CrossFlow: Cross-Organizational Workflow Management for Service Outsourcing in Dynamic Virtual Enterprises

Paul Grefen
University of Twente
Netherlands
grefen@cs.utwente.nl

Karl Aberer
EPFL-DSC
Switzerland
karl.aberer@epfl.ch

Heiko Ludwig & Yigal Hoffner
IBM Zurich Research Lab
Switzerland
{hlu,yho}@zurich.ibm.com

Abstract

CrossFlow is an ESPRIT/IST project for support of cross-organizational workflow management in dynamically established virtual enterprises. The business paradigm of CrossFlow is that of dynamic service outsourcing, in which one organization (service consumer) outsources part of its business process to another organization (service provider). Service consumer and provider find each other through electronic market places and specify their collaboration in an electronic contract. This contract is then used to dynamically configure an infrastructure that connects and controls the workflow management systems of both organizations to facilitate provision of the service. The infrastructure supports fine-grained monitoring and control to allow tight cooperation between the organizations.

1 The CrossFlow context

Today, companies focus on their core business and outsource secondary activities to other organizations. Growing complexity of products requires co-makership relations between organizations. Value chains require a tight cooperation between companies participating in these chains. To enable the creation and operation of these virtual organizations, the information processing infrastructures of participating organizations need to be linked. Automated support for processes crossing organizational boundaries is an essential element. The advent of business-to-business electronic commerce adds a dynamic dimension to this: virtual enterprises are formed and dismantled dynamically in rapidly evolving markets. Consequently, their process support infrastructure must also be dynamic. Two key elements need to be integrated: trading systems that allow business partners to find each other dynamically and workflow management systems that control the processes in and across the organizations.

Electronic trading systems have become commonplace in the large-scale advent of electronic commerce. Mostly, the trading systems focus on trading objects, i.e., physical objects like books, oil or wheat, or immaterial objects like seats in an airplane. To support the dynamic creation of tightly linked virtual enterprises, however, it is business processes or business services that are traded. This requires a detailed way to specify services in terms of abstract process structures, process parameters, quality of

Bulletin of the IEEE Computer Society Technical Committee on Data Engineering

service guarantees and primitives to monitor and control the enactment of services. On the other hand, this requires a standardization of services in the context of specific application domains, like the logistics industry or the insurance industry.

Today, workflow management systems (WFMSs) for automated process support are widespread. They ensure well-structured and standardized management of processes within organizations. Using workflow support in virtual organizations, however, implies that workflow management systems in different organizations be linked to manage cross-organizational processes. The extended workflow support must deal with heterogeneous workflow environments, well-specified levels of autonomy of partners in a virtual enterprise, and dynamic formation and dismantling of collaborations. Linked workflow systems should allow the service consumer organization to start a process (a service) on its behalf in the service provider organization and receive the results of this process. As black-box processes are too coarse for tightly cooperating organizations, advanced monitoring and control mechanisms are needed for fine-grained interaction between these organizations, while preserving their autonomy as much as possible.

CrossFlow is a European research project defined in the 4th ESPRIT Framework (currently IST) that researched and developed the integration of e-commerce and cross-organizational workflow management to support service outsourcing in dynamically established virtual enterprises. CrossFlow aims at an end-to-end solution, including all functionality from contract establishment for outsourcing services to advanced workflow enactment for executing services. The project covers the complete spectrum from requirements analysis to prototype assessment in two real-world scenarios.

The prime contractor in CrossFlow is IBM, participating with its Zurich Research Lab, its La Gaude development laboratory, and its Böblingen software development site. Technology providers in the consortium are GMD-IPSI in Darmstadt, and the University of Twente, who contribute their experience in groupware and workflow management. User partners are KPN Research, research division of the Netherlands' largest telecom operator, and Church & General, an Irish insurance company that is part of the Allianz Group. Sema Group in Spain acts as industrial observer. The CrossFlow project was started in September 1998 and successfully completed in September 2000. Further information on the CrossFlow project can be obtained via the web site of the project (www.crossflow.org).

In this paper, we outline the CrossFlow approach to dynamic service outsourcing, based on extended cross-organizational workflow technology. Then we focus on the workflow extensions realized in the project. We end with conclusions and a few words on ongoing research and development activities.

