

# Second decade on Collaborative and interoperable computing, CINCO

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*CINCO group is one of the original NODES groups, building up from distributed middleware paradigms and reaching towards efficient support of networked business computing needs over the Internet. The group goal is to facilitate the automation of the service collaboration management between peer partners by service interoperability and contracting support, as well as open service ecosystem capabilities of multifaceted control of collaboration correctness.*

## 1 Introduction

CINCO group is one of the original NODES groups. It builds up from distributed middleware paradigms towards efficient support for networked business computing over the Internet. As an application area, networked business involves collaboration and cooperation between independent organisations on shared business opportunities.

The general approaches for supporting business and enterprise computing has faced a significant change over the years, currently enforcing enterprises and organisations to transition from monolithic enterprise computing systems (such as ERP and CRM) to the use of more generic computing platforms, more modular service-based architecture, and compositions of business services across organisational boundaries. At large, the same supporting patterns are applicable to public sector services and federations of social networking services.

The CINCO group abbreviation stands for Collaborative and Interoperable Computing. The group name was changed from Open Distributed Computing Environments about twelve years ago, to reflect the advancement on the research field. While distribution middlewares have become widely accepted, supporting the networked business ideology and further utilising the paradigm of remotely accessible services in a global scale over the Internet have become the next widely accepted goals. As this research domain had no coherent name, so we had to rely on a combination of concepts on inter-organisational collaborations and interoperability.

The CINCO group specific goal has been to increase the facilities and automation opportunities on the collaboration management by shared processes by the peer partners. The work started with global architecture of infrastructure services including service discovery and selection, collaboration contract negotiation, contract-based control and monitoring of the collaboration. It was then extended towards business transaction management with breach discovery and resolution, and reputation-based trust management and privacy preservation architecture.

Further, management of the collaborations as a group lead to the definition of open service ecosystem architecture. The management routines have to do with the validity and verified correctness of the collaborations and the overall strategic direction of collaborations with ecosystem values (what kind of collaborations are preferred and what kinds denied), and awareness of overall cost, resourcing and equality of the services produced through the collaborations.

The ecosystem and collaboration facilities also set requirements for service engineering methodologies and tools. We rely on the modern model-driven engineering methodologies to produce models not only for service production and governance, but also for operational-time control and change management. Models of business processes, services, collaboration types, and policies also enable automated checking of service interoperability on technical, semantic and pragmatic levels, despite of the missing visibility of the peers' detailed solutions. Model repositories also enable automatically controlling the acceptability of actual collaborations dynamically at the operational time, thus defusing a lot of collaboration risks. Risks can be mitigated by adding facilities for detecting failures, and introducing new support functions for rectifying the failure situations at the appropriate level, whether it is within organisation, among the collaborating partners, or involves the whole ecosystem.

## 2 Evolution on service interoperation across organisational boundaries

In general, the fundamental challenge to be addressed in inter-organisational collaborations is related to the sovereign nature of the involved organisations. Autonomy must be preserved for deciding on provided services, utilised platforms, selected business domains, adopted business processes, acknowledged vocabulary, perceived trust and protected privacy.

Traditionally, enterprise computing systems formed isolated monolithic systems requiring costly integration projects to acquire necessary capabilities for collaboration. As a first wave, the intra-organisational "stovepipes" of workflows on each organisational activity area were connected with shared communication platforms and databases, shared vocabularies for products and service values, as well as definitions of shared workflows. Workflows between people were in due course automated to business processes involving humans and software services. Eventually, the same started to happen between organisations as well. Unified conversation patterns across organisation boundaries were called for, and standards for cross-organisational business processes developed, such as SWIFT and RosettaNet.

The traditional distributed computing platforms provided a flat, organisation unaware set of computing nodes connected with communication solutions with fixed properties. On top of those, the B2B middleware added awareness of inter-organisational communication and a variety of business transaction models. They helped with on-the-fly transformation of message exchanges to reach interoperability on technical and semantic levels. For example, with web services the XML-based annotation of data allows dynamic representation transformations. While solutions for distributed business process management, web services as remote service invocation mechanism, and ontologies were developed for sharing semantic annotation for information, the enterprise interoperability over internet was not mature.

We need platform-agnostic facilities that encapsulate the services with their computing platform and organisation-specific features, leaving only externally visible service behaviour abstraction for collaboration designers and run-time partners to manage.

