

# Process awareness for distributed software development in virtual teams

Schahram Dustdar and Harald Gall  
*Distributed Systems Group, Vienna University of Technology*  
Argentinierstrasse 8/184-1, 1040 Wien, Austria  
{dustdar, gall}@infosys.tuwien.ac.at

## Abstract

*Organizations increasingly define their software development projects as “virtual project teams”, where project members from within the organization cooperate with outside experts and therefore build a “community”, which in many cases operates as a highly distributed team. Process modeling, - composition and – configuration are substantial ingredients for team activities. This paper analyses the needs for process awareness for virtual teams and derives the requirements for location-transparent distributed and mobile collaboration. It describes the design of virtual project teams that contain mobile users, their artifacts, and processes. The paper distills a framework for process aware virtual project teams that goes beyond current technologies such as peer-to-peer, multiple servers and clients, as well as Workflow Management and Groupware systems.*

**Keywords:** software processes, virtual organization, distributed software development, Workflow

## 1. Introduction

The software engineering community refers to “software processes” as the sum of all software engineering activities, encompassing the entire software life cycle from requirements analysis to maintenance [11, 14]. Naturally, as with all high value business processes, software processes are subject to frequent changes (exceptions). Several process-modeling systems have been built in industry as well as in academia. The argument of this paper is that *process awareness* is of paramount importance to software teams. Teamwork is a fundamental property of many business processes. Business processes have well defined inputs and outputs and serve a meaningful purpose either inside or between organizations. Organizations in-

creasingly define their software projects as “virtual project teams”, where project members from within the organization cooperate with outside experts and therefore build a “community”, which in many cases operates as a highly distributed team. The project members work on business processes (e.g. Design Review, Product Development) but often project members realize their work as a project and not necessarily as part of a larger business process. Their work often leads to artifacts (documents, products etc.), which need to be shared among project community members.

Business processes in general and their corresponding workflows in particular exist as logical models (weighted directed graphs). When business process models are executed they have specific instances. A business process consists of a sequence of activities. An activity is a distinct process step and may be performed either by a human agent or by a machine. A workflow management system (WfMS) enacts the real world business process for each process instance [2, 3, 7, 20]. Any activity may consist of one or more tasks. A set of tasks to be worked on by a user (human agent or machine) is called work list. The work list itself is managed by the WfMS. The WfMC [21] calls the individual task on the work list a work item. Software systems for workflow management, Groupware, process modeling [9, 14, 15], and project management have been used to automate or to augment business processes in organizations [5, 8 10, 13, 20]. Workflow management systems have been defined as “technology based systems that define, manage, and execute workflow processes through the execution of software whose order of execution is driven by a computer representation of the workflow process logic” [21]. Workflow systems generally aim at helping organizations’ team members to communicate, coordinate, and collaborate

effectively as well as efficiently. Therefore WfMS possess temporal aspects such as activity sequencing, deadlines, routing conditions, and schedules. WfMS are typically “organizationally aware” because they contain an explicit representation of organizational processes (process model).

However traditional WfMS present a rigid work environment consisting of *roles* and their associated *activities and applications*. In this context they do not provide support for virtual project teams such as frequently changing process participants, ad-hoc formation of groups collaborating on a business process, and device independent support of group activities. Unfortunately today’s WfMS assume that each *work item* is executed by a *single worker* [1].

Hence, distributed teamwork as found in virtual project teams for software development, such as teams collaborating by jointly executing a work item find no support by WfMS. Current WfMS focus on automating structured (modeled) intra-organizational business processes. Groupware [13], on the other hand, typically does not contain any knowledge or representation of the *goals* or underlying business *processes* of the group [13, 20]. In recent years there has been considerable attempts to merge workflow-, groupware-, and business process modeling technologies [12]. Industrial research labs [6, 8] and product teams [4, 17, 18] have made significant steps forward. Future collaboration systems aiming at supporting virtual project teams focus on covering inter-organizational activities and processes including product value-chains on the Internet [19] regardless of location (mobility) and regardless of devices used.

Virtual project teams turn to software systems such as business process modeling tools, workflow management Systems (WfMS), groupware, project management systems and hope that those systems provide sufficient support for their requirements. In today’s business environments participants in virtual project teams (VPT) demand process awareness to a relatively high degree of the software they use for collaborative work. In addition organizational awareness (e.g. roles) and mobility aspects become increasingly relevant. Current WfMS and Groupware systems do not combine those features that virtual project teams require: *information sharing, process sharing, process composition, and process configuration*. Future systems for virtual project teams need to facilitate not just mobility of content to group members, but also *mobility of context* of activities in business processes, i.e. providing information about process instances, the team

configuration (i.e. participants and their roles), their associated artifacts, and connectivity modes of group members (such as fixed, mobile, or ad-hoc).