2 The CrossFlow approach

The details of the CrossFlow approach to service outsourcing in dynamic virtual enterprises can be found in [Gre00]. Here, we illustrate the CrossFlow approach via a simplified view on the CrossFlow architecture. During the service outsourcing life cycle, the architecture exists in different phases [Hof00]:

1. contract establishment to define service outsourcing in a virtual enterprise on the business level.
2. infrastructure setup to create the infrastructure for enactment of the outsourced service.
3. actual enactment of the outsourced service including cross-organizational monitoring and control.

In phase 1, the CrossFlow system acts as an electronic commerce platform. In phase 3, the CrossFlow system acts as an advanced cross-organizational workflow management system. Phase 2 caters for the transition between these two appearances.

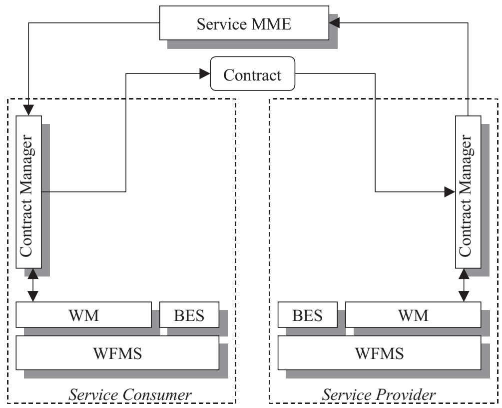

Figure 1: Contract making.

2.1 Contract establishment

In an electronic market for service-based virtual enterprises, three types of parties exist: service providers enact services on behalf of other organizations, service consumers outsource services to providers, and service matchmakers act as intermediaries (market places) between consumers and providers.

CrossFlow service providers advertise templates filled with service details to service matchmaking engines (MMEs). A consumer outsourcing a service contacts an MME with a template describing the service. The MME informs the consumer of matching providers by sending it their service templates. The consumer selects a provider and creates an electronic contract describing the specific service from the provider's service template by adding the service parameters it requires. The consumer sends the contract to the selected provider. If the provider accepts the contract, a virtual enterprise is formed.

The architecture for this is depicted in Figure 1. Both consumer and provider organizations use workflow management systems for their business processes. CrossFlow contract manager modules both contact the service MME and make the contract. The contract manager is shielded from the specific workflow management system by the workflow module (WM) for portability across workflow platforms. Back end systems (BES) may be required for specific functionality in contract enactment. The CrossFlow MME is based on IBMs e-market technology [Hof99]. Service templates and electronic contracts are based on the same data model that allows a definition of the service, including abstract process specification and specification of additional services required for service enactment [Koe00]. The data model is mapped to an XML-based contract specification language to allow easy module interoperability.

2.2 Infrastructure setup

After a virtual enterprise is defined by a contract, contract details are used to construct an infrastructure for service enactment. The infrastructure is built in a symmetric way by configuration managers at consumer and provider [Hof00]. The contract service details allow the construction of an infrastructure tailored to the specific service by selecting the appropriate modules and parameterizing them to obtain the desired behavior. As shown in Figure 2, the infrastructure consists of three types of modules. A coordinator module provides connection functionality between all modules at one site. A proxy gateway (PG) provides the external interface to another organization. Cooperation support service (CSS) modules provide additional cross-organizational services on top of plain workflow management [Lud01]. Depending on requirements specified in the contract, appropriate CSS modules are used in a specific infrastructure (discussed below).

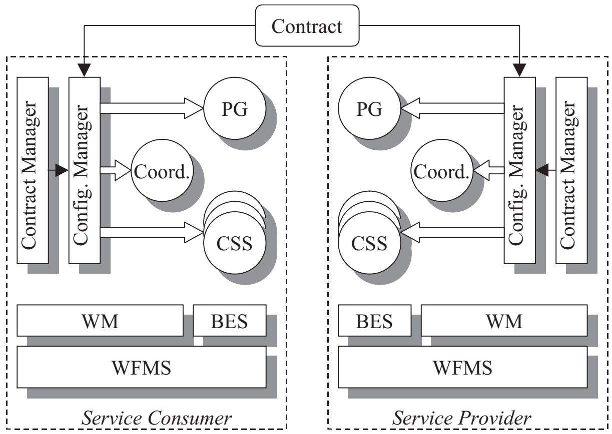

Figure 2: Infrastructure setup.