Therefore, the CINCO group provides support for concepts that bridge the business world practices and the distributed computing world techniques. The key concepts to be supported are **business services, contracts, negotiation, selection of services (and therefore partners), trust and privacy, and breaches**. At the same time the dynamicity of contracted collaborations must be maximized and the requirements on the shared distributed computing platform features minimized.

For reaching the maturity in inter-enterprise service collaborations, a number of development waves had to take place.

- **Service sciences** provides a view that is reaching over the business domain and other soft sciences and focus on the paradigm of service. Service became understood as a key element in cocreation of value by partners involved in exchange of services, whether provided by individuals, public or private organisations, groups, or software agents.
- **Maturing enterprise architectures** and frameworks capture both business models and the way business models get implemented by the use of business processes, knowledge, people, and computing facilities. As part of this, awareness of portfolios of services provided to other organisations. Further, the smooth use of these services call for ontologies to helping organisations to agree on the use of services.
- **Enterprise interoperability** is the domain of research that addresses organisation modeling, ontologies, information systems and internet-wide facilities for supporting joint work across organisational boundaries. While enterprise interoperability focuses on organisational collaborations, a more light-weight goal is service interoperability. **Service interoperability** means the effective capability of business services to mutually communicate information in order to exchange proposals, requests, results, and commitments. Technical interoperability is concerned with connectivity between the computational services, allowing messages to be transported from one application to another. Semantic interoperability means that the message content becomes understood in the same way by the senders and the receivers. This concerns both information representation and messaging sequences. Pragmatic interoperability captures the willingness of partners to perform the actions needed for the collaboration. This willingness to participate refers both to the capability of performing a requested action, and to policies dictating whether it is preferable for the enterprise to allow that action to take place. In comparison to other interoperability support systems, the pragmatic interoperability captures not only composability requirements, but also mutual willingness to work together, for example, sufficient trust. However, organisational or cultural interoperability aspects are out of the scope.
- **Metaprogramming** provides means for using abstract, formal models to capture, compare, agree and modify the key structure and behaviour of services without knowledge on their internal implementation. **Model-driven engineering** provides tools for the generation of implementations from models, and further, hierarchies in which metamodel levels can control the consistency and correctness of lower level nodes in the hierarchy. These properties are

valuable for constructing repositories collaboration-related knowledge, as independent organisations may contribute to the repositories while the main correctness criteria remain intact. Models are a key element also for **reflective systems**, where the abstract model is causally connected with a real system that it used to control. The reflective system has a structural and behavioural model about itself. It supports operations on changing its model by its clients, but is further able to react to the exceptions triggered by its controlled system by making deductions on required changes on its own model. Moreover, it is able to use management interfaces of the controlled system to implement required changes so that the model and controlled system remain in synchrony. Most importantly, the reflective system model allow us to use a contract model for controlling inter-enterprise collaborations.

With this background, the CINCO group research mission has been to develop solutions for service interoperability and management of dynamically formed collaborations for increased automation of multi-party, subjective management of inter-enterprise collaborations comprising of business services.

The solutions are

- enabled by **mature, open service ecosystem architecture** and governance;
- supported by a **global ecosystem infrastructure** that supports interoperability and contract-based collaboration management (establishment, control and breach recovery; trust, privacy, NFP); and
- complemented with **service-oriented software engineering, with MDE** and BPM based system composition practices.

The CINCO group results forward each of these domains into required directions for automated management of business service collaborations and for facilitating open service ecosystem use and evolution.

The CINCO group vision over the last ten years has been that the open service ecosystems provide individuals or organisations the means of composing inter-enterprise collaborations out of existing software-supported business services, and facilities to dynamically manage that collaboration during its operational time. While virtual organisation breeding environments provide tools for catching new business opportunities and facilities for jointly designing the necessary collaboration contracts, business processes, and monitoring routines, we wish to take a step further. The open service ecosystems add the goal of reacting quickly to routine opportunities by reusing the pre-designed collaboration types and adding eContracting processes with operational time renegotiation opportunities. Furthermore, the aim is to adopt new, previously unknown partners' services for scaling up the size of the ecosystem and its potential for spawning large amounts of inter-enterprise collaborations. In addition, the open service ecosystems present ecosystem wide governance and trust-decisions subjectively done by each of the independent collaboration partners.

Some of our contributions on the above areas are further described in the following.

