [25, 35, 19] viewpoints. Our approach exploits the autonomic concept and model with the ultimate aim of relieving small companies from repeatedly planning tasks and negotiations with partners. To this purpose it is worth analyzing what happens when a customer order for the supply of a certain quantity of product X reaches that company. In general, the process P(X)

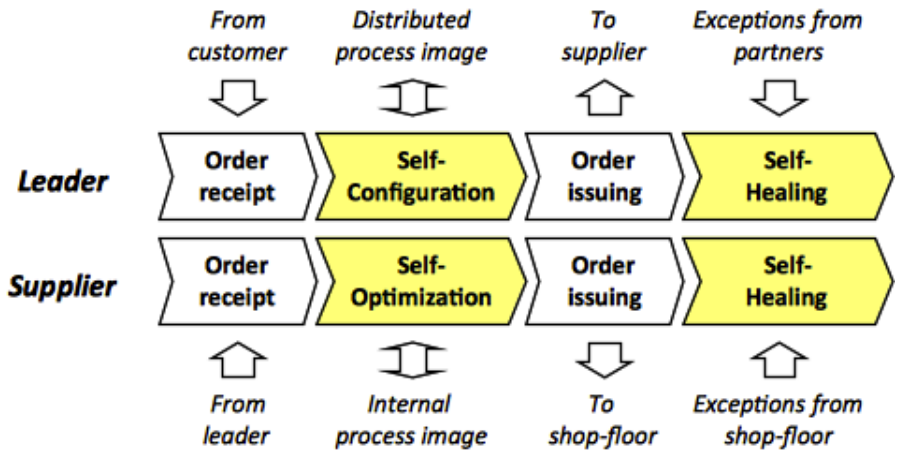

Figure 1.5: The full autonomic process is triggered by the receipt of a customer order and leads to planning the supply chain, issuing purchase orders and scheduling the internal resources.

for manufacturing product X includes a number of activities linked to each other by sequence, parallelism and alternative relations (1.6).

- Scan process P(X) left to right and identify A1 as first activity. Since A1 devises one or more candidate suppliers Sj, possibly including the "make" option, each of them will be informed of the possible involvement in A1 starting from time T1 and asked to foresee its respective lead time T1j and cost C1j.
- Consider now the upper branch and its first activity A2. Having in turn one or more candidate suppliers Sk, every pair (Sj, Sk) must be

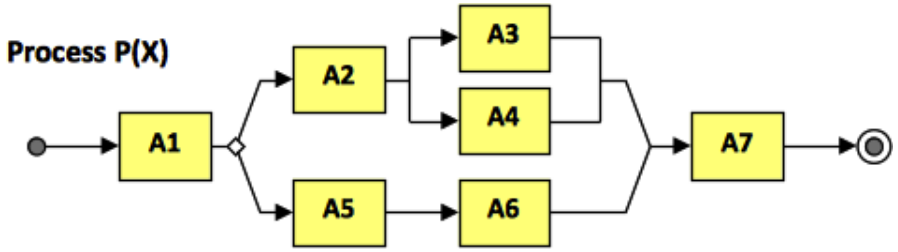

Figure 1.6: Example of distributed manufacturing process. It includes seven activities where A3 and A4 are executed in parallel while the A2 and A5 braches correspond to alternative paths

considered in order to estimate time Tjk and cost Cjk for moving materials (if any) from the one to the other. The starting time T2 for activity A2 is then given by T1+T1j+Tjk.

- With the following parallel activities A3 and A4 the number of combinations increases further but the procedure does not change: each candidate supplier of every activity is informed of the estimated start time for that activity and is asked to foresee time and cost of its possible contribution to process P(X).

- At the end of this procedure the algorithm has available a complete estimation of all the feasible process instantiations for that order, and detailed measures of intermediate and final lead times and costs. It can then choose the best one according to the established policy (e.g. the fastest, the cheapest, etc.).

The algorithm can be simplified to reduce the number of combinations to consider. To this purpose the policy could include some heuristics for the early selection of candidate suppliers or choice among alternative paths. In any case, reaching the optimal or suboptimal solution requires an intense message traffic with candidate suppliers that is hardly managed in a small company by means of not automatic tools. This problem is technically overcome by providing every company with automatic self-configuration and self-healing functions based on the described planning algorithm. The human intervention remains to identify interesting partners and define the policy that such a company intends to autonomously apply for driving the process instantiation phase and the exception handling phase. The benefits are important:

- No resource must be diverted from the company core business to manage real-time interactions with partners.

- The final response to the customer and the assignment of tasks to the selected partners are fast and accurate.

- The reaction to exceptions is also computed accurately, in a very short time and with minimal consequences.

It is worth observing that these benefits are particularly important to small companies, while larger ones are normally provided with resources letting them manage more easily the process configuration and re-planning phases. In other words, the smaller is a company the greater can be its advantage in adopting a full autonomic solution. Of course, other problems arise e.g. the

need to build confidence towards an approach that apparently subtracts the operation control to them.

The functionality of a company node depends on the role of that company in the collaborative network. In case it behaves as a leader it has access to the functions that are needed to interact with customers, plan the execution process, assign tasks to selected suppliers and keep the execution progress monitored. The eBEST project has developed a distributed planning function to be particularly reactive and suited to handle the frequent exceptions occurring in the network.

At design time the leader company defines the distributed processes it is asked to coordinate. As usual the process is split into activities, precedences are established between activities, and every activity is properly modelled and associated to the supplier(s) in the cluster that can execute it. Core activities are normally interleaved by auxiliary activities such as on-site requirement collection or final installation and, notably, transports of materials mirroring the condition of a geographically distributed virtual enterprise.

At run time the leader company activates the distributed planning function whenever it receives a request for quotation or an order coming from a customer. The leader company must in fact activate its network and to this purpose it performs a distributed planning activity to decide which tasks should be conveniently carried out by itself, if any, which tasks should be better assigned to suppliers in the cluster, and which are the preferred partners to whom those tasks should be assigned.

Then, the leader company submits to each selected supplier the proposed tasks and the supplier replies with its estimation of execution time and cost. Those suppliers leading in turn a cluster will carry out a similar planning activity with the involvement of further companies to fulfil the proposed tasks (see Figure 1.4).

According to the received answers and applying its own planning policy rules the leader company selects the best configuration of the working supply chain for that customer order, and confirms the assigned task to each of the involved partners. The configuration is static if partners are predefined for the tasks to assign, it is dynamic if partners are selected from constellations of competing companies. The distributed planning phase is concluded with the final response (e.g. quotation, order confirmation) to the customer. This distributed planning process and its propagation across the ecosystem mirrors the present time-wasting human interactions but replaces them with a much more efficient way of finding out the desired solution. Moreover it can take into account unusual variables, such as transport times between manufacturing steps, and compare alternative solutions to measure their actual profitability. Of course its best performances come from clusters where all

the members are provided with the same, or equivalent, technology.

Later, during order execution, the distributed plan is put into action and the tasks are progressively carried out by the selected companies. Should a task be affected by problems (e.g. on delivery date) it will be re-planned to damp down the exception: the assignee company will be asked to revise its involvement (e.g. by choosing alternative routings) and if this will not be enough the leader company will transfer the residual perturbation on the next supplier until the problem will be (possibly) completely overcome.

1.6.3 Resource scheduling

The last critical aspect of a full autonomic solution is the support that must be assured to each small company behaving as supplier in the supply chain. To this purpose let us analyze what happens when the supply chain leader proposes to this company to perform activity Ai belonging to process P(X). Normally the execution model of Ai is represented in form of a routing made by a sequence of operational phases. A phase is intended by the shop-floor as an individual operation to be carried out by a certain type of resource team. The resource team type is composed by a combination of primary and secondary resources (persons, machines, equipment, etc.) for each of which the company has available one or more instances. Scheduling the execution of activity Ai means allocating the resource instances able to perform the phases of the relative routing. More precisely:

- The routing is scanned one phase at a time. The first phase is expected to start as soon as possible after the established start time Ti for activity Ai. In practice it will start when an instance of the required resource team can be organized and allocated to it, taking into account the engagements of resource instances.

- To this purpose the work calendars of the proper resource instances are examined and one or more combinations are identified with the constraint to involve them for the estimated duration of that phase. The choice of the best combination will be based on the policy established by that company.

- After scheduling the resources allocated to the first phase it is possible to derive its cost and the delivery time of the worked materials. The latter is the reference start time for the next phase, with possible positive or negative slacks.

- At the end of the entire scheduling procedure the total activity cost and the total lead time are finally known and can be communicated to the leader company for feeding its planning decisions.

- Later, during task execution, exceptions can occur e.g. because of delayed operations, missing resource instances, loss of materials. The schedule must be modified in such a way to solve them and, if this is not sufficient, they must be communicated to the supply chain leader for higher-level intervention.

Although not so complex like the planning algorithm, the scheduling algorithm must however consider a large number of variables and conditions, and apply a policy that can be in turn quite complex. This calls again for an automated solution under the condition that it leaves wide margins for the definition of autonomous policies.

On the other hand, in case the cluster member plays the mere role of supplier it has access to the functions that are needed to receive task proposals from the leader, simulate their execution to estimate times and costs, book the involved resources after the task has been formally assigned, revise the resource allocation for exception handling. This calls for an easy and efficient scheduler of internal resource that, normally, are just skilled persons and few machines or technologies.

At design time every task type is represented as a routing made of a number of operational phases, that is, atomic operations to be carried out by a certain kind of resource team. The resource team is composed by a combination of primary and secondary resources for each of which the company has available one or more instances. Thus in the set up phase the company is asked to formalise a tacit knowledge at the desired detail degree, with clear benefits in terms of increased awareness.

Then, scheduling the execution of a task means allocating the resource instances that are able to perform the phases of the routing under consideration according to a finite-capacity approach. This calls, in particular, for work calendars of resource instances to be managed in such a way to assure that the resource team components are allocated for the estimated duration of that phase. Special care is put in making the scheduling function suited to manage efficiently the human resources of the company.

Moreover, the scheduling function is able to support the company in facing and solving perturbations (delays, accidents, missing materials) than can occur during operation. With respect to the supplier viewpoint the exceptions come from two different directions: (a) the leader company asking for order reduction/extension or due date change, and (b) its own shop-floor

signalling missing resource, delay or loss of materials. If also leading in turn a supply chain further exception might come from its members.

The supplier company tries to solve the exception and damp down its effects by re-scheduling its tasks. In the best case no impact will affect the rest of the network (and the final customer), in the worst case the company can evaluate immediately the effect of the perturbation and undertake the necessary actions to handle it (negotiate with partners or customers, identify new partners or modify the internal calendars).

Further improvements are obtained by periodic revisions of the current schedule aimed at squeezing the resource work calendars to remove possible idle times generated by odd durations or cancellations. In fact idle times can regularly occur as consequence of task cancellations or modifications. Note that this approach results in optimal solutions for the single company and, since combined with the distributed planning process, assures the local optimisation of network processes.

1.7 eBEST autonomic approach

The adaptation of the autonomic model to the approach studied and developed during my research acrivity establishes the following relations: self-configuration for distributed planning, self-optimization for internal resource scheduling, self-healing for (distributed and internal) exception handling. Self-protection affects the previous functions with performance indicators derived by off-line functions. Every company is subject in principle to a double autonomic process, respectively as leader of the supply chain and as subcontractor (Figure 2). If leader it will be provided with self-configuration and self-healing functions allowing automatic reaction to customer orders and automatic propagation of purchase orders to suppliers. If supplier, possibly of itself, it will automatically manage the internal scheduling phase and face possible exception coming from the shop-floor.

The combination of the distributed planning and internal scheduling services of the eBEST platform cover the first three capabilities of the autonomic approach. In other words, the eBEST software is able to automatically react to external signals without diverting resources from the company core business to manage real-time interactions with partners. Communications flow down from the function triggered by the customer order to those of the lower-level nodes, and responses flow back inversely.

It has been ascertained that the autonomic approach is not easily accepted by the target companies because of its full automation. Therefore it was introduced for each company the possibility to shift to the manual mode

until the brought benefits are actually proved. This is what was required by the users involved in the eBEST project, which are thus provided with proper web-GUIs to perform and modify work assignment to resources and give explicit confirmation of times and costs to customers and leader partners.

1.8 Final remarks

The functions described in this are presently under validation in a number of real-life cases in six different countries. In particular it is worth to recall two of them:

- One pilot consists of a company working in the ICT maintenance sector, which is mainly interested to proper work assignment to its 30 technicians performing periodic and on-demand interventions on the customer ICT infrastructure. Much effort has been put in this case to model the customer contracts, so as to obtain the automated generation of periodic maintenance tasks. Two further added values are recognised by the company: (a) the possibility to schedule both periodic and urgent tasks having a clear picture of the resource statuses and using the automated or manual scheduling modes depending on the cases, and (b) the possibility to automatically export the generated maintenance reports with the incurred costs into the company ERP system so as to immediately issue the relevant invoices to the customer.

- Another pilot consists of a network of nine independent companies working in the fashion sector, which joined their efforts to provide a full service to important buyers and customers in Italy and abroad. The network is using the distributed planning functions and half of the members are using the scheduler for their own internal activities. A challenging requirement was the need to dynamically change the activity execution order in the production processes depending on the single customer order. The nine companies have different size and ICT skills, but are very satisfied to use a collaboration tool allowing fast assignment of work, tracking of all the operations, transparent exception handling, and automatic generation of business documents (delivery notes, invoices) for the customers.

Both pilots are substantially confirming the benefits brought by the proposed model and software and, at the same time, show that sectoral specialisation could increase its acceptance in different application contexts.

Making the cluster collaboration model fully autonomic is a real challenge since, on the one side, it assures a fast reactivity (few seconds) to customer

requests and to possible perturbations by the automatic (unmanned) execution of the implied functions but, on the other side, it requires that every cluster member is definitely confident in the correct and "neutral" application of the decision rules that itself has defined to represent autonomously its own behaviour.

The first success condition is designing and developing proper distribute planning, resource scheduling and communication functions that, besides meeting the given company requirements, can interoperate and trigger each other with no human interventions. These functions have been realised by the research work in argument, thus proving that the autonomic model is actually feasible. The possibility to switch to the manual mode is just an artifice to obtain the acceptation of the ICT support.

The second success condition is assuring that the change is adequately prepared, trained and managed. As a matter of fact, few of the companies taking part in the validation phase are already provided with (very simple) ERP systems. Once interfaced with the eBEST platform they can exchange those data and documents that are of common interest with the cluster. All the other companies see the new software functions as the first opportunity, for them, to automate activities that were so far managed manually.