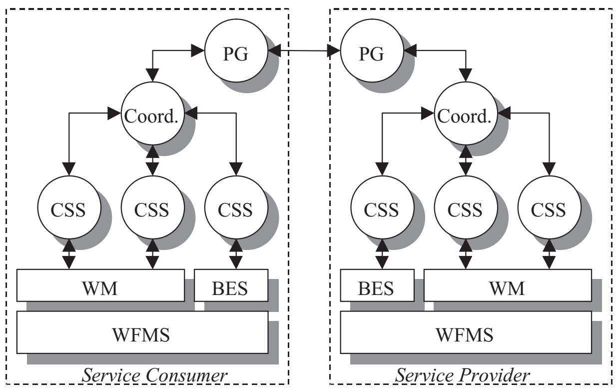

Figure 3: Service enactment.

2.3 Service enactment

After the enactment infrastructure has been set up, the outsourced service can be enacted. For this purpose, the various modules communicate with each other as illustrated in Figure 3. Specific CSS modules may need to access dedicated back end systems (BES) to perform their tasks. The enactment of outsourced services requires a complex cooperation between all CrossFlow modules and the commercial platform below them. The CrossFlow modules are all realized in Java and communicate via RMI. The commercial platform consists of MQSeries Workflow (extended with a dedicated module to enable high-level transaction management) running on top of the DB2 database management system.

The dynamically constructed infrastructure is discarded once service enactment is completed.

3 Cooperation support services

In the CrossFlow project, three types of CSS modules provide advanced support for cross-organizational workflow management. These are discussed in this section. As mentioned before, the CrossFlow architecture allows the addition of more types of CSS modules as required by application domains, e.g., to support automatic remuneration or trust management. The selection in the CrossFlow project is based on requirements of the scenarios used in the project and the background of the participants.

3.1 Quality of Service monitoring

Quality of Service (QoS) parameters associated with the execution of outsourced workflow processes relate to different dimensions, like the time needed to execute a service, the quality of its results, and the cost of service execution. Constraints on those parameters are specified within a contract. A workflow that is outsourcing part of its process needs to know about the proper execution of the outsourced workflow part. This is achieved by observing the actual values of the QoS parameters. For this purpose, the QoS CSS module provides both online and offline monitoring functionality.

Online monitoring allows the inspection of QoS parameters during the execution of an outsourced service. By default, monitoring is performed in a pull mode by the consumer. To enable a push mode, notifications can be specified in the contract by means of simple event-condition-action (ECA) rules. The information obtained during online monitoring can be either used for immediate reactions or be stored in a log for offline monitoring. Immediate reactions can be performed by informing the Flexible Change Control and Level of Control modules (see below).

In the log file for offline monitoring, the externally observable events of a service together with time stamps are collected. From this, a stochastic model of the observed workflow is built. This model is used to predict future executions of the service, based on continuous time Markov Chains [Kl99a]. These predictions are required by the planning algorithm of the Flexible Change Control.

3.2 Flexible Change Control

Flexible Change Control (FCC) provides the ingredients for executing flexible workflows [Kl99b, Kli00]. The flexible workflow model allows the global goals of the business process to be expressed explicitely. They are given as part of the workflow specification (QoS goals). In addition, execution alternatives can be specified as part of the workflow process specification. Depending on the workflow execution state, those alternatives are selected at runtime that satisfy the global goals optimally.

The flexible workflow model is based on a standard workflow model, providing the usual constructors, including OR-split, OR-join, AND-split and AND-join. This model is extended with additional constructors that allow the specification of execution alternatives. These alternatives are specified in the FCC enactment clauses of a contract. The additional constructors allow the specification of alternative activities, non-vital activities, and optional execution order.

Actually deciding, i.e. optimally selecting the next steps for reaching the global workflow goals under a given workflow state is then done by the FCC module that provides efficient planning algorithms and can exploit available knowledge on the requested services. This knowledge is derived both from the specifications given in the contracts and the performance models derived from offline QoS monitoring.

3.3 Level of Control management

The Level of Control (LoC) cooperation support service provides fine-grained process control in cross-organizational workflow execution and addresses both implicit and explicit process control.