### 3 Inter-enterprise collaboration management facilities

The overall Pilarcos ecosystem architecture for inter-enterprise collaboration management includes

- business services published in the service ecosystem by member organisations;
- inter-enterprise collaborations composed of eContract-agent governed compositions of business services from independent organisations;
- local ecosystem infrastructure service agents for each organisation for contract negotiations, contract-supported collaboration lifecycle management interfaces, private decision-making facilities for trust and privacy aspects, and storing enterprise policies for restricting local business services; and
- globally accessible ecosystem infrastructure services such as populator agent, eContract agent, business process and service type repositories, and breach recovery processing.

This is illustrated in Figure 1 as a four tier solution. Tier 1 represents business service agents and their eContract-agent controlled collaborations and dynamic life-cycle. The lifecycle is supported by the second tier agents that together form a CaaS, Collaboration as a Service, ecosystem infrastructure interface. The ecosystem infrastructure has both agents local for the ecosystem member organisations, and global agents that are provided by organisations making business out of that. The ecosystem services and collaboration patterns are created using the tools and methodologies provided by the third tier that supports service-oriented, model-driven software engineering. In the bottom, the ecosystem is grounded by joint regulation and rule setting facilities by which the infrastructure agents are fed the rules on service consistency and collaboration style acceptability governance, for example.

*The architecture itself is somewhat different to the related work*, for example, in terms of focusing on multi-partner contracts, utilising a concrete contract agent at operational time, and having a different take on trust and privacy management aspects. The contract agent allows reflective system pattern to be used for collaboration control across heterogeneous organisational environments. The contract also includes both business level and technology level details. Further, the breach management approach aims at reacting to breaches at real time, instead of as post-processing, and involves the ecosystem as well the original collaborating parties to the breach recovery phase. The overall architecture has been formally modeled and verified.

Below some key agents and subsystems are discussed further. These have been realised as research prototypes as well, to elaborate on their usability, feasibility in performance terms, and potential risk areas.

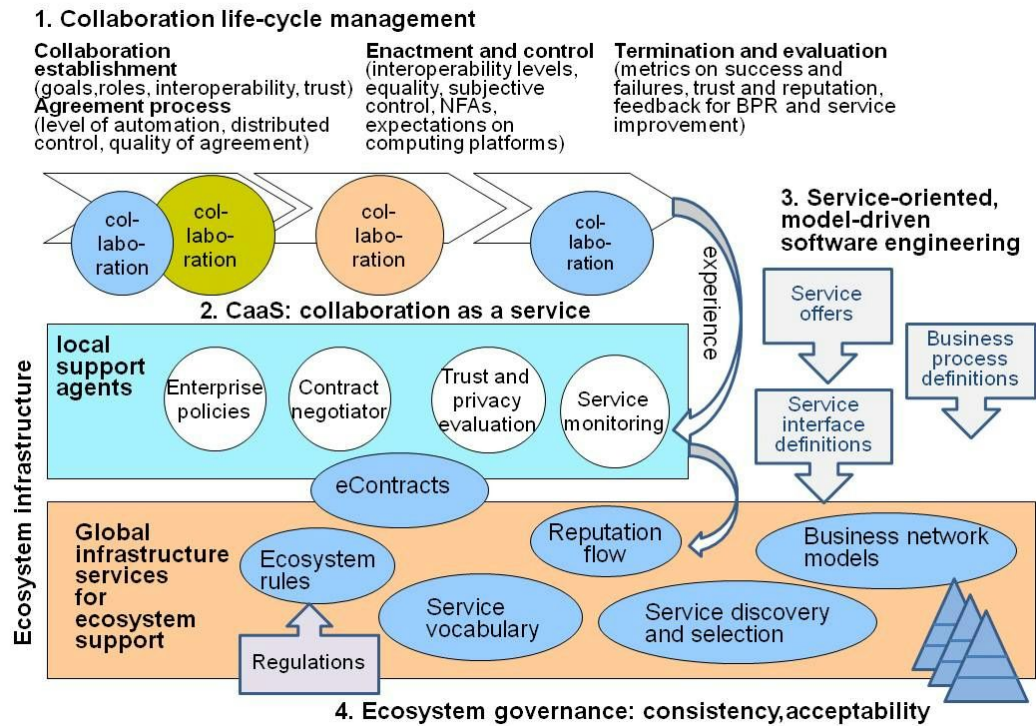


Figure 1: Open service ecosystem architecture presented in a four-tier solution.