The third success condition is introducing the new collaboration model by an effective testing period, showing that the decisions taken by the software functions are correct and corresponding to the current operational style at every company. In particular, it is important to keep the design-time effort limited by choosing the proper detail level, to move to the autonomic mode at the right time, and to provide sector-specific additional functions to increase the solution acceptance.

Finally, the fourth success condition is the contribution that enterprise associations can give to build trust and help overcoming difficulties. Indeed, small companies do not have resources and skills to discuss collaboration means with the partners in the cluster, nor they can take directly benefits form similar successful experience in the ecosystem. Enterprise association can do it by relying on the useful supports they previously assured in different fields to their associated companies.

Chapter 2

Business document exchange

This chapter is aimed at presenting an ontology-based approach, allowing small companies to exchange business documents in different formats and languages with minimal impact on their legacy systems and working practices. The foreseen interoperability solution requires the definition of a reference domain ontology and the ability to use it for annotating the semantics of data fields in user company legacy systems. The same approach can then be used to map the reference ontology with existing standards in order to remove the cultural and technical obstacles for small companies to join the global electronic market. These results have been mostly achieved during the KASSETTS and eBEST projects, partially funded by the EC in the frame of the INTERREG and FP7-IST Central Europe programs, respectively.

A key factor to increase interoperability between small companies, concerns the possibility to provide them a technology enabling to import/export business documents into/from their own information (legacy) systems and exchange these documents with customers and partners. Very important, the exchanged documents normally differ by both data model and language and only some of them are compliant with or inspired to official standards. This calls for business document transformation, including simultaneous structure conversion and contents translation, but at present very few examples of such a technology exist to be taken as reference. More precisely, the ultimate objective for small companies is safeguarding their (often poor) ICT investments and nonetheless opening to document exchange in a multi-cultural, multi-standard and multi-lingual operational environment:

- Multi-cultural. Even when acting in the same region collaborating companies belonging to different sectors are used to represent their respective knowledge with sets of concepts and tests that are only partially overlapping. Therefore the first interoperability problem concerns the possibility for them to correctly understand each other.

- Multi-standard. The number of standards regulating document definition and exchange is quite large and includes general standards such as the Universal Business Language (UBL) by OASIS [33] and the Business Interoperability Interface (ISSS BII) by CEN [39], as well as EDI data models and those of the most-known enterprise information systems.

- Multi-lingual. One of the most critical limitations affecting small companies willing to participate in the global electronic market is the difficulty to communicate in a language different from the home one or (sometimes) English. Special support is required to overcome this problem and let the intended companies make business without restraints.

Thus, while larger companies find it useful to invest in document standardisation there is no need or benefit to force small companies to do the same. In fact small companies have often to adapt to more that one standard, as imposed by their large customers, and obviously cannot afford that expensive effort. Much better is for them to keep working as usual with their legacy systems and exploit the possibility to transform their business documents only when exchanging them with customers and partners in the supply chain. This means approaching smoothly and at minimum cost the complex world of document standardisation and exchange.

This challenge is made more critical by the need to hide the document transformation process complexity under an easy and simple user interface. A promising direction is towards the construction of a domain ontology – a reference data model and multilingual vocabulary for the specific application – and its use to "annotate" (or "map") the concepts of legacy systems and standards and to cross-reference their terms from the origin language to English as "lingua franca" up to the destination language [34, 9]. Examples of tools are PROTÉGÉ [12] the most known open-source editor of OWL ontologies, and MAPFORCE by Altova [3], a professional mapper of data models.

2.1 Interoperability scenarios

The focus is on small companies willing to play an active role in the global electronic market by gaining visibility, establishing relations with new partners, and collaborating across sectoral and regional boundaries. In order to overcome their limitations in resources and innovation capability, they must adopt evolved organisational models and be supported in this by suited ICT functions with special attention to interoperability services

This section examines the typical scenarios, as described in[6], where the intended companies are involved, the kinds of information they exchange and the conditions under which collaborations can conveniently take place.

The scenarios are expressed in terms of the interactions that are established, by means of such a hypothetical ICT environment, between two companies playing respectively the roles of customer and (candidate) supplier, in the negotiation phase and in the collaboration phase. The negotiation phase starts with the discovery, by the customer, of potential partners and ends with an agreement or a contract. The collaboration phase starts with the planning of the distributed process and ends with the invoice issued by the supplier. It is important to notice that in a business ecosystem every company behaves, at the same time, as customer and supplier.

The identified interactions between companies require the availability of specific ICT functions that, in turn, rely on a number of basic services the most important of which pertain, respectively, to trust building, semantic aid and legacy interface:

- Trust building. Trust is a critical condition for companies to make business with partners, and this is particularly important in the electronic market where it is possible to find new partners possibly established in other regions. The need for trust building is enforced by the problems that small companies could meet in facing legal questions and disputes with contracts subject to different regulations. Reputation rating mechanisms, online dispute resolution and other trust building services can help overcoming this problem.

- Semantic aid. Every company behaves according to its own culture and habits, which represent its business knowledge base. If moving towards the electronic market so as to collaborate with partners belonging to different sectors and regions, and likely speaking different languages, it must undergo some changes that however must be limited in extent. Services assuring the needed semantic aid, e.g. by translating the exchanged documents, are then very important to safeguard most of the previous knowledge and behaviours.

- Legacy interface. A further success condition for the participation of small companies in the electronic market is the possibility to move data and documents from their legacy systems and send them to partners, and vice versa receive from partners data and documents from their respective legacy systems. This is indeed another interoperability problem that can be solved by the availability of basic services assuring

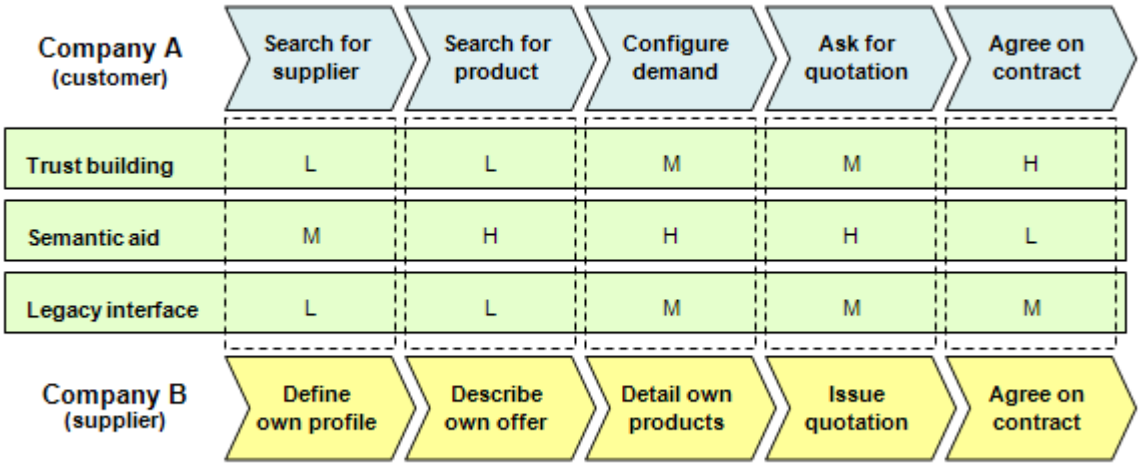

Figure 2.1: Company behaviour in the discovery and negotiation phase

the automatic (and unmanned) conversion of the exchanged data from the origin to the destination formats.

2.1.1 Discovery and negotiation phase

Figure 2.1 shows the main interactions between a customer (company A) and a supplier (company B) in the discovery and negotiation phase. Although a number of variants to this simple picture could be proposed to enrich or better specify such interactions, especially with respect to the habits found in particular sectors, the five proposed operational scenarios summarise what normally happens between companies where at least the supplier is small in size.

Let me briefly analyse the implied operational scenarios, according to the vertical strips, and the intensity of the required supports by the basic services, represented horizontally and roughly measured as low (L), medium (M) or high (H):

- Define own profile / search for supplier. Company B is willing to gain visibility in the global market, then it needs a function to describe and publish the its profile according to a proper data model, taxonomy and vocabulary. This knowledge is preferably expressed in the Company B local language. Company A is willing in turn to find candidate suppliers

and uses to this purpose the specific function. This function includes a filtering facility acting on the data model, taxonomy and vocabulary adopted by A. Although differing in language and in (some) company profile attributes the matching companies found in the network are reported to company A in a form that is understandable to it.

- Classify own offer / search for product. Company B is particularly interested to be found by potential customers for the products it can offer. To this purpose it needs a further function to classify and publish this offer according to a proper taxonomy possibly based on product families (e.g. cylinder, pump, gear) and major properties (e.g. hydraulic, self regulating, telescopic). This is a rough product representation that however assures the possibility for company A to identify B in a one-step selection. In fact, when searching for candidate suppliers, company A is specially interested in those companies supplying certain products and, at this stage, the simplest possibility is using generic keywords and properties.

- Model own products / configure demand. Company B knows that if selected by a potential customer this will ask for more detailed information about its offer. A specific function allows it to characterise every product family by a free number of parameters and their options. In the cylinder case parameters could be Power (20..80 HP), Screw (ball, roller, acme, lead) or other properties. In order to start the negotiation phase, the searching company A accesses this parameterisation and uses it to specify which kind of products (e.g. cylinders) it is demanding. Once again the critical point for company A is the possibility to represent its needs using terms defined by another company possibly in another language.

- Ask for quotation / issue quotation. The product configuration defined at the previous step by company A is the basis to ask company B for a quotation. Company B perfectly understands the request since it is expressed in terms of the parameters and options introduced by itself in the product modelling phase. Then company B is in condition to issue the quotation and possibly propose to company A further parameters to consider in the following iterations so as to precisely identify the desired product. The negotiation is semantically supported in such a way that company A and B keep using transparently their respective languages when sending and receiving messages to/from the partner.

- Agree on contract. The negotiation phase, if successful, normally ends

with a contractual agreement between the two parties. In spite of the interesting research works performed on eBusiness contracts, this step is hardly supported by ICT functions especially when the actors are small companies not used to establish trade relations with unknown partners. Possible aids could come from the publication of contract templates and the relative cross-references in the different languages, and even by the mediation role of the intermediary organisations that small companies are already used to exploit. This is indeed a field requiring further investigation and the establishment of standard procedures and conditions.

The success of the operational and communication scenarios constituting the discovery and negotiation phase is strongly dependent on the provisioning of the intended basic services accordingly to the following conditions:

- Trust building. In this phase trust is a fundamental condition. The searching company must trust on the information found in the web, the discovered company must trust in turn on the possibility to establish a business relation. The intensity of the services that can be set-up to help building trust increases dramatically while moving from the initial contact and approaching the signature of a contractual agreement.

- Semantic aid. When searching for and negotiating with partners belonging to different sectors or regions the main problem is establishing a common language and an effective condition of mutual understanding. This is particularly important in the central negotiation phase since it is the richest knowledge exchange part of the negotiation. As it will be shown later the solution relies on the construction and mapping of domain ontologies.

- Legacy interface. A further success condition in the discovery and negotiation phase is the possibility for the user companies to save data and documents received from the partners into their respective legacy systems (if any), and vice versa. For instance, it could be useful to store the new found partners and their quotations. To do this it is necessary that the legacy data model is made interoperable with the data exchange model.

2.1.2 Collaboration phase

Figure 2.2 shows in turn the main interactions between a customer (company A) and a supplier (company B) in the collaboration phase. Even in this case

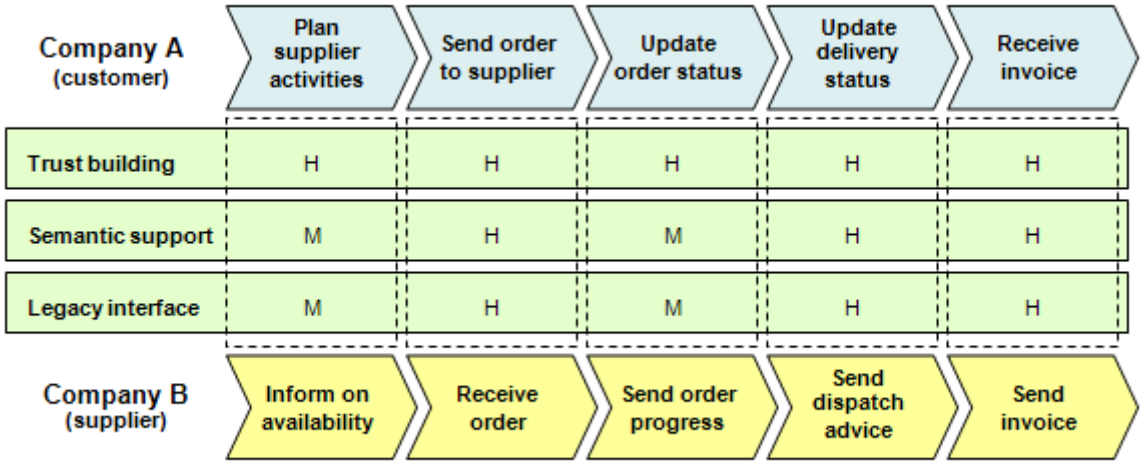

Figure 2.2: Company behaviour in the collaboration phase

the picture could be refined with additional and/or detailed behaviours but it can be assumed that the five proposed operational scenarios are sufficient to summarise what normally happens between collaborating companies where at least the supplier is small in size.

Let us briefly analyse the implied operational scenarios, according to the vertical strips, and the intensity of the required supports by the basic services, represented horizontally and roughly measured as low (L), medium (M) or high (H):

- Plan supplier activities / inform on availability. The leading company A periodically plans the activities that are required to satisfy its customer demand. Some activities are assigned to external parties, including those found in the discovery phase. In principle, when planning the activities of external resources the leading company must know their current availability e.g. in terms of maximum volumes, lead times and the like. This information must be provided by the supplier companies, e.g. company B, according to an established protocol. The planning phase, and the communication protocol itself, are very much depending on a number of variables such as leading company habits, product nature, production model, market conditions.

- Send order to supplier / receive order. The outcome of the planning activity, that should be carried out by the legacy system, in a list

of purchase or work orders some of which to be addressed to supplier companies. Company A sends the relative orders to company B in such a way that the sent document is written according to the customer data model and language and the received document is read according to the supplier data model and language.

- Send order progress / update order status. While the order execution is in progress it happens that the leading company A is interested to know which is its current status or the supplier company B has to communicate delays or exceptions. This is done by exchanging documents in such a way that once again they are written according to the sender model and language and read according to the receiver model and language.