The organization of this paper is as follows: Firstly, it presents current technology support for virtual project teams. Secondly, it discusses relevant issues on process awareness including a case study for virtual project teams in the context of process aware collaboration. Then a framework for process aware teamwork is elaborated. Finally our paper concludes with a summary.

## 2. Current technology support for virtual project teams

Recent advances in the area of Internet Computing and collaborative business process management systems (WfMS, Business process modeling systems, Groupware) are often seen as key enablers for facilitating business processes in organizations. Cooperative tasks in teams are increasing, and as a consequence the use of collaborative systems is becoming more pervasive. To understand current collaborative technologies it is important to first analyze current systems. Figure 1 (adapted from [12]) denotes two dimensions for analyzing collaborative technologies potentially supporting virtual project teams: *Process structure* and *Task Automation*.

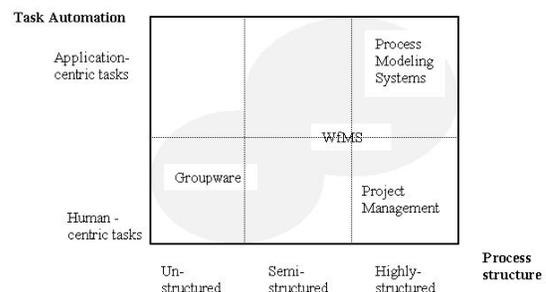


Figure 1. Collaborative Technology Framework

A business process can be unstructured (ad-hoc), semi-structured, or highly structured (modeled). For example a business process such as “customer order entry” can be modeled using a traditional WfMS. However a *highly structured* process can only be enacted (instantiated) as it was designed. If an exception occurs, a workflow administrator needs to re-model the process before the execution can continue. This limits the usability of WfMS in a world where

constant adaptation to new situations is necessary [13] and where teams are increasingly mobile and distributed. An example of an *ad-hoc* process is discussion of a project's design review using Groupware. A *semi-structured* process consists of groups of activities, which are modelled; however in contrast to a structured (modelled) process it may also consist of activities, which are not pre-defined. A process is semi-structured, when there might be one or more activities between already modeled activities such as *assign process* (see Figure 1), which are not known beforehand and therefore cannot be modeled advance. An example of a semi-structured process such as "Design Review", which can be found in many engineering groups, is explained in more detail in Section 3.1.

The second dimension presented in Figure 1 is *Task Automation*. Here we distinguish between two modes: human centric and application centric tasks. Human participants of a business process perform human-centric tasks. Application-centric tasks are mostly automated by software systems. Technologies used in organizations today basically can be associated to one quadrant of the framework shown in Figure 1. For example WfMS' strength is the instantiation of highly- or semi-structured business processes. WfMS are weak when applied to teams where no process model is known (e.g. new product development). Groupware systems ranging from message-based systems to group decision support systems offer support for teamwork. However, they are not designed to enact workflow processes and are not "process aware". Project management systems only support one view, namely the project manager's view. They do not support dynamic interaction (instantiation) of processes. More recently project management systems combine with information sharing tools (shared workspaces) to provide a persistent storage for artifacts. To summarize: Current systems on the market do not provide enough functionalities as required by virtual project teams: flexibility, dynamic views of relationships between artifacts and team members, and process awareness.

### 3. Process awareness

Today's virtual project teams have a set of characteristics: Team members are increasingly mobile, they jointly work on artifacts, and team members require knowledge about the multiple relationships between the artifacts and the context they were created, shared, and distributed (i.e. who, what,

when, in which context). Shared workspaces such as shared folders or web-based folders do not provide any information on the relationships between artifacts (e.g. a document) and the associated activity of a business process (e.g. activity "presentation for customer XYZ"). Process aware systems have to enable participants to join virtual project teams, to share process artifacts in teams and across teams, and to use different means of communication to collaborate on a particular business process (e.g. asynchronous or synchronous).