First, the *Pilarcos populator* (in Fig.1: service discovery and selection) expands the simple service discovery concepts most related architectures provide. Instead of a client-server relationship, the populator addresses the need of finding business services for all the roles of involved business processes. A concept of business network model (BNM) is used here to denote a collection of business processes with some roles required to be connected; for example, in a purchase situation the role of buyer in one process and the payer in another business process must be taken by the same partner. The benefit of using BNMs is in using a construct that captures all business processes involved with the joint activity, and all supporting organisations as well; therefore, for example refusals of collaborations with some partners extend to supporting processes as well. In addition (to, or instead of,) selecting business services to fill the BNM roles, the populator checks the interoperability potential between the parties.

Second, *eContracting process* continues from where the populator leaves off. While the populator works totally on the public information exported by the ecosystem organisations in the form of service offers (tenders), the refining negotiation phase involves only the potential partners in the collaboration proposal generated by the populator. Each organisation makes a private decision on joining or discarding the collaboration proposal, depending on strategy-dependent rules on partners, business network models, or goals of the collaboration, as well as trust and privacy related decisions. Trust is judged by balancing the importance of capturing the business opportunity and the risk involved into it, based on the experience and reputation on the peer services' history of successes and failures.

Privacy risks are judged separately, to be able to focus on the potentially accumulated information on peers that might reveal sensitive knowledge. These decisions can be automated whenever organisational policies categorise the situation as a routine opportunity, if the trust decision is clear enough. New type of opportunities and trust values between automated rejections and approvals are forwarded to human decision-making.

Third, the eContracting process creates an **eContract agent** that is unique for each collaboration. It is structured according to the **BNM**, and carries the selected service offers for each role fulfilled. Further, it carries the agreed **policies that restrict the collaboration's behaviour** from what is generally possible based on the BNM. The eContract agent also has interfaces for collaboration members to change the collaboration structure, policies, membership and other properties.

The eContract agent utilises reflective system structure where the abstract model is used for controlling the real system by connecting the model and system together with causally connecting routines. This structure enables encapsulation of heterogeneous platforms, service implementations, and organisational structures. The reflective model isolates the abstract model used for agreements from the local technical realisation of services and monitoring.

The eContract agent further enables a well-structured way of **controlling business transactions**; business transactions are commonly agreed to be "dirty" and cause external, real world effects, that cannot be reversed at failure situations.

Our definition of interoperability points to capability of exchanging knowledge and information about process control events, making proposals and counter-proposals, and committing to contracts. Further, interoperability requires **capability to detect contract breaches** and settling them with a negotiated resolution processes. Breaches are defined in terms of **deontic logic** instead of boolean logic, thus addressing the independence of organisations. The communication protocols supporting interoperability management involve speech acts from multi-agent system theories.

Fourth, the use of eContract agent and the selected interoperability definition enables us to give a novel definition for **trusted business transaction**:

*A business transaction is a complex interaction between multiple independent business services that*

- *strives to accomplish an explicitly shared business objective (either periodic or continuous);*
- *has a clearly defined cobehaviour leading to this objective in terms of exchanges of information and behaviour controls; that is, has*
  - *mutually negotiated conditions of success (reached state over relevant aspects); and*
  - *mutually negotiated but subjectively detectable breaches:*
- *has clearly defined, mutually negotiated set of actors (not necessarily the same than in the beginning) and their cobehaviour for breach recovery for each identified class of contract breach.*

Still as part of the fourth subsystem, trusted business transactions provides facilities for **subjective management of collaborations** by each partner. Each of the collaboration peers is able to use



eContract agent operations for suggesting contract changes. These change operations fulfil ACID transactional properties. In the interactions between business services, there are no ACID property requirements or overall data consistency requirements, but only the requirement of following the contracted BNM and policies. The eContract controls this collaborative behaviour that is enacted by autonomous business services (considered as agents), by listening reports from **local monitors** in the peer organisations. The local monitors listen the messaging of the business services and look for indicators of misbehaviour either in their own organisation or in the peer organisations. The outgoing requests may not fulfil the requirements of enterprise policies, while incoming requests may be unexpected communications from contracted parties or unknown parties. The architecture of eContracts and business transaction management is illustrated in Figure 2.