- Send dispatch advice / update delivery status. Whenever a batch of products is dispatched by the supplier company B to the customer company A (no matter if intermediate or final delivery) it is normally preceded or accompanied by a dispatch advice. Even this is done by exchanging documents whose structure and contents are transformed, in the analogy with the other cases, from the sending to the receiving forms and languages

- Send invoice / receive invoice. Finally, when the order has been completely executed and the products completely delivered by the supplier company B to the customer company A, the supplier company issues the devised invoice. The invoice itself undergoes a proper form and language transformation and, if required, could be addressed to one of the emerging eInvoicing services in that region.

The success of the operational and communication scenarios constituting the collaboration phase is even more strongly dependent on the provision of the intended basic services according to the following conditions:

- Trust building. In the collaboration phase trust is actually the fundamental condition. On the one side, the collaborating companies already know each other since they undersigned at least one contractual agreement. On the other side, they are now working with each other therefore goods and money are moved between them. The intensity of required trust is the highest possible in all operations and proper trust building mechanisms, including online dispute resolution, are now of paramount importance.

- Semantic aid. In the collaboration phase the semantic support is mainly addressed to transform every exchanged document between the sender and the receiver forms and languages. This is indeed a necessary condition to assure that the partners perfectly understand each other without the need of devoting specific skills to translation and interpretation. The intensity of the required semantic support is particularly critical for those business documents that are considered mandatory in a business relation.

- Legacy interface. This is a very important condition in the collaboration phase. In fact most of the exchanged documents either come from the legacy system of one of the actors, e.g. the supply orders, or are generated outside it, e.g. order progresses, but in all cases have to be saved into the legacy system of the collaborating parties. Even for this service the support is more intense in case the document to save is considered mandatory by the legacy system. Interoperability requirements

From the analysis of the negotiation and collaboration scenarios between partner companies, with the participation of at least one small company, it results that the main interoperability problems to overcome are basically three:

- Document transformation. The exchanged documents must undergo a number of transformations from the origin to the destination formats. This is necessary to assure that every actor in the supply chain keeps working with its legacy data model and nonetheless its documents become perfectly readable to its customers and suppliers.

- Product configuration. When describing the offered / demanded products, e.g. from catalogues to requests for quotation up to purchase or service orders, the involved parties must understand each other. This objective has to be achieved in spite of the fact that every company tends to use its internal conceptual categories and technical terms.

- Language translation. In either case an additional problem could come from the use of different languages because of cross-border business transactions. This is a real difficulty for most small companies, only partially mitigated by the adoption of English as lingua franca, which sets a further strong interoperability requirement.

Much effort has been spent in the last years to standardise business processes, electronic documents and the underlying data models. An example

is given by the already-mentioned Universal Business Language (UBL) by OASIS defining a common XML library of business documents to be exchanged in the supply chain. In addition to recognised standards, further data and document models are introduced by the well-known EDI systems as well as by commercial planning and management ICT packages including MRP, ERP, TMS, SCM and CRM systems that, if widely adopted, become a sort of de-facto standard to cope with.

On the other hand, standard taxonomies have been introduced to classify the products and services offered by companies. Generic taxonomies such as NACE and the already-mentioned UNSPSC and eCl@ss are intended to code products and services of all the sectors at a limited detail level, while a plurality of specialised taxonomies provide a deeper view on single sectors. In general taxonomies are organised in hierarchies of thousands of terms while a company normally needs just tens or (few) hundreds of terms to represent its offer. Finally, both data models and taxonomies are available in English and are seldom translated into other languages. In synthesis, the electronic market is based on a number of (almost) standard models for data and document coding and exchange that, as a rule, evolve in successive versions requiring additional effort to be managed. Moreover, small companies often use information systems adopting proprietary models that mirror their age and cultural context. When adopting one of these models for its information system a company renounces to the others and this immediately introduces the interoperability problem, which is further emphasised if the company participates in two or more supply chains and then has to comply simultaneously with as many models.

2.2 Collaboration Environnement

The multi-cultural, multi-lingual, multi-standard issues above discussed can be fully satisfied by providing small companies with an easy collaboration environment behaving as a bridge between their experienced models and the other models of the electronic market. The collaboration environment must be based on a reference domain ontology made of a data model and a vocabulary with the only concepts and terms that are actually useful in product description as well as in document and data exchange. In other words the reference domain ontology is intended to represent a knowledge base shared by all the actors and enabling them to understand and explain the concepts of the involved models.

2.2.1 Ontology Approach

The term "ontology" can be defined as an explicit specification of concepts [1] while "domain ontology" focuses on the concepts that are meaningful in a given application domain. The conceptualisation describes the knowledge about the domain, not about the particular state of affairs in the domain. In other words, the conceptualization is not changing, or is changing very rarely. The ontology is then a specification of this conceptualization - the conceptualization is specified by using a particular modelling language. A formal specification is required in order to be able to process the ontology and operate on it with automatic tools as described in [31].

In general an ontology defines a common vocabulary and a shared understanding. The ontology itself is composed by an explicit description of a domain: (i) classes, (ii) properties and attributes of classes, (iii) constraints on properties and classes, (iv) individuals (often, but not always).

Classes A class is an abstract representation of a concept in a domain as a collection of related classes. It is a collection of elements with similar properties. A class can have a set of properties that represent the attributes of the class. Classes usually constitute a taxonomic hierarchy. A class hierarchy is usually an IS-A hierarchy: an instance of a subclass is an instance of a superclass. Taxonomy is a classification of things in a hierarchical form. It is usually a tree that express subsumption relations.

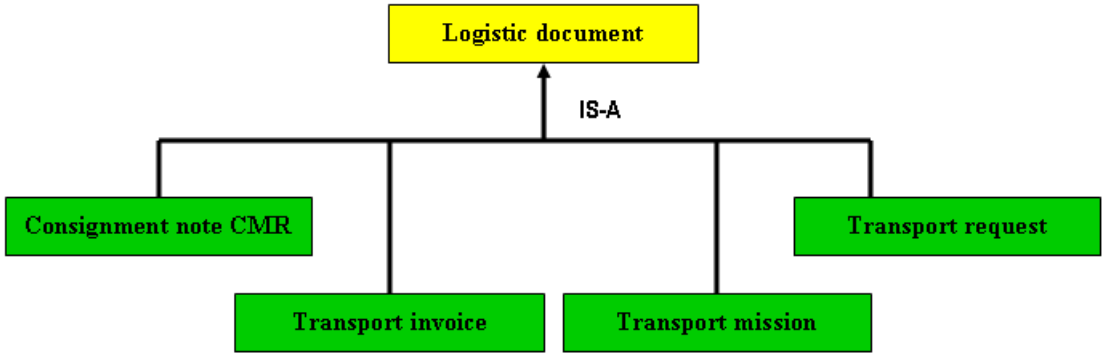

Figure 2.3: Example of Logistic document IS-A hierarchy

Properties A property represents attributes of a class. Within an ontology, any property is identified by a unique name. According to the Ontology lexicon, class properties can have different facets describing the value type

(the property range), possible allowed values, the property cardinality. From an ontological point of view, a property represents a connection between a container class (domain) and the associated range. On the basis of the property range and domain, OWL (a widely used Ontology representation Language) distinguishes between two main categories of properties:

- Object properties. An object property puts in relation objects belonging to different classes. In the example above, the property has02OrderCustomer relates Order to Company.

- Data type properties. A data type property puts in relation objects to primitive types, such as has01DocID in Figure **??**.

For data types properties, the widely used are:

- String. It represents a free text string.

- Number. It describes slots that can assume numeric values. Sometimes, more specific definitions as Float or Integer are adopted as well.

- Boolean. This property represents a simple true/false flag.

- DateTime. This property holds date and time values.

The property cardinality defines a number representing how many relations of that type can be established between the specific domain and range. In some cases it is suffice to distinguish between single cardinality (allowing at most one value) and multiple cardinality (allowing any number of values). In some other cases it is possible to declare a minimum and maximum cardinality value in order to constraint the property definition more precisely. The minimum cardinality N means that a property must have at least N values. The maximum cardinality M means that a property can have at most M values.

As previously asserted, the classes belonging to the ontology represents an hierarchical taxonomy. Concerning properties, inheritance among classes is guaranteed and subclasses inherit every property of the root class. In the picture below, the Customer class properties, between brackets, are inherited from the Company class.

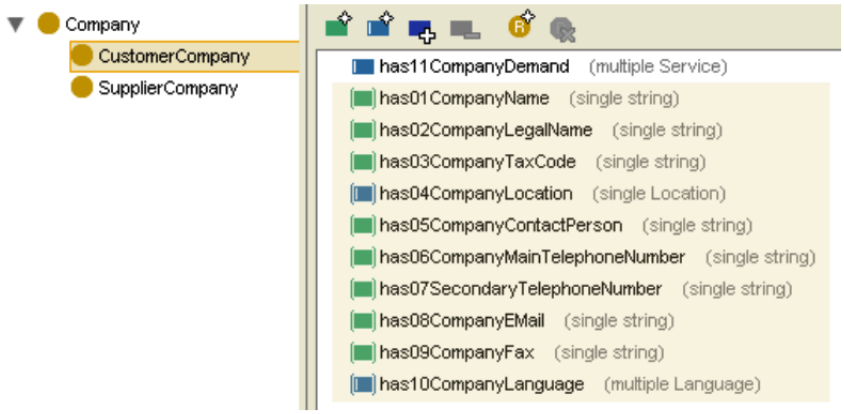

Figure 2.4: Inheritance mechanism

2.3 Ontology Contents

A project ontology-based shares common understanding of the structure of information among people, among software agents, thus enabling reuse of domain knowledge to avoid *"re-inventing the wheel"* and to introduce standards to allow interoperability. For projects that involve collaborative development of knowledge bases by computer scientists and domain experts, there is a pressing need to make the content of knowledge bases intelligible to those who are not users of sophisticated knowledge-engineering tools. The reasons to create a project ontology-based are:

- To make domain assumptions explicit, easier to change domain assumptions (consider a genetics knowledge base), easier to understand and update legacy data.

- To separate domain knowledge from the operational knowledge, re-use domain and operational knowledge separately.

The format should abstract away from the knowledge representation formalism, but at the same time presents an accurate view of the knowledge content. For the purpose of *reviewing* the knowledge content, the format should also expose large amount of information. Having such a review format not only benefits collaboration with domain experts, but also provides knowledge engineers with an efficient method for reviewing a knowledge base systematically.

2.3.1 Which contents?

Then the first question to answer is, of course: which (type and quantity of) knowledge should the ontology capture to assure the expected level of interoperability? To this purpose it is worth starting from these simple considerations:

- In practice only a limited portion of the knowledge base available at a company is actually used when interacting with partners in the supply chain. This portion is well represented by the only concepts and terms that appear in the exchanged business documents.
- Then, with specific reference to the interoperability problem there are no reasons to consider the entire standards or data models since it is sufficient to work on that portion of them (say, 20%) that concretely impacts on information exchange.
- If one compares that portion taken from different standards and information systems it can be found a partial overlapping. The correspondence of many concepts and terms is direct or can be reconstructed but there are items present in a model and missing in another.
- Taking as reference model the envelop of all those knowledge portions is a nonsense because it would result in a cumbersome ontology not preventing from loss of information in document transformation. Taking the intersection would in turn maximise the loss of information.

The right solution is building the reference ontology with the concepts and terms that either fully overlap or are common to a relevant number of sources. This is a balanced approach leading to an agile domain ontology that however reduces the loss of information. In fact, when two actors exchange business documents the receiving company understands and uses the only part of them that corresponds to its operational data model. Then there is no practical interest (nor success hope) in forcing companies to dramatically enrich the sent documents with additional fields that are meaningless to them, since this will not reduce the loss of information.

Much better is identifying a set of reference concepts taken from relevant standards and the data models presently in use at the most known commercial systems, and using them as transit concepts between the origin and the destination information systems. This is particularly convenient if the communicating companies are small in size since their information systems adopt data models that are normally much poorer than the reference ontology. Therefore in the transformation phase the fields of their documents are

almost sure to match equivalent concepts in the ontology and this is the condition to prevent from loosing information. At this point the next question is: which are the actual reference ontology contents and how are they represented? The answer comes from analysing the relevant business concepts and expressing them according to the classic object-oriented paradigm:

- Independent concepts. These are the main domain concepts or classes. They represent objects that are fundamental in business transaction for that application domain. For example, "business document", "product", "company" are typical independent concepts. Each of them is characterised by a number of properties and can be the root of a subclass hierarchy.

- Specialised concepts. They introduce further knowledge by detailing defined concepts with additional properties. For example, "invoice", "finished product", "small company" are possible specialisations of the mentioned independent concepts. A specialised concept inherits the properties of the upper-level concept that can be independent or specialised in turn.

- Concept properties. They represent attributes of that concept or relations with other concepts, and behave like functions associating each concept instance with one or more values taken in the specific codomain (range). Possible properties of business document are "issue date", an attribute mapping onto date, and "issuer", a relation mapping onto company.

- Attribute values. Attribute ranges are value sets sometimes given by enumeration of terms (words, strings). For example, the possible "currency" attribute of business document maps onto a value range made of the finite list of currency names. These names must be considered in the reference ontology since they represent items of the collaboration language.

- Extensible taxonomies. Other attribute ranges are extensible taxonomies of terms. For instance, the attribute "family name" of product takes an increasing number of values progressively introduced by users (e.g. bike, car, truck), further specified by parameters (e.g. colour) whose values are enumerated in turn (e.g. white, yellow, black).

The definitions in Figure 2.5 constitute the fragment of an ontology representing concepts of the eBusiness domain, built up in the frame of the KASSETTS project and including examples of attributes and relations with other concepts:

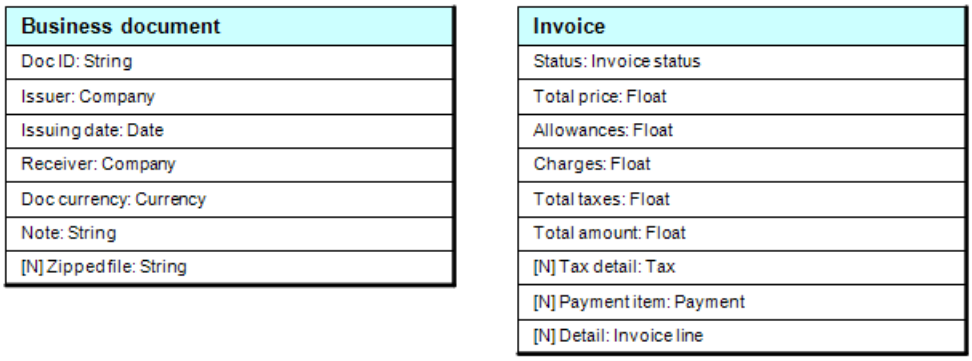

Figure 2.5: Ontology concepts and properties (example)

- The "business document" concept presents doc ID, issuing date, note and zipped file as attributes defined on primitive ranges (date, string), currency as attribute mapping onto the currency enumerated range, and issuer and receiver as relations with the company concept. The zipped file attribute can take more than one values for each business document instance.
- These properties are inherited by the "invoice" concept that adds in turn five attributes defined on the float range, the attribute status mapping onto the enumerated range invoice status (whose values are e.g. issued, sent, confirmed, etc.), and multiple relations with the tax, payment and invoice line concepts that will be defined further.