To provide process awareness support for virtual project teams, we propose a framework consisting of three orthogonal dimensions: Organizational Unit, Location, and Process. The dimension "Organizational Unit" (e.g. an organizational role such as "Project Manager") consists of functional departments or skill sets that have to be applied to various business process activities. The dimension "Location" denotes the geographical location of the virtual project community team members. The dimension "Process" describes possible process stages of any given business process (e.g. Testing, Engineering, Manufacturing). A virtual project team (VPT) can therefore be defined as a 3-tuple consisting of information on Organizational Units (O), Location (L), and Process (P) or  $VPT := \langle O, L, P \rangle$  with the following definitions: Organizational Units  $O = \{o_1, o_2, \dots, o_n\}$ ; Locations  $L = \{l_1, l_2, \dots, l_m\}$ ; Process  $P = \{p_1, p_2, \dots, p_k\}$

Virtual project teams can be instrumented in many different ways considering the requirements of the actual organizational unit, the process, and the location: some instrumentations consider the location-aware dimension, i.e. it is of particular interest where the resource actually is residing; others use the framework in a location-transparent way in which it is important that some task is carried out but independently of where the actual resources are. The same principle applies to the other two dimensions "organizational unit" and "process." In a particular context the use case "expert search," for example, can be considered location-transparent (on, pk, \*) or location-aware (on, pk, "Vienna"). For another context it could also be useful to consider variations of it, for example, ("Implementation", pk, "Vienna") or combinations of it. Depending on the requirements for the mobile distributed collaboration scenario, the instantiator of a process would define the corresponding virtual team along the O, L, and P dimensions. A business process, which often can be

found in virtual project teams across industries, is a “Design Review” process.

### 3.1 Case Study: Design Review Process

This section introduces a typical semi-structured generic design review process to be found in many engineering projects. The process involves several roles. A *Program Manager* is responsible for multiple projects and assigns a *Review Manager* to a concrete project (e.g. design review for the mobile phone product named “Talky”) and informs him about the constraints such as budget and time. The *Review Manager* is the overall process (project) owner and as such responsible to the *Program Manager*. He delegates two major activities, process composition and - configuration to the *Project Manager* by providing two directives to the *Project Manager*: compose a process (instance) by defining its activities, the direction of the workflow, and by the respective activity durations and secondly configure the process by defining a member list and the associated artifacts (e.g. documents).

The *Project Manager* assigns *Project Members* (1, 2) and searches for *External Experts* in the *Expert Pool* by the expert field, the overall process and the required project time frame. Finally, he selects those experts to join the virtual project team and assigns them to the process (process participants). The *Project Manager* assigns *External Experts* and *Project Members* with the required information about the process, the activities they will be responsible for, and the duration of those. *Project Members* as well as *External Experts* report the results of their work by submitting artifacts to the *Project Manager*. The *Project Manager* merges those artifacts, integrates his own input and provides the results to the *Review Manager*, who reports the end of the design review process to the *Program Manager*. Figure 2 summarizes the case study in an UML sequence diagram.

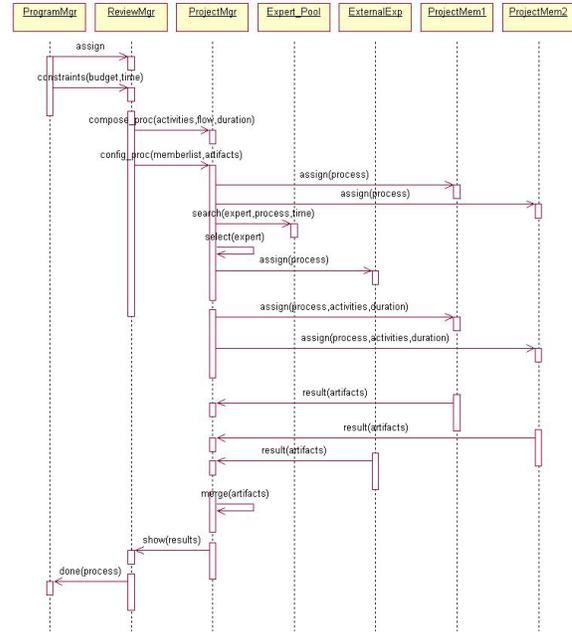


Figure 2. Sequence Diagram: Design Review Process

This case study can be found in many engineering project teams and provides the ground for our elaboration on the requirements and is used as a basis for a framework for process awareness support of virtual project teams. We explore this framework in the following section.

## 4. Framework for Process aware teamwork

The challenge is to build software systems supporting virtual project teams (VPT), which enable distributed, process aware, and mobile collaboration. Such system require functionalities currently found in *different* software application domains such as WfMS, Groupware, Business Process modeling tools, as well as in distributed systems, mobile computing and Internet applications. It is of paramount importance for a VPT system to enable geographically dispersed users with different modes of connectivity (fixed, mobile, or ad-hoc) to share information in various kinds such as using middleware and/or peer-to-peer technologies. Users need to register themselves and receive notifications on events, regardless of their location or device they use. Collaboration partners need to be empowered to locate each other, find experts in required domains and link all coordination information with artifacts

such as documents. Therefore the mobility of context (dealing with the questions of “who, what, why, when, and using which resources”) is essential for systems focusing on virtual project teams.