Implicit process control, in the form of advanced cross-organizational transaction management based on the X-transaction model [Von00], provides reliable cross-organisational workflow executions. The X-transaction model distinguishes three transactional process levels in a cross-organizational workflow: outsourcing level at which the workflow is started; contract level at which a mutual process is defined; and internal level at which the outsourced process is implemented. X-transaction process rollback is based on compensation. For this, an extension of the WIDE approach [Gre99] is used. Management of X-transactions is realized by two software layers. The ITM layer handles rollbacks within one organization on the concrete workflows level. The XTM layer handles rollbacks on the abstract workflows level defined in a contract. Pairs of XTM and ITM CSS modules in two organizations cooperate to support cross-organizational rollbacks. The ITM module is linked to the underlying WFMS to actually execute a rollback.

Explicit process control is offered to support process control primitives (PCPs) that provide means for the consumer to control the providers workflow execution. Supported control primitives are *stop*, *continue*, *rollback*, *abort*, and *change case variable*. A pair of PCP CSS modules handles cross-organizational process control, invoking transaction management CSS modules where necessary.

4 Conclusion and outlook

CrossFlow has been a broad investigation of a marriage of cross-organizational workflow management and electronic commerce. The project has resulted in a framework for electronic contracts, an architectural framework for dynamic service outsourcing, frameworks for three types of cooperation support servcies, and an integrated prototype implementation of the frameworks. The prototype was used to build demonstrator platforms for two real-world scenarios in the logistics and insurance domains. The demonstrators are currently on display in IBM's Industry Solutions Lab in Zurich. Detailed information on the CrossFlow results is available through the CrossFlow web site (www.crossflow.org).

From a commercial exploitation point of view, the concepts and technology developed in the project will be used in IBM's e-business and workflow development groups. The two demonstrators form the basis for analyzing the application of CrossFlow technology by the two user partners in the consortium.

From a research point of view, a number of issues require further work after the completion of the project. Spin-off research has been defined by the academic partners in the areas of e-contract support, flexible change control, and flexible architectures for e-business systems.

Acknowledgments. All current and former members of the CrossFlow project team are acknowledged for their contributions to the project.

References

[Gre99] P. Grefen, B. Pernici, G. Sánchez (eds.); *Database Support for Workflow Management*; Kluwer Academic Publishers, 1999.

[Gre00] P. Grefen, K. Aberer, Y. Hoffner, H. Ludwig; *CrossFlow: Cross-Organizational Workflow Management in Dynamic Virtual Enterprises*; Int. Journ. of Computer Systems Science & Engineering, Vol. 15, No. 5, 2000.

[Hof99] Y. Hoffner; *Supporting Contract Match-Making*; Procs. 9th IEEE Int. Worksh. on Research Issues in Data Engineering; Sydney, Australia, 1999.

[Hof00] Y. Hoffner, H. Ludwig, C. Gülcü, P. Grefen; *Architecture for Cross-Organisational Business Processes*; Procs. 2nd Int. Worksh. on Adv. Issues of E-Commerce and Web-Based Information Systems; Milpitas, CA, 2000.

[Kl99a] J. Klingemann, J. Wäsch, Karl Aberer; *Deriving Service Models in Cross-Organizational Workflows*; Procs. 9th IEEE Int. Worksh. on Research Issues in Data Engineering; Sydney, Australia, 1999.

[Kl99b] J. Klingemann, J. Wäsch, K. Aberer; *Adaptive Outsourcing in Cross-Organizational Workflows*; Procs. 11th Conf. on Adv. Systems Engineering; Heidelberg, Germany, 1999.

[Kli00] J. Klingemann; *Controlled Flexibility in Workflow Management*; Procs. 12th Conf. on Adv. Systems Engineering; Stockholm, Sweden, 2000.

[Koe00] M. Koetsier, P. Grefen, J. Vonk; *Contracts for Cross-Organizational Workflow Management*; Procs. 1st Int. Conf. on Electronic Commerce and Web Technologies; Greenwich, UK, 2000.

[Lud01] H. Ludwig; Y. Hoffner; *CRAFT: A Framework for Integration Facilitation in Cross-Organisational Distributed Systems*; Procs. 9th EUROMICRO Worksh. on Parallel and Distributed Processing; Mantova, Italy, 2001.

[Von00] J. Vonk, W. Derks, P. Grefen, M. Koetsier; *Cross-Organizational Transaction Support for Virtual Enterprises*; Procs. 5th Int. Conf. on Cooperative Information Systems; Eilat, Israel, 2000.