2.3.2 Ontology visualization

To improve ontology usability it is worth coding the ontology contents in such a way to show it easily as a concept tree and as a vocabulary. The screenshot in Figure 2.6 presents a fragment of the tree output taken from the Ontology Manager developed for the KASSETTS project.

This presentation form is particularly suited to examine the relations between concepts and then navigate the ontology by moving from one concept to its superclass or subclass, as well as to its domain or range. The other output, presented in form of vocabulary, is shown by the screenshot reported in Figure 2.7 and is particularly suited to examine the ontology contents through its terms and their definitions. Note that some terms report the

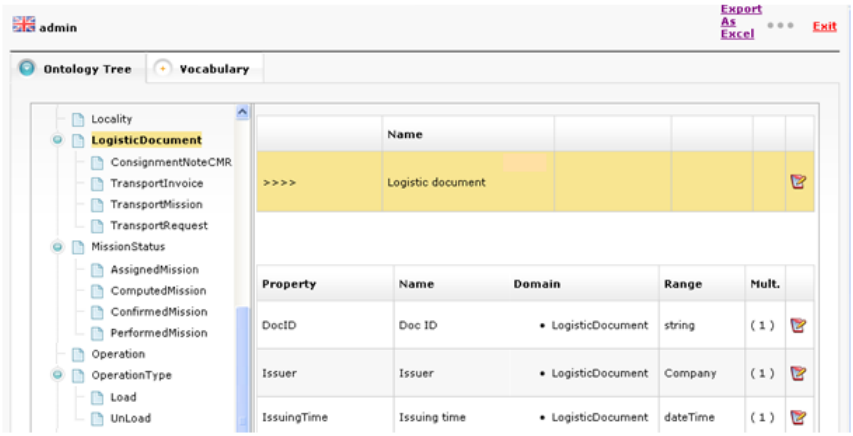

Figure 2.6: Ontology presented as a concept tree

domain name between brackets to disambiguate its meaning e.g. in case of homonymy. A filtering facility can help the search and of course it is useful to let the user move easily from the tree to the vocabulary and vice versa.

2.3.3 Multilingual ontology

To overcome the language translation problem above discussed the ontology has been developed with built-in multilingual features.

Every meaningful item introduced so far, namely classes and properties, are related to an Unique Identifier, a Name and a Description. The Unique indentifier is a string that recall the concept they represents. The Id is in English and, it cannot be translated. However, this is not an actual limitation since the name is just for internal usage, a quick way to identify different items within the ontology. Names are used to provide a human-readable version of a concept's name, textual descriptions helps clarify the meaning of classes and properties in the ontology. The Logistic ontology tree discuss above shows the Unique Identifier names exactly alike for all the partner languages (due to the fact that are universal software keys). The logistic ontology, in a first step, has been created in English as lingua franca, to be more precise as intermediary language among translations (from/to English and the partner languages) to guarantee communication among people and document exchanges in a international domain.

Each concept belonging to the ontology is translated into English language, and each concept in English is translated into a partner language.

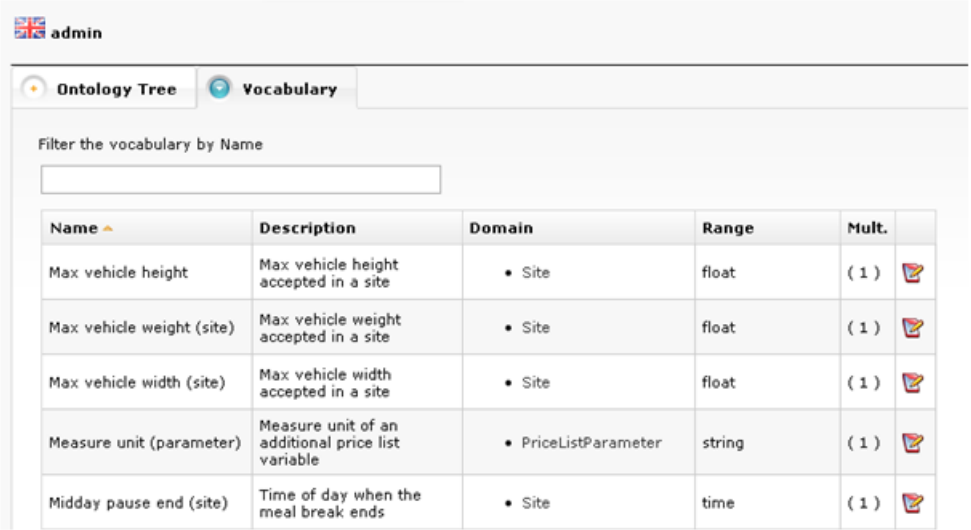

Figure 2.7: Ontology presented as a vocabulary

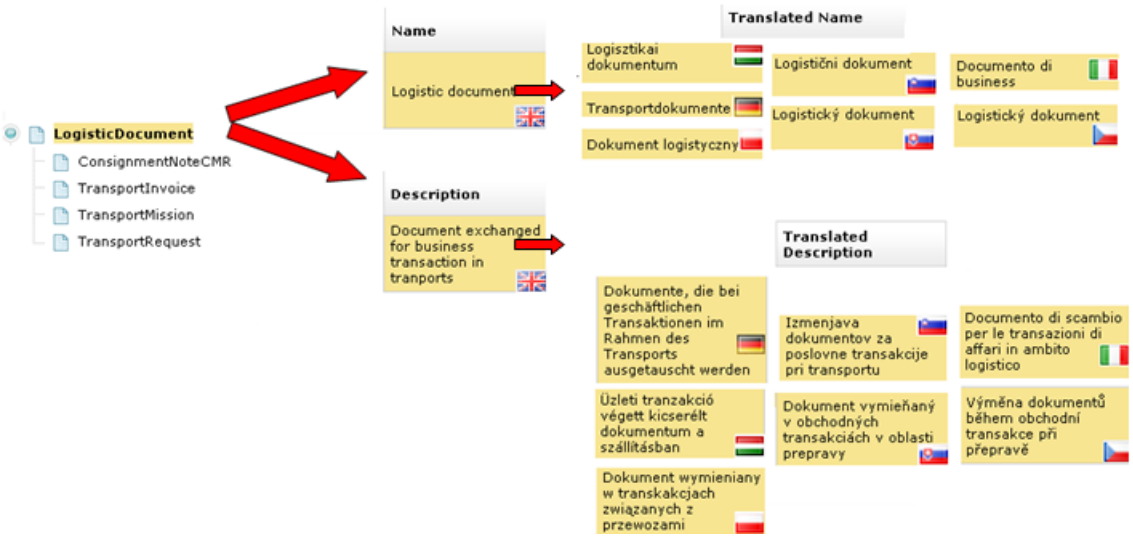

Figure 2.8: Logistic document class translations

The local language translations made so far are: Czech, German, Hungarian, Italian, Polish, Slovenian and Slovakian.

2.4 Ontology Editing Tool

This section explores the technical choices made to develop and maintain the English version of the Logistic Domain Ontology. The ontology is fully compliant with the W3C OWL DL syntax thus ensuring a complete portability among different OWL authoring systems. Among them, one of the most appreciated tool is Protégé (http://protege.stanford.edu), a platform used by a wide community of developers and users spanning from academic to government and corporate sectors.

Protégé platform since it represents a very mature software solution, constantly maintained and improved, supported by a wide and active community. Additionally, the Protégé platform features a comprehensive set of functions specifically aimed at creating and editing ontologies fully compliant with the W3C standards. The Protégé tool allows two main working mode that are detailed in the next sections.

2.4.1 Protégé client mode

The Protégé Client is a Java Swing-based GUI (Graphical User Interface) used for editing an ontology in a standalone mode. The client mode is used by software engineers to edit and perform the taxonomic scheme ontology as shown in figure 2.9. The client mode has been adopted for most of the creation and editing activities concerning the developed logistic ontology. One limitation of the client mode is that is mainly suited for single-user model, thus making problematic the usage in a distributed and concurrent environment. Additionally, the rich set of available functions makes the GUI not very intuitive for beginner users. This represents a limitation any time not very skilled users are asked to provide the ontology with a simple contribution.

2.4.2 Protégé client-server mode

The client-server mode allows multiple Protégé clients to simultaneously edit a shared ontology stored on the Protégé server (fig. 2.10). The client-server mode is also referred to as the multi-user mode of Protégé and is suitable for projects in which multiple users need to access and edit the same ontology. The communication between client and server is realized using the Java

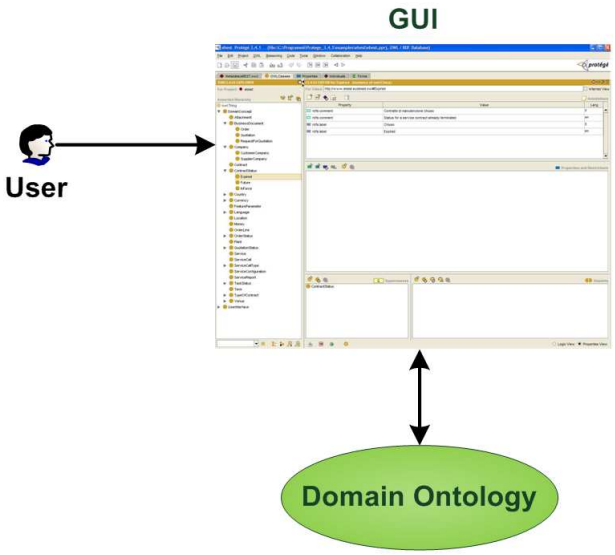

Figure 2.9: Protégé client mode

Remote Method Invocation (RMI).

2.4.3 Protégé server mode with Web Service interface

In order to overcome the intrinsic limitations of the RMI communication protocol and to provide final users with a tailored, easy-to-access, distributed mode of accessing the ontology, a dedicated architecture and proper software modules have been developed on top of the basic Protégé client-server mode.

The Ontology Manager (OM) is a Java Enterprise application aimed at providing users with simple yet effective functions for managing the ontology localisation.

From the architectural point of view, the Ontology Manager is composed by two separated modules: the Web Application and the Web Service as described in figure 2.11 .

The OM Web Service is a platform that operates like a wrapper above the Protégé Server. It is connected to the Protégé Server via RMI and exposes regular SOAP ports via the HTTP protocol. The OM Web Application is connected via HTTP protocol to the OM Web Service module and renders the Web pages by which partners can access the ontology in a controlled manner. This architecture choice centralises the GUI rendering logic thus simplifying the access to the Protégé ontology via a regular Web browser. This architecture was chosen with the objective to facilitate the participation

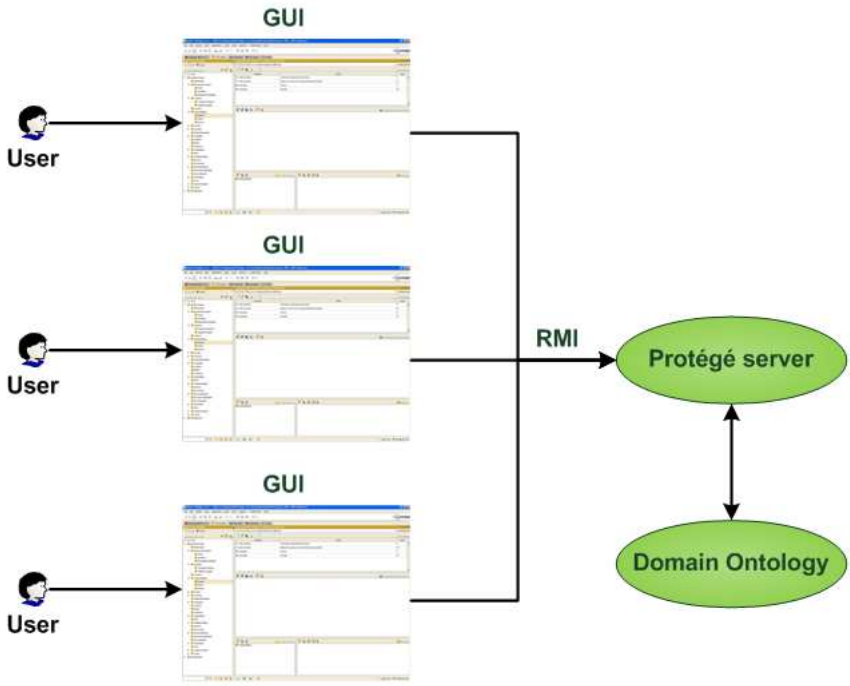

Figure 2.10: Protégé client-server mode

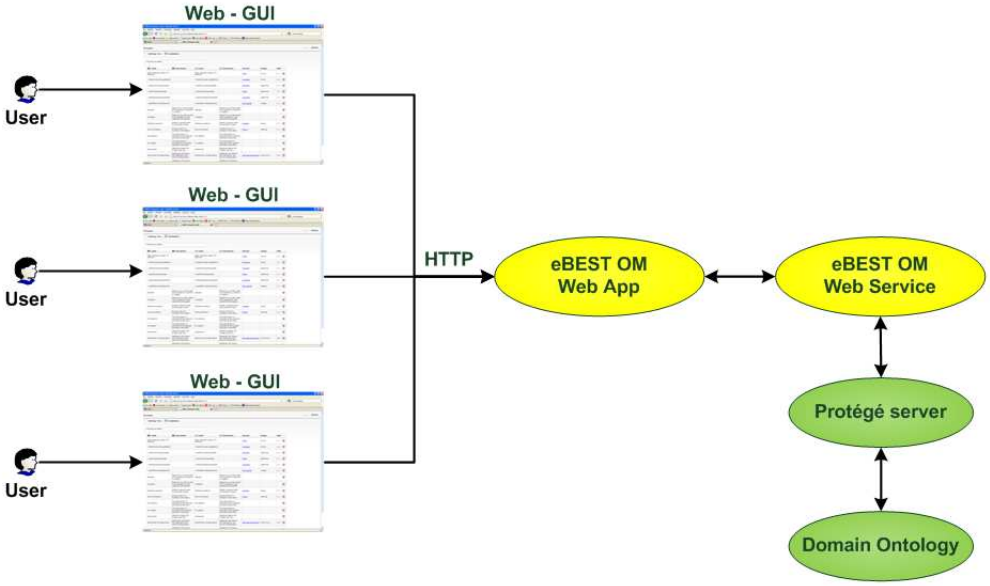

Figure 2.11: Ontology Manager Architecture with Protégé

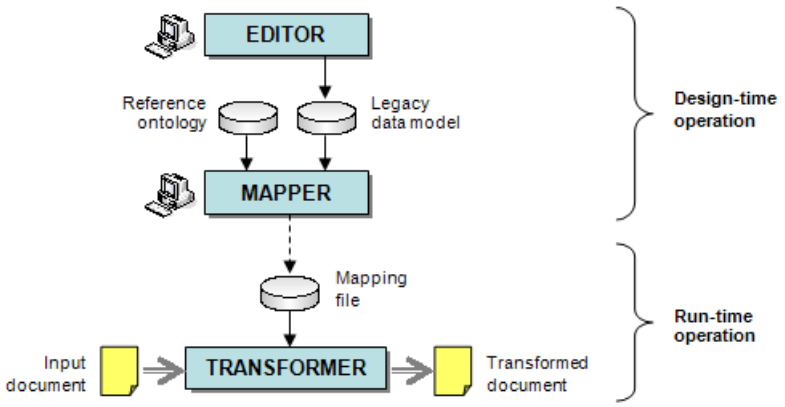

Figure 2.12: Document transformation process

of a plurality of actors, starting from the KASSETTS project partners, in the definition of that domain ontology.