Example *use cases* of distributed and mobile collaboration include:

- Information sharing in teams (e.g. information about users, artifacts, processes);
- Expert search to look for human expertise in an enterprise;
- Searching for information in and across teams to allow users exploit enterprise knowledge;
- Notification of availability of resources (e.g. users going online, documents being updated, new teams being found, etc.)
- Communication in a team (different kinds of messages such as team messages, SMS, e-mail etc. as a means to reach team members even if they are not online)
- Team establishment and updating;
- Searching and inviting people for synchronous communications (e.g. chat, video/telephone conference);
- Synchronous collaboration on artifacts (e.g. shared group editing of a document);

Table 1. Requirements for virtual project teams

Requirements	Software Support
Information Sharing	Peer-to-Peer (P2P), Client/Server (C/S), Shared Workspaces for artifacts
Distributed Search	Peer-to-Peer, distributed queries (e.g. XQL), meta-data (XML)
Process Sharing	Workflow Management Systems
Process Composition	Process Modeling Systems
Process Configuration	Workflow instantiation, Artifacts-to-Process mapping persistence, Team-configuration management

To fulfill the above requirements, several technical solutions can be adopted. In the following we focus on the information sharing and distributed search requirements, as they are significant in adapting specific middleware software components.

P2P middleware allows different connectivity modes such as ad-hoc, fixed, or mobile and does not rely on the existence of particular servers [16]. Ad-hoc teams can be established easily or artifacts can be shared on peers as known from systems such as Napster or Gnutella clients. This flexibility can be combined with servers hosting particular artifacts or information about resources that should be available all the time (e.g. some documents or process information might have to be accessible all the time and reside on a special “peer” that is up and running all the time). For these different requirements P2P data sharing and C/S data sharing can be combined in an effective way to exploit the advantages of each paradigm in the context of process aware teamwork [18].

To further enhance the effectiveness of virtual project teams resources are described in meta-data that cover a description of each resource (such as documents, processes, users, teams, etc.) and enable a much more powerful search for information in an enterprise network. People can join teams based on their expertise or interest. Others can also search for information or people’s expertise and be notified whenever this is available in the system (on some peer or server peer). Meta-data is represented in XML and can be searched through, for example, XQL [22]. This allows flexibility in the definition of attributes for meta-data and provides additional extensibility for changing requirements. Artifacts themselves do not need to reside on server peers but can be on the peer of the team member who shares his document with a particular community. For important artifacts again the same scenario as described for persistent meta-data can be applied. Distributed searches exploit the P2P nature of the enterprise network by querying each community peer’s repository for artifacts. If meta-data are additionally stored on server peers then such searches even provide results if some peers hosting the particular documents are offline. Notifications and messaging services can be used to ask team members for certain documents or process descriptions in a location independent way since members can be notified by means outside such a process aware framework (e.g. SMS). For downloading the actual resources a direct Internet

connection based on http is established and, therefore, current Internet technology is exploited that way.

The mentioned technologies above allow a collaboration of team members regardless of their location or organizational unit but that is aware of the actual status of the process being followed (e.g. a Design Review Process template) in their team. Establishing teams, sharing artifacts such as design review checklists and review templates can easily be deployed according to the needs of enterprises and their specific processes. Process information and process status is distributed via the team concept. Co-ordination can be organized within teams and by integrating special purpose tools for virtual meetings or videoconferences.

Process awareness support is currently being implemented in a prototype for a large telecommunications company that focuses on design review processes and their support in a distributed and mobile collaborative setting across multiple geographically dispersed organizational units.

## 5. Conclusions

Today's collaborative technologies such as WfMS, Groupware, Project Management (PM) systems, and Business Process Management Modeling systems have assumptions about the structure and way of teamwork, which need to be reassessed. We increasingly find virtual project teams collaborating within and between organizations. However those virtual project teams find today's collaborative systems not in full support for their requirements. The fundamental problem relates to the lack of integration among those systems. With Business Process Modeling tools process designers may design a business process, but cannot enact it. Workflow management systems instantiate modeled business processes, are organizationally aware but typically lack flexibility and location independence, which is a key requirement for mobile teamwork. Groupware's strengths on the other hand are the flexible and often ad-hoc way of establishing teams and supporting their point-to-point collaboration. However groupware systems lack support for organizational issues (groups, roles, authorization, etc.) and are not equipped to design and to enact workflow processes. Project management tools typically only allow one view of a project, namely the view of the project manager. Project management tools also lack instantiation support of activities. In a sense they are static and require project (process)

participants to inform the project manager about their work status. Typically PM-tools do not provide support for collaboration among project participants. To summarize, process awareness, which requires visible association between process activities, their actors, and artifacts on one hand and support for geographic mobility and device independence on the other hand, is lacking in today's systems aiming at supporting collaborative virtual project teams.