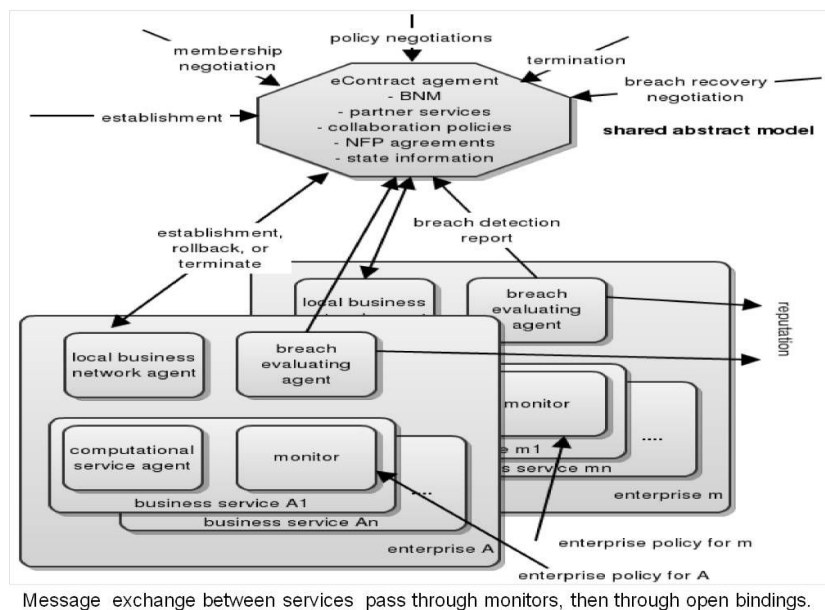


Figure 2: The eContract enables subjective management of trusted business transactions.

The local monitors is often considered as an essential subsystem on its own, as it enables not only breach detection, but also collection of measurement information on business service behaviour in terms of non-functional properties, such as timeliness, privacy preservation, and fulfilment of user expectations. In Pilarcos, all purposes of monitoring utilise the same set of monitors, and all administrative policies are to be transformed to simple, efficient-to-compute rules for these monitors. For Pilarcos monitors, the characteristic feature is that they monitor also outgoing messages, thus protecting the organisation from violations against its own policies, and enables for example documents being protected from being accidentally exposed due to too generic data sharing policies.

Fifth, Pilarcos architecture includes a **reputation-based trust management system**. In social sciences, it has been discovered in that any group of humans or organisations can scale only up to about 150 units, given some rules of behaviour. A group of about five individuals can collaborate

without further rules or external assignment of authority figure. In larger groups, up to about twenty independent actors, a leader must be identifiable and norms be expressed by the leader. Furthermore, some form of social punishment must exist to create the incentives for collaborative behaviour. For larger groups, all group members must participate the norm control, not only by punishing those who breach the norms but also those who fail to control that norms are followed. Reputation-based trust management is a computational analogy for this. Furthermore, as the upper limit of the group size depends on our capability of identifying individuals without help, computer support allows the ecosystem size to scale up far further.

The trusted business transaction management hooks in the trust decision making points at collaboration establishment time and further at each milestone or epoch during the collaboration life-cycle. The trusts decision is based on the organisations own experience on the collaborators but also on the received experience reports from other members of the ecosystem, taken in as weighted with the source credibility and letting older experience reports having less weight. Each organisation make their own interpretation on the credibility of the reputation flow, instead of the ecosystem making such decisions on behalf of its members. The reputation flow messages may be either negative or positive in nature. In the trust decision-making the organisations consider four assets, namely monetary, reputation, fulfilment and control aspects. This reflects to the facts that in each transaction funds may be lost or gained, and reputation likewise, as the collaboration failure may affect the reputation of all partners in providing a service, although there might be just one guilty participant in that collaboration. Fulfilment refers to the collaboratively provided service match to the required service, and finally, the control refers to potential mitigation methods availability for deminishing the potential risks occurring.

Sixth, beside the trust decisions, the **privacy management** is enacted. Privacy preservation subsystem includes functions for declaring organisations or individuals privacy declaration, i.e. definition of policies for privacy preservation, and ecosystem infrastructure level functions to control that these policies are followed. The privacy policies can be controlled by monitors in a large degree. The computing differs tough from the trust decision computing, because the sources of information are different. The suitable algorithms for privacy preservation should, in addition to policies, also be aware of the accumulation of information to the partners and thus making in possible to detect the identity or other protected property of the organisation. Further, at the ecosystem level, it would be preferable to be able to catch information that has been forwarded against the permitted usage policies set by the organisations or individuals. This requires a log of users of information to follow the exchanged documents and information units.

Seventh, the **open service ecosystem infrastructure** contains two levels of basic agents and knowledge repositories, local and global, **for** the purposes of **correct behaviour of the collaborations**. The local agents address the private needs of organisations, including contract negotiations, and trust and privacy decisions. The global level includes repositories of service offers, business process definitions, and service types. These repositories support the agents such as the populator, as described above.