2.5 Mapping phase

The reference ontology is then an explicit and steady description of the relevant domain concepts and terms aimed at obtaining a common language and reaching a shared understanding. Its introduction enables domain knowledge usage by a plurality of actors, its controlled updating and extension, and a clear separation from operational knowledge. Although collected and systematised by knowledge engineers it can be made available to all the individuals and applications that can take benefit from its exploitation. Finally, its formalisation is a necessary condition for the development of a variety of software functions that can automatically process it.

The solution that was experimented first by the SEAMLESS project and is now refined by the KASSETTS project consists in splitting the problem into two parts requiring, respectively, design-time and run-time operations (see Figure 2.12).

Design-time operations The design-time operation is executed manually once for all by every company and is intended to map the data of its legacy system data model onto the concepts of the reference ontology. This phase

is carried out by means of two support tools:

- Ontology Editor. This tool is the same that was used when building up the reference ontology. In this phase it allows describing the legacy system data model as a sort of simplified ontology, thus reporting it to the same formalisation level of the reference ontology. Although facilitated by a simple user interface this task must be assigned to a knowledge engineer.

- Ontology Mapper. The same knowledge engineer moves to the next tool for mapping the pre-existing reference ontology with the specific legacy pseudo-ontology (that is, for annotating the legacy system data with the concepts of the reference ontology). The result is a mapping file containing the instructions to translate documents between the two ontologies.

There are several techniques to realise the mapping file. For instance, if the input documents are available as XML files the mapping file could be in XSLT format (in practice this solution presents some mapping limitations and low performance when dealing with large numbers of documents). Independently of the chosen solution the ultimate objective is coding the transformation rules identified during the mapping operation in such a way to be automatically executable by a proper virtual machine. In the KASSETTS project the mapping file is indeed a Java routine capturing all the correspondences between the mapped ontologies.

The transformation rules that are coded in the mapping file pertain to either structural aspects or to vocabulary translations. More precisely, four are the principal cases to be identified and represented during the mapping phase:

- Relations showing 1:1 cardinality. It often happens to find concepts or properties in the legacy pseudo-ontology that directly correspond to homologous concepts or properties in the reference ontology. In this case the resulting transformation rule is quite simple.

- Relations showing M:1 cardinality. In some cases some attributes in the legacy model correspond to one attribute in the reference ontology. The transformation rule must include a specific function expressing the implied operation.

- Relations showing 1:N cardinality. In other cases a single attribute of the legacy model must be mapped onto a number of reference attributes. The transformation rule must include a specific procedure to derive the output values form the input one.

- Translation of vocabulary terms. The values of enumerated attributes in the legacy model must be put in relation with the homologous terms in the reference vocabulary. For instance, the legacy invoice status "X02" will be annotated as "issued" from the reference vocabulary.

To conclude the analysis of the design-time operation let us observe that the annotation of the legacy system data model must produce not one but two mapping files, corresponding respectively to the legacy-to-reference (L2R) and reference-to-legacy (R2L) transformations. The former is required when sending a business document to the partner, the latter when receiving a business document that the partner has previously transformed into the reference form. Because of the M:1 and 1:N relations that can be found (and the possibility of homonymies / synonymies in the vocabularies) the most complex part of the mapping operation must be carried out twice.

2.6 Transformation phase

For interoperability purposes the reference ontology represents the "official" domain knowledge and its concepts can be used by every actor to "annotate" the data in the data model of its legacy system so as to explain their meaning. This is the key step for business document transformation, including simultaneous structure conversion and contents translation. It is a well-known mechanism [13, 14] but at the time being there is no evidence of its practical use in systemic document transformation. For small companies the challenge is made even more critical by the need to hide the process complexity under an easy user application. The transformation process is done by Run time operations as already depicted in figure 2.12

Run-time operations Moving now to the run-time operation it can be observed that it is completely automatic and consists in executing the proper mapping file on each document to be sent or received. In other words, this phase requires just one support tool:

- Document Transformer. It works on the input document by behaving as a virtual machine able to execute the instructions contained in the selected mapping file. The input document could come from the legacy system (L2R transformation) or from a partner (R2L transformation) and could require transformations on either data structure or language, or both.

In practice the Document Transformer should be conveniently hosted as an innovative user-transparent service in the frame of a general bridge

application, particularly suited to small companies, offering the following kinds of functions:

- Document management. The bridge application allows the user to create new business documents and manage them together with those received from customers and supply chain partners or exported from its legacy system. All the documents are available in the format and language (likely English) of the reference ontology.

- Document exportation. Business documents can be moved from the user company legacy system into the bridge application. Whenever this happens the documents are automatically transformed from the legacy data model to the reference ontology structure and language, thus becoming somehow "normalised" for future use.

- Document importation. Vice versa, business documents that are available in the bridge application (therefore in the reference ontology format and language) can be imported into the user company legacy system. Whenever this happens the documents are automatically transformed into the data model of the legacy system.

- Document dispatching. A business document that is available in the bridge application can be sent to a partner by any communication channels. If the receiver company uses in turn a bridge application based on the same reference ontology the document is sent as it is and the receiver can read it immediately.

- Document receipt. Finally, the bridge user company can receive a business document by any communication channels, e.g. as attachment to an email. If it comes from a sender using in turn a bridge application with the same reference ontology the document is ready to be read or imported into the legacy system.

Thanks to its simple logic it is quite easy to hide the complexity of the transformation process behind a simple and intuitive user interface. The bridge applications should be then perceived as a workspace where documents are moved through to obtain the required level of interoperability. It is important to observe that, although explicitly conceived for small companies, the proposed approach can be useful to companies of any size. A company adopting the reference ontology is immediately enabled to send and receive normalised documents. More complex, but equally resolvable, is the case of companies not adopting it, as it is shown in the following of this section.

2.6.1 Mediators

The critical aspect of the proposed approach is that every company is required to map the data model of its information system onto the reference ontology. Although not so difficult and time consuming per se this task calls anyway for the support by a knowledge engineer, a skill that is hardly found at a small company. My research shows that this help is naturally provided by intermediary organisations (mediators), typically sectoral and/or regional entities such as entrepreneurial associations or chambers of commerce that are used to assist the associated small companies to carry out their daily management, organisational and bureaucratic activities.

As a matter of fact, in Europe most small companies are associated to some kinds of mediators and this percentage increases while their size decreases. Then mediators can contribute to solve for them the interoperability problem in several directions:

- Create a localised version of the reference ontology. Part of the mapping problem comes from the need to annotate the legacy system data with concepts expressed and described in English as lingua franca. Having available a translation of the reference ontology in the home language simplifies the task, relates the local knowledge base contents to the ontology concepts, and dramatically reduces possible misunderstandings.

- Help classifying the offered products and services. Mediators can further contribute to the localisation task by keeping under control the growth of the ontology vocabulary due to the free addition of taxonomies representing the global offer of products and services by the associated companies. A strong support to offer classification in that region assures a corresponding controlled growth of the global reference ontology.

- Extend the localisation effort to different domains. Many (generic) mediators have associated companies working in (and for) different industrial sectors and then requiring the possibility to interoperate with partners adopting different domain ontologies. Besides assuming the task to localise two or more reference ontologies, an important consequence (as discussed later) is the ability of these mediators to understand their commonalities and differences.

- Promote the new model and the underlying technology. Mediators are in the best condition to explain the benefits of the new approach, adapt it to the local habits and real needs of the associated small companies,

and assist them in overcoming the entry barriers. Also, mediators can ensure the rapid introduction of a critical mass of companies to make the eBusiness information workspace become soon a large scale system.

The benefits for mediators in undertaking the devised promotional and deployment role are basically two. On the one hand, in the frame of their core business they add innovative services to the support they already provide to the associated companies. On the other hand, they can take this opportunity to extend their core business to the provision of the devised technology, typically in SaaS mode. Taken together these activities will likely result in a significant extension of their customer basis and revenues, and then in a fast return of investments. From a macro-economic viewpoint this will result in turn in a massive participation of small companies in the electronic market. How will this solution impact on reference ontology construction and maintenance? The picture becomes slightly more complicated but also clearer and closer to its practical realisation. As depicted in Figure 7 a three-stage architecture is finally foreseen:

- D-1 is the reference ontology for a certain application domain. It contains the concepts and terms useful to that domain and is normally written in English. L-1.1 and L-1.2 represent to versions of D-1 translated (by mediators) into the home languages of the respective regions. They are used to annotate the data fields in the legacy systems of the corresponding associated companies.

- During the annotation phase the local reference ontologies are progressively enriched by the addition of taxonomies representing the offer of products and services by the user companies. It is the task of mediators to support the associated companies in performing this activity and assuring a controlled growth of their local ontology vocabularies.

- The extensible taxonomies generated for the local ontologies are migrated towards the global reference ontology so as to keep the knowledge bases aligned. This is done again by mediators by preventively translating the new taxonomies from their local language to English. This is a bottom up approach to extend that part of the global ontology vocabulary.

- It is worth observing that this process produces a progressive growth of the global ontology that should scatter further alignments in the local ontologies. Should this be considered a burden by mediators, the translation of taxonomy terms could be incomplete in some cases by limiting it to the English term in place of the local one.

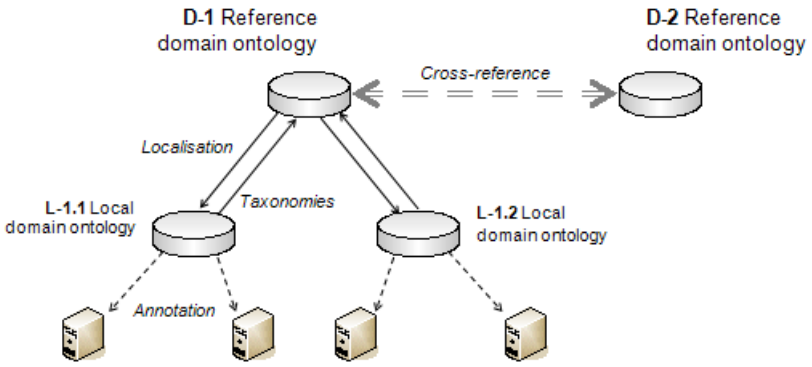

Figure 2.13: Overall ontology architectures

- Finally, in presence of reference ontologies for different domains it would be useful to assure, for companies working in one of such domains, the possibility to interoperate with companies working in another. This can be done by extending the mapping and transformation process to cross-reference the overlapping concepts of the two ontologies.

This last mechanism is the key to open small companies to the widest world of standard data models, thus overcoming the boundaries of the closed world of the single reference ontology. To this purpose it is sufficient to map that ontology to the concepts of every interesting standard (or even EDI model) for enabling companies to have translated the sent document into its format, vice versa, to have translated the received standard documents into its own legacy format. The maximum number of required translations is three in either direction: Legacy model ¿ Local ontology ¿ Global ontology (English) ¿ Standard model, and vice versa.

2.7 Mapping and Transformation

In this section is described the ontology based software solution for document mapping and automatic transformation I developed within the framework of the Kassetts project.

2.7.1 From OWL to XSD

XSD files are used in KASSETTS to provide a set of primitive data types that are the same Data Type used in the whole Logistic Ontology and that can validate every single Logistic Document in XML format exchange between two actors of the logistic chain.

An XSD files represents the data types of each document in each language, they are directly extracted from the ontology. There are 7 XSD files (one for each language + English language and Glob language) for each Logistic Document (Consignment Note CMR, Transport Request, Transport Mission, Transport Invoice), which means a totals of 7 * 4 = 28 XSD files. The XSD files are built starting from the subclass of "Logistic Document", each Document is scanned finding out each property. If the property is a Data Type property it is directly inserted into XSD Schema, in case of object Property every Object is scanned recursively until Data Type properties are discovered.

The output of the validation process is a document expressed in the "KASSETTS (valid) format" and still in its original language. Afterwards, the document must be translated into the KASSETTS Glob language in order to be managed by the system. This translation process is done with the use of a number of XSLT files. XSL Transformations (XSLT) is a declarative XML-based language used for the transformation of XML documents into other XML documents. In the Logistic Ontology, XSLT files are used to translate Logistic Documents from the original language to the KASSETTS Glob language and vice versa. That means 7 * 2 = 14 XSD files have been written.

It is worth noticing that since the Logistic Document is already validated before the translation process takes place, also the resulting document translated in KASSETTS Glob language is valid. Of course, the document expressed in KASSETTS Glob language can be translated whenever required in another partner languages. The whole process guarantees that Logistic Documents stored in the system are always expressed in the KASSETTS Glob language and validated, moreover translation operations can always been performed on those data and the output is still validated.