This paper discussed the shortcomings listed above and provided a typical case study for virtual project teams in the engineering domain. Based on these requirements this paper distilled a framework for process aware virtual project teams exploiting technologies such as peer-to-peer, multiple clients and servers as well as Workflow- and Groupware systems. Future work will report on the evaluation results of the current prototype for this VPT framework.

## 6. References

- [1] Aalst, W.M.P. and A. Kumar (2001). A reference model for team-enabled workflow management systems. *Data & Knowledge Engineering* 38 (2001), 335-363.
- [2] Aversano, L. et al. (2001). Introducing Workflow Management in Software Maintenance Processes. *Proceedings of ICSM 2001*, 441-450.
- [3] Barnes, A. and J. Gray (2000). COTS, Workflow, and Software Process Management: an exploration of software engineering tool development. *Proceedings of the Australian Software Engineering Conference 2000*, pp. 221-232.
- [4] Bolcer, G.A. (2000). Magi: An Architecture for mobile and disconnected Workflow. *IEEE Internet Computing*, May and June 2000, 46 – 54.
- [5] Bussler, C. (1999). Enterprise-wide Workflow Management. *IEEE Concurrency*, 7(3), 32-43.
- [6] Casati, F. et al. (2001). Developing e-Services for composing e-services. In *Proceedings CaiSE 2001*, Computer Science Lecture Notes, Springer Verlag, 171-186.
- [7] Chan, D.K.C. and K.R.P.H. Leung (1997). Software Development as a Workflow Process. In *Proceedings of ICSC 1997*, 282-291.
- [8] Chen, Q. et al. (2001). Peer-to-Peer Collaborative Internet Business Servers. HP-Labs Technical Working Paper HPL-2001-14.

- [9] Conradi, R. and M.L. Jaccheri, "Process Modelling Languages", *Software Process: Principles, Methodology, Technology*, 1999, pp. 27-52.
- [10] Craven, N. and D.E. Mahling, (1995). Goals and Processes: A Task Basis for Projects and Workflows. In *Proceedings COOCS International Conference*, Milpitas, CA, USA.
- [11] Cugola, G. and C. Ghezzi (1998). Software Processes: a retrospective and path to the future. *Software Process – Improvement and Practice*, vol. 4, 1998, pp. 101-123.
- [12] Dayal, U. et al. (2001). Business Process Coordination: State of the Art, Trends, and Open Issues. In *Proceedings of the 27<sup>th</sup> VLDB Conference, Roma, Italy*.
- [13] Ellis, C.A. et al. (1995). Dynamic Change within Workflow systems. In *Proceedings COOCS International Conference*, Milpitas, CA, USA.
- [14] Garg, P. and M. Jazayeri (1996). *Process-Centered Software Engineering Environment*, IEEE Computer Society Press.
- [15] Gruhn, V. and U. Wellen (1999). Software support for distributed business processes. *Proceedings of the Software Engineering Conference APSEC 99*, pp. 200 – 205.
- [16] Gnutella (2001). Gnutella Homepage <http://gnutella.wego.com>
- [17] Hausleitner, A. and S. Dustdar (1999). Caramba - Ein Java basiertes Multimedia Koordinationsystem. In *Erfahrungen mit Java. Projekte aus Industrie und Hochschule*. Silvano Maffei, et al. (Eds.), dPunkt-Verlag, Heidelberg 1999.
- [18] Kirde E. et al. (2001). A Web-based peer-to-peer architecture for collaborative nomadic working. In *Proceedings of the 10<sup>th</sup> IEEE Workshop on Enabling Technologies: Infrastructures for Collaborative Enterprises (WETICE)*, Boston, MA, USA.
- [19] Puustjärvi, J. and H. Laine (2001). Supporting cooperative inter-organizational business transactions. In *Proceedings DEXA 2001*, Computer Science Lecture Notes, Springer Verlag, 836-845.
- [20] Schal, T. (1996). *Workflow Management Systems for Process Organizations*. New York: Springer
- [21] Workflow Management Coalition (WfMC) (1995). *Workflow Management Specification Glossary*, <http://www.wfmc.org>
- [22] XQL (1999). XML Query Language. <http://www.ibiblio.org/xql/xql-proposal.html>