The infrastructure repositories do not present plain ontologies as usual, but are ***built according to MOF (meta-object facility) and MDE (model-driven engineering) principles***. Therefore, the repositories are able to restrict the acceptance of published models into those that are formally correct instances of the upper level modeling principles and also acceptable according to the criteria set by the ecosystem governance for the repositories. Ontology based repositories would just allow reusability of units in registries.

From the ***ecosystem governance*** point of view restricting BNM repository contents restricts the potential templates of collaboration contracts allowed in the ecosystem. Similarly, the restrictions to service offer repository restricts the acceptability of business services in the ecosystem. As eContract inherits features from BNMs, service offers, BNM policies, enterprise policies, the eContract model supports the use of reflective, dynamic management of the correct collaboration behaviour.

Eight, a methodology for engineering an open service ecosystem has been developed and evaluated. The metamodel repositories discussed above belong to the products of this methodology.

Finally, the ***service oriented software engineering*** that involves the production of business services and related software, models of the service interfaces and BNMs can utilise the MDE processes. ***As the benefit, models that provide an efficient production method are the same that are needed for enterprise architecture management and correctness control of the inter-enterprise collaborations at run-time.***

## Research methods

In the preceding ODCE group, and nowadays, in CINCO group, the prototypes of the individual facilities as well as the overall architecture carries the name Pilarcos. The prototypes have constantly been an important research asset, allowing us to use several research evaluation methods simultaneously, including architecture evaluation methods (such as ATAM), simulation, queue network analysis for performance estimation, and partially, for testbed and benchmark design.

In addition, the ecosystem infrastructure architecture has been formally modeled in Petrinet style, which allow observation of some essential system properties.

Besides the Pilarcos architecture and platform services we have developed a maturity model for service ecosystems for comparison purposes. It has a scope over the ecosystem infrastructure services, while related work focuses on SOA based technology solutions, business ecosystems or innovation ecosystems addressing different goals. This maturity model has been introduced in scientific forums and used in education.

## CINCO projects

CINCO group has run a number of projects during the last ten years, including the following TEKES funded projects:

- web-Pilarcos I and II in 2003-2005,
- Tube in 2004-2005,
- SOAMeS - Service oriented architecture for multi-channel electronic services in 2006-2007,
- Wish in 2007,
- Content Factory in 2009-2011,

The group has also been involved with ICT SHOK (initial preparation phase name), TIVIT (old name) or DIGILE (current name) activities as follows:

- ICT SHOK Flexible services preparation around 2007-2008,
- TIVIT Future Internet programme in 2009-2011,
- TIVIT Cloud Software programme in 2010-2013.

Moreover, much of the work was done in the Academy of Finland project

- Trusted business transactions (TBT) in 2009-2011.

## CINCO group participation on international research community on the field

CINCO group members have participated a number of international network, either as members or in more leading positions. These networks include:

- InterOP NoE in 2004-2007,
- InterOp VLab from 2008 onwards, including its educational committee,
- IFIP WG5.8 Enterprise interoperability,
- IFIP WG11-.11 Trust management,
- COST801 - Agreement technologies in 2009-2012, and
- SOCOLNET.

The work in these networks has resulted in the organisation of international workshops, conferences, and journal themes on the area. These networks are aimed both for research community, and for researchers and enterprises to mix.

Some of the resulting events belong to the series of conferences called EDOC, DAIS, IWEI and I-ESA. All of them have been sponsored by IEEE, ACM and/or IFIP, and have had low acceptance rates on submissions and excellent keynote speakers.

In addition, CINCO group members have participated standardisation work. Early on, the main involvement was with RM ODP (Open distributed processing reference model) later with SOA and Cloud computing.

## CINCO group educational activities

The CINCO group educational mission is to educate experts for

- enterprise engineering for global networked business;
- ecosystem infrastructure renewal;
- creation of tools and methodologies for developing software-based services and service systems, involving appropriate quality aspects of the services and systems;
- developing governance facilities for aligning business and computing systems.

The CINCO group provides courses, seminars, and PhD and MSc thesis advisory on the above mentioned research issues, and works toward integrating this educational program to an international curricula.

Regular courses have included

- Service Ecosystems,
- Service oriented software engineering with MDE,
- Business process automation, and
- Model-driven engineering.

Regular seminar series run on each term on

- Trends in Enterprise interoperability and
- Trends in Service-oriented computing

with a changing theme depending on the topical issues and level of students registered.

Further, the practical aspects of service ecosystem infrastructure service production and use can be practiced in CINCOLab where small programming and modeling oriented tasks can be tried out.

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