2.7.2 Logistic document mapping

The translation of a Logistic document from a legacy system (of a user company or a logistic operator) to KASSETTS and vice versa, requires the creation of a mapping file, in XSLT format, defining the conversion rules from/to the proprietary format and the KASSETTS Logistic Documents in XSD for-

mat. The mapping process may be seen as composed by two phases: format mapping and language mapping:

- Format mapping: As format we identify the structure used to represent the data inside a document. Since the source and the destination formats are generally different, it is necessary to define a set of rules to convert any document written in the first one to a document written in the second one. A typical format example is the XML, which is the one used in the KASSETTS project.

- Language mapping: The second needed step is to convert the content of the documents from the source language to the destination one.

XML mapping projects are often not simply one-to-one mappings of a source to a target component with the same structure. Most XML mappings involve the use of data processing functions to manipulate data between the content models. It may needed to perform logical comparisons, mathematical computations, or string operations, and/or make other modifications to the data to complete the mapping.

The XSLT format has been chosen as it is well known, almost a standard de-facto to translate one XML file into another, and can be built using a variety of editors, both proprietary and open-source. Among the proprietary environments, ALTOVA is the most widely spread and complete. In addition, it has a graphical user interface very clear and understandable, as shown in Figure 2.14.

2.7.3 Logistic document transformation

At this stage an XML logistic document in proprietary format can be transformed into another XML file compliant with the KASSETTS XSD. The transformation is based on applying the mapping file, in XSLT format, and is implemented in form of web service that can be invoked whenever a user of the KASSETTS platform sends or receives a logistic document.

This process is divided into two steps: format transformation and language transformation. Each step correspond to a call to a web service. This call is transparent to the user which simply starts the process by importing the source XML logistic document. As result the user sees a new document in its workspace, expressed in the application format. The first step converts the document from the legacy XML (in the user language) to the KASSETTS XML (still in the user language). The second step starts from there and generates a document in the KASSETTS XML format but in the application language.

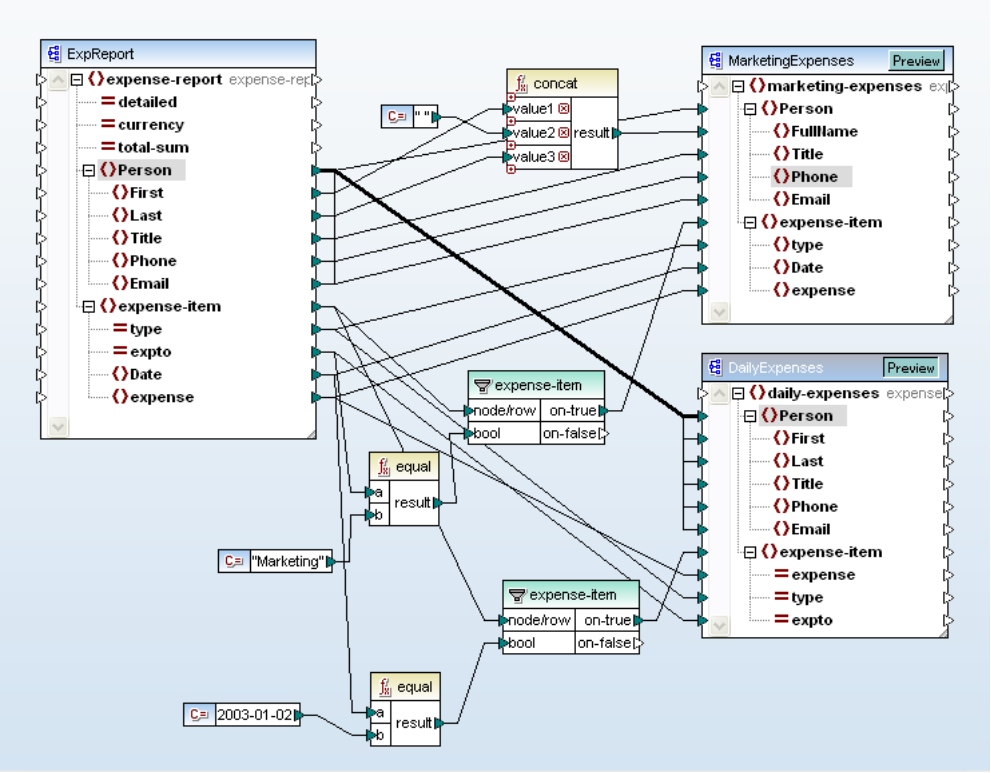

Figure 2.14: Altova MapForce mapping example

2.7.4 KASSETTS Results

The final multilingual ontology, which has reached a good steadiness level after some incremental iterations, is reported in [28]. The entire Ontology, namely data model concepts and vocabulary terms, is represented in English as lingua franca.

The ontology management tools, supporting ontology editing, translation, mapping and logistic document transformation, are described in [29] and available to all the KASSETTS partners. Such tools, with the exception of ALTOVA MapForce, which can be replaced by other open-source XSLT file generators, are open-source and can be made available to anyone interested in the scientific community.

The industrial significance of the ontology, and of the business document transformation and translation functions built on top of it, relies mainly on the opportunity it gives to make different legacy systems of the logistic chain actors interoperate with a very limited effort. Any electronic business document sent by actor A and written in an XML proprietary format can be transformed into the XML standard format derived from the ontology and from that to the XML proprietary format of actor B, the receiver. The capability of transforming proprietary formats, and languages, one into each-other is the real added value of the KASSETTS ontology, acting ad a knowledge bridge between different formats and languages.

2.8 Final Remarks

The proposed approach to make interoperable the information systems (if any) of small companies and open them to the global electronic market is still under development. The mentioned SEAMLESS and KASSETS projects are intended to realise proofs of concepts showing the immense potential of the mapping and transformation process. At the same time they define domain ontologies that can be taken as living examples of the limited effort actually required for their construction. However other projects are needed, possibly working in different sectors with peculiar operational requirements, to refine the methodology and tune the technology.

At the time being at least two important research directions shall be explored in the next few years for overcoming the still open problems. They pertain, respectively, to annotation (mapping) and to system governance:

- Automatic annotation (mapping). The major obstacle to the adoption of the proposed approach is the required support by knowledge

engineers when annotating a legacy data model or mapping the reference ontology with another ontology or a standard model. Much faster would the involvement of mediators and the participation of small companies if such an activity were assigned to an algorithm. Then, the first research direction is studying how to make the annotation and mapping process (at least partially) automatic.

- System governance. The proposed approach distributes the ontology management tasks among a plurality of actors most of which are mediators that will be rewarded by the advantages they can take of the new role. However, global reference ontologies and their mapping with standard models call for a wide organisation with adequate governance. This is the second important research direction to be followed in strict collaboration with the European and international standardisation bodies.

Chapter 3

Adoption of the RFID technology by SME

The RFID technology can be fruitfully exploited in a number of services intended for SMEs, ranging from logistics to security, access control, consumer services. Although technological developments are very promising, the adoption of RFID solutions by SMEs is still limited, mainly due to both cost (hardware and software are quite expensive) and performance uncertainty in specific contexts (performances and margin of errors are crucial in industrial applications). This chapter presents a RFID solution to manage paper documents, with particular regard to tracing and archiving processes.

The proposed solution is a pilot case developed in the context of the RFID-ROI-SME project (ICT PSP programme grant agreement number 250438), aimed at boosting the adoption of the RFID technologies. The outcome of this pilot case is a fully working prototype that has been already developed and is currently under testing.

In the current era of global recession (as a result of the financial crisis), ICT in general and RFID technologies in particular can serve as valuable innovation tools, which could help companies increase productivity, reduce operation cost, while also boosting the competitiveness. Specifically, RFID technologies have the potential to contribute to increased efficiency in a range of areas including industry, trade and logistics. Despite these potential benefits, most SMEs do not have the equity capital to research and invest on RFID deployments. Furthermore, SMEs have usually very specific problems and needs, which large RFID vendors and consultants fail to address successfully.

The RFID technology has the potential to increase efficiency in a range of areas including industry, trade and logistics. Despite these potential benefits, most SMEs do not have the resources to research and invest on RFID deployment. Furthermore, SMEs have usually very specific problems and needs,

which large RFID vendors and consultants neglect to address successfully.

In order to fully exploit RFID solutions at small-medium sized companies some important requirements have to be faced [5, 26] :

- Reasonable cost effectiveness of project implementation. It is a matter of fact that RFID projects are expensive, not only for the hardware, software and infrastructure components, but also for the consultancy and customization effort needed to adapt non-standard solutions to the specific context.
- Good performance and ease of use of readers, mainly related to operator acceptance and ease of use of the hardware and software infrastructure.
- Easy and not expensive experience replication in other contexts.
- Integration with existing legacy systems.

3.1 The RFID-ROI-SME project

The main goal of RFID-ROI-SME [37] (co-funded by the European Commission in the frame of the ICT PSP programme under grant agreement number 250438) is to boost the adoption of the RFID technology by wide SME communities, while at the same time creating business opportunities for innovative RFID solution providers within the EU. The aim is to demonstrate tangible benefits of RFID technology across many different sectors and business cases.

The projects aims ad deploy 8 RFID pilots in 6 different Eu countries belonging to different sectors such as: logistics, apparel, food, public event management, recycling, security, document management.

Each pilot is focused on the individual needs of the end-user SMEs of the RFID-ROI-SME consortium, which will be the recipients of the benefits of each deployed solution. In addition the pilot will be developed by SME RFID solutions providers pursuing the vision where SMEs deploy for SMEs.

Each pilot deployment will become operational for SME end-users from a minimum of twelve (12) months. The scoping of the trials covers use cases and scenarios focusing on selecting business processes of the RFID end- users. Each trial will emphasize on few yet critical business scenarios, where RFID can provide value. Hence, the scope of each pilot will target a clear demonstration of the business value of RFID technology. It does not target a full coverage of all the processes of the SMEs.

The RFID-ROI-SME project general objective is to allow SMEs to innovate based on RFID technology and in particular:

- To showcase the benefits of global interoperability of the RFID technology. This will be accomplished on the basis of transnational trials involving RFID deployments across various stakeholders of the supply or value chain.
- To boost the competitiveness of RFID solutions provider SMEs, through increasing their ability to develop, integrate and deploy innovative RFID solutions.
- To demonstrate that RFID can have tangible value in the scope of processes, products and services, which could have direct benefits for the vast majority of the EU citizens.

Objective of the pilot case here described is to build a satisfactory RFID-based distributed application used to manage document folders, applicable to a variety of document types and related management processes.

Both SMEs solution providers and SMEs consortium members will gain benefits from the adoption of RFID technology: possibly developing/adopting solution based on pilots results and achievement.

- SME End-Users members will directly gain benefit from RFID-enabling mission critical business and the deployment of RFID technology solution will be disseminated through SME Associations to their members (outside RFID ROI SME consortium).
- RFID-ROI-SME offers end user providers the possibility to gain and improve expertise in RFID products and competencies, as well as the ability to provide and integrate innovative RFID solutions.

The project will boost, if possible, open source solutions, given also that these solutions can serve as a TCO reduction driver.

3.2 The RFID technology

Before introducing the focus of my research activity in the adoption of RFID by SMEs it is worth introducing some information about the RFID technology.

RFID (Radio Frequency IDentification) is a set of contactless radio system technology for Automatic Identifying and Data Capture (AIDC) of item (objects, people, animals).

A typical RFID system transfers data from a transponder (or tag) attached to an item to the interrogator (RFID Reader). Information stored into tags that are made available from up to 100 meters away.

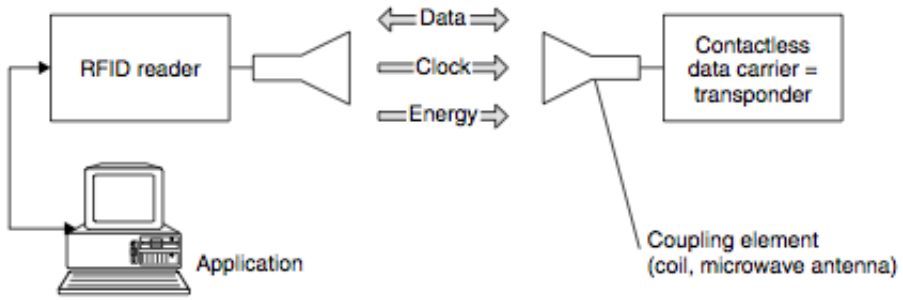

Figure 3.1: Typical Rfid System

Accordingly to [21] an RFID system is always composed by two components as depicted in figure 3.1:

- the tag (transopnder), which is located on the object to be identified. The tag is composeb by an RF transmitter receiver
- the reader , which, depending upon the design and the technology used, may be a read or write/read device. A typical reader is made up by a radio module, a control unit, and an interface (RS 232, USB, TCP/IP) used for interconnection with an external system (PC, Smartphone, embedded system).

3.2.1 Tag classification

Usually the information is stored into the tag non volatile memory. An RFID reader transmits an encoded radio signal to interrogate the tag, which receives the message and responds with stored information. Tag can store only a unique serial number or additional information depending on the memory capacity of the tag itself. Depending on the tag power supply system, three main category of tags can be identified:

- Active tags have battery onboard used to power the on board circuits that periodically transmit stored information over the air.
- Battery assisted passive (BAP) tags have a small battery that power the circuits only when the tag is activated by an external signal from the reader.
- Passive tags are typically smaller (and cheaper) because they don't use an external battery to power the internal circuits. The use instead the energy gathered from the reader.

Another very important differentiation criteria for RFID is the operating frequency of tags and reader.

- Close coupling: The transponder must be placed very close (up to 1 cm to the reader). The operating frequency is between DC and 30 MHz. Nowadays the role of close coupling systems on the market is becoming less important.
- Remote coupling systems: Operating rage up to 1 meter and frequency between 135 Khz and 13,56 Mhz.
- Long-range systems: This technology operates in the UHF fields, the operating frequency is near 868 Mhz (Europe) and 915 Mhz (USA). Accordingly to ,REF Passive UHF RFID Packaging With Electromagnetic Band Gap (EBG) Material for Metallic Objects Tracking, UHF RFID is one of the most promising and widely use technology in product tracking and routing packaging in supply chain.

The RFID technology is now a widely spread technology used in differents fields such as:

- Product tracking
- Access control
- Transportation and logistics
- Asset management
- Inventory systems
- Advertising
- Security

Let's now focus on the regulations related to the use and deploy of RFID technology in Italy, where RETE operates with its associates.

RFID in Italy

Italy is among the EU countries that lead RFID deployment. Its UHF band has been regulated with the following characteristics: 865.6-867.6 MHz. Only temporary licenses are available due to conflict with band allocated to military application.

Italy through Ente Italiano di Unificazione (UNI). Indicod ECR, (http://www.indicod-ecr.it/progetti/index.php) (EU), which is an institute that associates more that 30.000 industrial enterprises of large consumption and active modern distribution in Italy is participating actively in RFID ISO standardization. With reference to the RFID, Indicod-Ecr is taking care of the diffusion in Italy of the EPC standard, developed by EAN International in collaboration with the Massachusetts Institute of Technology.

3.2.2 RFID middleware

Forrester Research defines RFID middleware as "Platforms for managing RFID data and routing it between tag readers or other auto identification devices and enterprise systems." RFID middleware is a software layer that allows the integration between different application in particular where data acquired from different readers have to be sent to different 'consumers'.

Accordingly to [30] these are the typical features of a typical RFID Middleware:

- Data Filtering. The amount of information generated by an RFID infrastructure is vast, sometimes it is necessary to filter this data in order to improve performance and waste resources.
- Reader virtualization. Unfortunatly different RFID reader vendors equip their reader with different (and often proprietary) communication protocol between reader and PC. This features allows to interact with different RFID reader using a common language, providing a fixed instruction set to the higher layer.
- Routing of different data stream. Succesful deployment of a middleware reader enable the routing of different RFID tag streams to different applications and data stores.

In the following two different RFID middleware (Aspire RFID and Fosstracj) are illustrated.

Aspire Rfid

AspireRfid (http://wiki.aspire.ow2.org/) is a relatively new Open Source RFID project [4], which was launched during the second semester of 2008 by the OW2 Consortium (http://www.OW2.org) and the research project ASPIRE (http://www.fp7-aspire.eu).

OW2 is an independent industry community dedicated to developing open source code middleware and to fostering a vibrant community and business

ecosystem. The OW2 consortium hosts nowadays more than one hundred technology projects.

ASPIRE is a collaborative European research project, that aims at lowering software and integration costs associated with RFID deployment. The most important result of the ASPIRE consortium is the AspireRfid open sure project, a lightweight, programmable, standards- compliant, integrated and privacy-friendly RFID middleware platform, along with a range of tools that facilitate RFID deployment.

AspireRFID is motivated by the need to lower the total cost of ownership (TCO) for RFID deployments. This is particularly important for many small and midsize enterprises (SMEs), which typically lack sufficient equity capital to invest in radio frequency identification. Moreover, most SMEs do not have the resources and expertise necessary to research the optimal blending of RFID into their business processes. For many SMEs, RFID incurs a significant TCO, comprising hardware, software, integration, consulting and training costs. Hence, it becomes very difficult for these companies to leverage the technology to create innovative products and services. AspireRFID represents an effort to lower RFID costs based on royalty-free middleware, as well as tools enabling the setup of RFID-based solutions without the need for tedious low-level programming.

AspireRfid Tools

The AspireRfid tools enable RFID consultants to configure RFID solutions, in accordance to standards without tedious low-level programming. In particular they empower RFID deployers to:

- Configure the way they will interface to heterogeneous multi-vendor readers (e.g., according to the protocols that these readers support).
- Specify a company's master data in terms of readpoints, warehouses and most important business processes.
- Defining logical readers (i.e. readpoints) that aggregate multiple readers and antennas.
- Define filtering specifications, which instruct logical readers to filter the tags based on the requirements of the target solution.
- Implement configurable adapters for interfacing RFID middleware with legacy ICT applications (such as ERP, WMS and corporate databases).
- Manage and monitor the underlying RFID network.

Due its modularity nature, the AspireRifd can be used in conjunction with other RFID middleware,such as the FossTrak OSS middleware.

3.2.3 Fosstrack

Fosstrak is an open source RFID software platform intended to support application developers and integrators by providing core software components for track and trace applications. The adoption and use of OSS components, will allow for lowering the TCO of the RFID solution, while at the same time fostering the OSS RFID community.

3.3 Automated Document Tracing pilot case

My research activity has been focus on the development of RETE SERVIZI pilot case. This pilot case aims at deploying an RFID pilot on paper document management, enabling the company to improve its efficiency in both tracking and archiving processes. RETE SERVIZI is an accounting organization working for SME by its 12 branch offices spread throughout the Province of Milan, Italy. Each of them collects and submits sensitive and legally important business documents, coming from their user companies for accounting purposes, whose flow must be traceable in order for the whole activity to be valid.

3.3.1 Pilot case objectives

Every RETE SERVIZI office collects and processes documents relevant from the legal viewpoint, whose flow must be tracked to be valid.

The organizational process targeted in the pilot case is Tax Assessment process, which implements one of the most important services provided by RETE SERVIZI that today allocates most of the company resources three months a year. The 90 % of the companies associated generate 2 to 4 declarations, for the company, for the partners, for some family members.

Relevant documents used to compute the tax assessment arrive to RETE SERVIZI from January 1st up to May 31st. When the deadline (June 16th) is closed many documents are missing, then branches and central offices work under stress.

The current workflow is briefly recalled in the following:

- One folder per year collects all the relevant documents for every customer (company or person) subject to tax statement. The folder stays

in a cabinet from January to April, progressively filled with documents brought by the customer (medical invoices, nursery school fees)

- In the last two months the incomplete folders are put into boxes with post-its recalling the missing documents. As soon as a new document arrives it is put into the folder

- Every few days (every few hours in the last hot days) every folder is checked to issue a reminder to the customer. As soon as a folder is complete one employee takes it to process the tax statement

- Not all the employees are able to complete the tax statement, then in many cases the folder passes from one desk to another. When a branch is overloaded with statements to process, one or more boxes can be transferred to other branches.

The RETE SERVIZI pilot addresses in general the need to localize and check the status of documents. Such documents at RETE SERVIZI are stored in folders. A folder can be placed in a cabinet, or in a box on the floor, or on a desk. A folder can be moved from one office to another, for specific operations or in order to balance employee workload.

Typically the unit to control is not the single document, but a folder that contains a number of documents from the same user company, about which the operator must know where it is, to whom it is currently in charge, which is the folder contents, which is the folder status (depending on its contents).

In the new RFID-based organisation all the folders to manage are properly tagged, together with the boxes and desks hosting them. The number of folders to tag for the only tax assessment process is of several thousand for the whole organisation.

The information relevant to the folder status and contents, which is dynamically updated by different operations and employees, is stored in a distributed web application (described later), and are coupled with the physical folder by the corresponding tag.

Whenever a document enters or exits a folder, a proper workflow system manages the consequences of this fact, in terms of folder status change, notification to the person in charge, change of the person in charge, notification to the customer and so on.

In spite of the technological development of RFID technology in the last years, successful applications in the field of document management are still few. In fact such implementations present some main requirements:

- Intensive use of portable readers, whose cost should be limited (also

when coupled with palm top or net-book to get immediate understanding of what is read).

- Readability of overlapped and very close tags, as it may happen that a folder must be searched into stacks of folders (sometimes empty) with RFID tags put on their tops.

RETE SERVIZI has high expectations about the possibility to increase quality and speed of service to its customers. First, the probability to lose or hide original documents decreases significantly. Then, RETE SERVIZI can make substantial controls on the documents delivered by the customers, highlighting the lack of a document needed for a given activity or that a document is no more valid after a given date, or other significant exceptions.

Most important generic requirements for the whole pilot case are:

- Reasonable cost effectiveness of project implementation.
- Good performance and ease of use of portable readers.
- Reducing the margin of error with respect to current technology.
- Support employees in stress conditions (for instance in the final tax assessment phase) making their job more rational and organized.
- Easy and not expensive experience replication in other contexts.

The risks and major concerns in the implementation of RFID in the RETE SERVIZI context are mainly related to operator acceptance and ease of use of the hardware and software infrastructure. In order to increase the process control, more information should be collected and managed and some work reorganization is needed. The actual risk is that the positive outcomes of the pilot are evident to the management but not to the operators, and then the new practice is rejected.

3.4 Methodology

From a technological perspective, a general solution to exploit RFID technology accounts for hardware, software and middleware [27, 22, 11]. In terms of hardware assets, it will require RFID readers and servers/controllers, as well as the required amount of consumables (i.e. tags).

In terms of software and middleware, SMEs can use already existing software/middleware solutions and in particular open-source projects in order to

cut down costs, agree on standard and facilitate the integration with already existing legacy systems.

The work assumption for the RETE SERVIZI pilot case is that the relevant document folders as well as the relevant places (desks, cabinets, boxes, offices) are tagged.

Accordingly the main hardware requirements for RFID devices are:

- The use of handheld antennas, without installing fixed antennas in the RETE SERVIZI offices.

- The possibility to read simultaneously about 30 tags associated to folders put into the same box, so as to make an inventory of the box contents in a fast and reliable manner.

- Reasonable cost of hardware and tags, use of passive tags.

About software, the requirements are:

- Distributed document management & Folder tracing: all document tracing (where the folder is, which is its status) should be managed by the application accessible in local network as well as geographical networks. It is also very important to keep and update information on folder contents: how many documents are inside, which documents are inside, which document are missing, scanned images of all documents.

- Integration with the RETE SERVIZI accounting system. Information on customers are in the RETE SERVIZI accounting system, then at least a mono-directional dialogue with the new application is realized.

- Ease of use, steadiness and accuracy. Operator acceptance is a key issue, the time spent to retrieve a document in the new scenario must be equal or lower to that spent with the current way of working. Moreover employees, especially when deadlines are close, cannot lose time and must be confident in system reliability.

The middleware requirements in general account for a good level of independence of the specific reader technology, then they are openness, potential for development, and reasonable solution cost [10]. In particular we use some modules form the Aspire open-source RFID Middleware developed within the framework of the ASPIRE project (Advanced Sensors and lightweight Programmable middleware for Innovative RFID Enterprise applications [4]). The resulting general system architecture is depicted in 3.2.

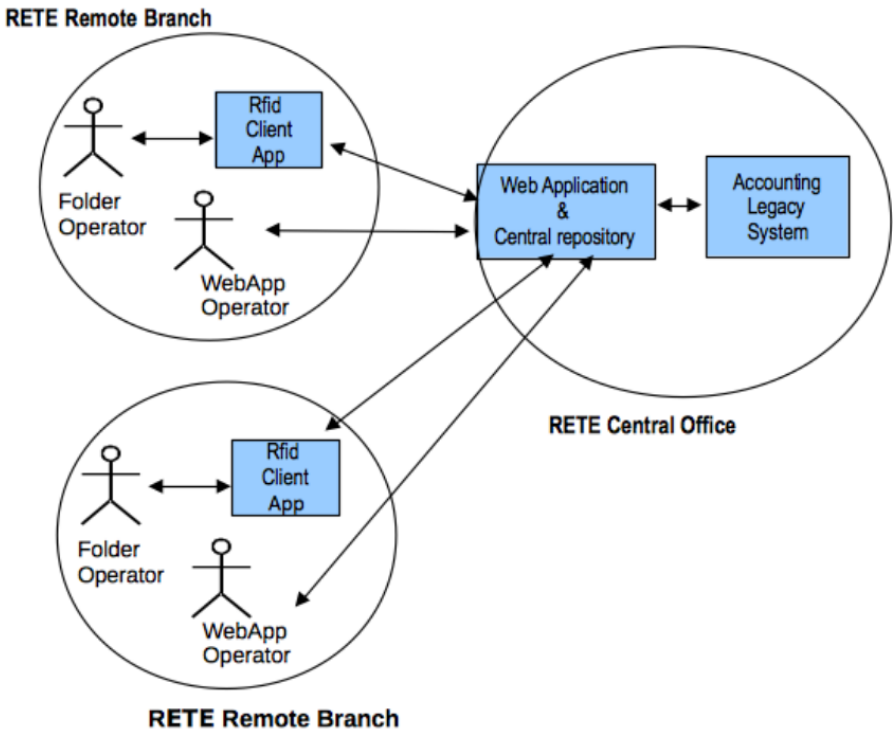

Figure 3.2: System Architecturee

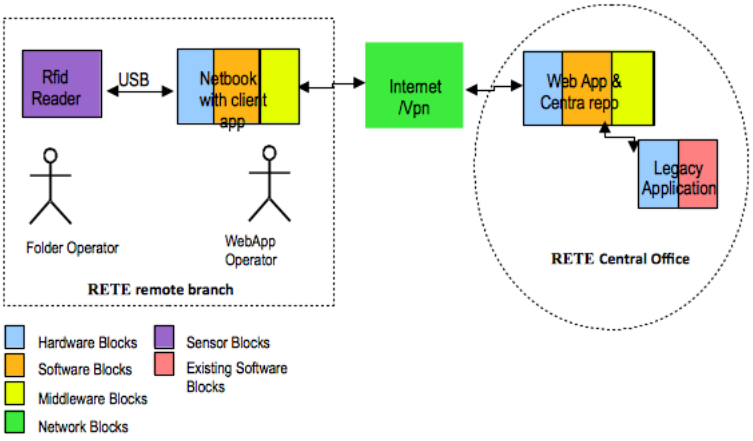

Figure 3.3: Detailed system architecture

3.5 Pilot Case Technology Description

In order to meet the system requirements, a distributed web application has been developed. It is composed by three different modules, namely central repository, web-gui, RFID-client-gui. The main features offered by the application suite, as depicted in Figure 3.3 are:

- Access and modify the status of a virtual folder (i.e. a virtual representation of a physical folder).
- Trace the folder when moving in and out from a box, and between branches
- Make an inventory of each box, to update the folder position in the application
- Notify RETE SERVIZI customers about missing documents into the folder
- Support the operator in asking expert colleagues for help for a specific customer

The central repository module, deployed on the server, is used to access and retrieve the information stored into the database. This information contains details about the status of each virtual folder. This module also exposes web-services for accessing and modifying the repository used to provide integration with:

- Accounting legacy system interface: this is the legacy software used by RETE SERVIZI operators to compute annual tax fees for their customers.

- RFID-client-gui: acts as an interface to the RFID reader, used to read and display tags assigned to folders, boxes, and locations in order to perform operations above described.

- web-gui: used for modifying status and content of a virtual folder.

The web-GUI module, used by operators working at their own desks, is hosted on the same server of the central repository module and will be used to modify status and contents of a virtual folder. The main technologies used to built the main application are Java, JavaServerFaces, Icefaces, Hibernate, Spring, JSON.

The central repository module is also used to issue notifications to other employees and directly to customers. Notification include lack of documents to complete the tax assessment process, errors during process evaluation. The Central repository module is also connected to the following already existing external service:

- Email Gateway System: this subsystem is used to send email notification to customers. The integration has been developed using Spring Mail API provided by spring framework

- Sms gateway System: used to send Short Message Service (SMS) notification to customers. The integration with the SMS module has been developed using Jax-Ws reference implementation.

- Legacy Accounting System: this system is actually used by RETE SERVIZI

The operations onto the physical folders are made available using the client-GUI module. This application is deployed into a net-book and it is able to drive the RFID reader connected. The net-book is connected to the Wi-Fi network of the office, in order to enable the access via web-services to the software central repository. The notebook is also connected via USB to the RFID reader. The client-GUI module is realised by a Java Swing GUI interface. In order to keep the development of the system independent from the DBMS used, an O/R (Object/Relational) mapping layer has been placed between the database itself and the business logic. In particular Hibernate was used, as it provides both a query language and a persistence mechanism.

In general, RFID systems generate an enormous number of object readings, many of which represent non-actionable noise. To balance the cost and performance of this operations with the need for clear accountability and interoperability of the various parts, the Aspire middleware is intended to:

- Minimise, through filtering and counting, the number of readings the application must deal with.
- Minimise the amount of business logic embedded in tags. The Filtering and Collection Middleware is intended to facilitate these objectives by providing a flexible interface (ALE (Application Level Events) interface) to a standard set of accumulation, filtering, and counting operations that produce reports in response to client requests.

The RFID-client is responsible for interpreting and acting on the meaning of the report. Depending on the target deployment the client of the ALE interface may be a traditional enterprise application, or it may be new software designed expressly to carry out an RFID-enabled business process which operates at a higher level than the middleware that implements the ALE interface. In the scope of the RETE SERVIZI pilot, the RETE Client module would consume the results of ALE filtering (so called reports). The Aspire middleware integration is depicted in Figure 3.4.

Once the RFID reader capture relevant tag data, it notifies the F&C middleware which combines the data in a report that is sent according to a pre-determined schedule to the RETE subscribed module.

The middleware provides specific filtering functionality depending on the already defined specifications. So redundant events from the reader from a specific location are not included into the dispatched report, thus accomplishing the reduction of filtering and aggregation required towards the RETE module interpreting the captured RFID data.

Moreover the RFID tag classes will be grouped with specific report names so as to ease the distinction of the different scanned items at the RETE module (folders, desks and so on).

3.6 Final remarks

Document management is intrinsic in all RETE activities, as its consultancy services are based on processing customer documents for accounting and archiving purposes. Every new technology enabling shorter lead times for service provision and savings in personnel effort is welcome, as these are key factors to limit the cost of service and/or improve service completeness

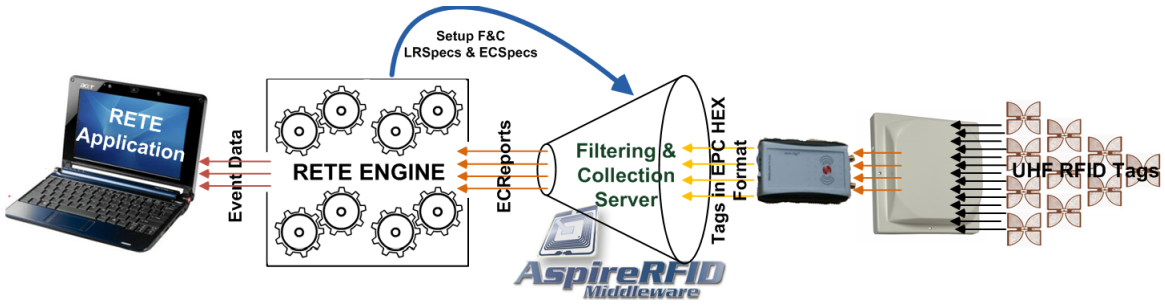

Figure 3.4: Aspire Middleware integration

and quality. In recent years RETE tried to derive benefits from dematerialisation but, being the documents originated at the customers, the cost of scanning becomes a pure additional overhead without producing real advantages. Instead, the RFID technology and related applications seems to be very effective for process improvement, and the pilot on tax assessment could pave the way for targeting further processes (such as passive invoice management) which now presents some RETE director asserts that the time spent by RETE resources for tax statement is 50% for folder processing and 50% for data collection and reminders. The objective is to reduce the incidence of the latter component from 50% to 20%-30%.

Then, operational measures identified so far to ascertain the expected improvement are:

- Time spent in searching a single folder
- Time spent in container inventory
- Number of misplaced documents
- Time spent by a folder to pass from status “opened” to status “ready for tax computation”
- % of time spent in calling customers for missing documents
- % of automated issues of e-mail/SMS notifications
- Number of overtime related to tax declaration
- Costs saved related to overtime (employees and external people)
- Time spent to identify bottleneck in folder management

RFID is technology suitable to be exploited in a number of applications for SMEs, nevertheless it is not widely adopted due to technological issues, companies budget limitations and the lack of standard solutions to be customized. In this paper we presented the prototype of an RFID-enabled document manager that supports the company in tracing and archiving processes. The proposed solution accounts for hardware, software and middleware components. In particular, the hardware requirements have been chosen in order to keep reasonable costs for SMEs while, at the same time, guarantying steadiness and accuracy.

Conclusions

One of the most important challenges for SMEs in time of economic crisis is to become credible actors in the global electronic market. This goal can be achieved by improving visibility to customers and partners, exchanging knowledge and collaborating with complementary or competing companies belonging to the same ecosystem.

Reaching that goal is not easy for SMEs. As a matter of fact they cannot invest significantly in advanced ICT solutions and divert resources from their core business. Moreover even though fundamental in the European economy they are neglected by the most important producers of ICT tools.

These considerations are at the basis of my research activity. More precisely the research work is intended to study and experiment the conditions for SMEs to overcome their present difficulties in accessing the eMarket. Among the numerous aspects to consider, three are the fields on which my research is focused:

- Autonomic management of networked small factories.
- Facilitated business document exchange.
- Mass adoption of the RFID technology.

The opportunity to investigate in these fields was given by my active participation in the already-cited European projects, namely eBEST of the FP7 programme, KASSETTS of the INTERREG Central Europe programme, and RFID-ROI-SME of the CIP programme.

The lessons learnt and the results achieved so far are summarized in the following points:

- SMEs leading enterprise networks can improve their performances if introducing proper distributed planning techniques able to optimize the network behaviour even though based on limited process models. An effective planning tool for distributed processes has been developed in the frame of the eBEST project and tested by several pilot networks belonging to different industrial sectors.

- SMEs belonging to a specific ecosystem can increase their efficiency and efficacy improving internal resource scheduling. This goal can be achieved using the propose ICT platform for resource scheduling studied and developed during the eBEST project.

- Networked SMEs can improve the exception handling to provide fast reaction to run time problems. This can be done using the exception handling feature of the ICT tools under testing by the eBEST consortium, that offers solution to these problems in a semi automatic manner.

- In oder to gain visibility in the global eMarket, SMEs have to increase collaboration with other companies. A solution for this problem is offered by the ontology approach proposed and under testing by the members of KASSETTS and eBEST consortia that allows SMBs the possibility to collaborate sharing only a limited amount of internal knowledge.

- While SMEs can continue operating in their local languages, they have to gain visibility towards foreign companies, to increase their business. The automatic document translation tools developed during my research let companies to exchange business document without changing the data format and language with a seamless interaction with the existent legacy ICT data sources.

- SMEs shall maximize the ROI of already existent ICT investments. All the tools developed and described above were designed with the aim to minimize the impact on existing software solution and working practices.

- The optimal use of internal resource is fundamental to increase the steadiness of the company. The RFID technology along with the use of proper open source middleware can optimize the use of these resources while at the same time increase the ROI of already done ICT investments. An example is the document management pilot case developed within the framework of the RFID-ROI-SME project.

In synthesis, the results of my research activity come from collaboration models proposed by the literature into practical experiments carried out with the participation of research institutions of different EU countries.

Moreover the achieved results have been validated by a pair of dozen ecosystem involving one hundred different SMBs in different countries (Italy,

Greece, Spain, UK, Poland, Germany, Czech republic, Hungary, Slovak republic, Slovenia, Hungary, Belgium, Bulgaria) and operating in different sectors (ICT, entrepreneurial association, chamber of commerce, industrial associations, logistics, university, textile, construction, mechanical).

Bibliography

[1] Gruber T. R. 1995. *Toward principles for the design of ontologies used for knowledge sharing.*, volume International Journal of Human-Computer Studies, 43, pages 907–928. 2009.

[2] Abels S. Campbell S. Hahn A. Accessing and managing heterogeneous information in the single european electronic market. In *eChallenges 2004*, 2004.

[3] ALTOVA. Mapforce web site. http://www.altova.com/products/mapforce/, Jun 2009.

[4] ASPIRE-consortium. Official project web site. http://www.fp7-aspire.eu, May 2011.

[5] Tortorella M. Bodhuin T., Preziosi R. Building an rfid document management service. In *International Conference on Innovations in Information Technology (INNOVATIONS 2006)*, 2006.

[6] Monari P.D. Martinelli L. Bonfatti F. *Business Document Exchange between Small Companies.*, volume Electronic Business Interoperability: Concepts, Opportunities and Challenges, pages 482–510. IGI Global, 2007.

[7] Bonfatti F. Monari P. D. *Special needs of SMEs and Microbusiness.*, volume Evolution of Supply Chain Management – Symbiosis of Adaptive Value Networks and ICT, pages 501–508. Kluwer Academic Publishers, 2004.

[8] Bonfatti F. Monari P. D. *Putting semantic interoperability between small and micro companies into practice*, volume Expanding the Knowledge Economy: Issues, Applications, Case Studies, pages 1055–1062. IOS Press, Amsterdam, 2007.

[9] Bonfatti F. Monari P. D. *Semantic-based integration of innovative networking services and existing systems.*, volume Collaboration and the Knowledge Economy: Issues, Applications, Case Studies., pages 907–928. IIMC International Information Management Corporation Ltd, 2009.

[10] Kefalakis N. Leontiadis N. Soldatos J. Donsez D. Architecting rfid middleware. In *Internet Computing, IEEE.*, 2006.

[11] Kefalakis N. Leontiadis N. Soldatos J. Donsez D. *Middleware Building Blocks for Architecting RFID Systems.*, volume MOBILE LIGHTWEIGHT WIRELESS SYSTEMS Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering Volume 13, pages 325–336. Springer, 2007.

[12] Protégé developers. Protégé web site. http://protege.stanford.edu., July 2006.

[13] Beneventano D. et al. *Synthesizing an Integrated Ontology.*, volume IEEE Internet Computing Magazine 9-10, pages 42–51. IIMC International Information Management Corporation Ltd, 2003.

[14] Bokma et al. *Improving business information exchange using semantics.*, volume Collaboration and the Knowledge Economy: Issues, Applications, Case Studies., pages 501–508. IOS Press, Amsterdam, 2007.

[15] Rodriguez-Fernandez D et al. *Demonstrating Autonomic On-demand Content Delivery.*, volume Future Multimedia Networking, pages 206–211. LNCS, 2009.

[16] DG Enterprise. European Commission. e-business watch, October 2009.

[17] DG INFSO EuropeanCommission. European interoperability research roadmap, July 2006.

[18] DG INFSO EuropeanCommission. European interoperability research roadmap, July 2006.

[19] Bonfatti F. Berselli M. Martinelli L. Stradi F. Reactive planning and scheduling in clusters of small companies. In *proceedings of Echallenges 2011*, 2011.

[20] Goncalves R. J. Bonfatti F. *The Road for SEEM: a reference framework towards a Single European Electronic Market.* John Wiley & Sons, Inc., 2008.

[21] Klaus Finkenzeller. *Fundamentals and Applications in Contactless Smart Cards and Identification.* Wiley, 2003.

[22] Lampe M. Floerkemeier C. Rfid middleware design - addressing application requirements and rfid constraints. In *Proceedings of the 2005 joint conference on Smart objects and ambient intelligence: innovative context-aware services: usages and technologies (sOc-EUSAI 2005)*, 2005.

[23] Pucihar A. Bogataj K. Lenart G. *Increasing SMEs'efficiency through the single European electronic market as a new business model.*, volume Synthesized organization, pages 347–368. P. Lang, Frankfurt am Main, 2009.

[24] IBM. Ibm autonomic computing initiative. http://www-01.ibm.com/software/tivoli/, March 2010.

[25] I. et al. Ignatiadis. Virtual breeding environment for smes in the erp/crm industry using a service oriented approach. In *World review of Science, Technology and Sustainable Development, 7, 1-2, (2010)*, 2009.

[26] Martinelli L. Kefalakis N. Soldatos J. Automatic document tracing using the rfid technology. In *proceedings of Echallenges 2011 conference*, 2011.

[27] Zarokostas N. Dimitropoulos P.D. Soldatos J. Rfid middleware design for enhancing traceability in the supply chain management. In *Proceedings of the IEEE 18th International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC 2007)*, 2007.

[28] KASSETTS-consortium. Deliverable 4.1.2 "data model and vocabulary". http://www.kassetts.eu, March 2010.

[29] KASSETTS-consortium. Deliverable 4.2.2 "networking ict platform". http://www.kassetts.eu, March 2010.

[30] Leontiadis N. Soldatos J. Donsez D. Kefalakis N. Middleware building blocks for architecting rfid systems. In *Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering.*, 2005.

[31] Bonfatti F. Monari P.D. Martinelli L. A proposal for a logistic domain ontology. In *proceedings of IST-Africa 2010*, 2010.

[32] Li M-S. Meeting the grand challenge of the enterprise interoperability research roadmap – a business perspective ecosystems of small companies in the enlarged europe. In *Expanding the Knowledge Economy: Issues, Applications, Case Studies*, pages 505–512, 2007.

[33] OASIS. Ubl specification. http://goo.gl/VU6uh, Jun 2009.

[34] Barbi M. Bonfatti F. Monari P.D. A concrete step towards seem implementation: the seamless infrastructure and services. In *ICE 2008 international conference, Lisbon (Portugal).*, 2008.

[35] Bonfatti F. Martinelli L Monari P.D. Autonomic approach to planning and scheduling in networked small factories. In *proceedings of Pro-Ve 2010 conference*, 2010.

[36] Delina R. *Reputation Building for Electronic Marketplaces*, volume Ambient Intelligence Perspectives, pages 66–72. IOS Press, Amsterdam, 2009.

[37] RFIDROISME-consortium. Official project web site. http://www.rfid-sme.eu, May 2011.

[38] D. et al. Romero. A virtual breeding environment reference model and its instantiation methodology. In *PRO-VE'08, Poznan (2008)*, 2008.

[39] CEN ISSS WS BII Workshop. Business interoperability interfaces on public procurement in europe. http://goo.gl/O44Ik, Jun 2009.