Computer Supported Mobile Adaptive Business Processes for 3gERP Systems*

Position paper on the CosmoBiz research project (2007-2011)

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Abstract. Dynamic changes and evolution of workflow process descriptions and active instances has been an active research area since the mid 1990s. Most work has been focusing on centralized workflow servers executing workflows described in flow-graph languages formalised as variations of Petri Nets. We present a research project on Computer Supported Mobile Adaptive Business Processes (CosmoBiz) initiated in 2007 jointly with Microsoft Development Center Copenhagen, which aims to extend the state of the art to cope with mobile and distributed workflows, by uniting research in formal models for graph rewriting and typed process calculi, design and implementation of distributed systems, and computer supported collaborative work.

1 Introduction

Workflow and business process management systems based on high-level process description languages and a service oriented architecture are increasingly advocated as a means for providing flexible IT support of business processes and integration of enterprise applications.

The need for dynamic evolution of workflow processes and active instances has long been recognised, and it has been an active research area since the mid 1990s [1, 2]. Most work has been based on a flow-graph meta model similar to UML activity diagrams and formalised as a variation of Petri Nets. A formalisation makes it possible to state precisely in what sense dynamic changes are correct and allowable, and how changes in active instances and process definitions relate and propagate to each other. A precise definition of the effects of changes is crucial in order to achieve trustworthy systems.

Alas, the emerging standards for business process execution languages such as WS-BPEL [2], standardised by OASIS and pushed by major industrial players

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including Microsoft, IBM, Oracle, and SAP, are as yet only based on informal and ambiguous specifications and as such thus have no basis for supporting trustworthy dynamic evolution. Additionally, a large number of business and work processes, for instance within the transport, construction and sales domains, are inherently distributed or even mobile and location based. Since the need for dynamic evolution and adaptations of workflow processes often originates decentrally from the services or workers carrying out the individual activities, architectures and formalisations supporting the execution and evolution of business processes and workflows at any location are required.

We present in this position paper a cross-disciplinary research project at the IT University of Copenhagen on Computer Supported Mobile Adaptive Business Processes (CosmoBiz) initiated in 2007 and running for four years. The aim of the project is to provide formalisations and implementations of business process languages extended to allow for flexible mobile and disconnected operation of Enterprise Resource Planning (ERP) systems as developed by Microsoft Development Center Copenhagen [3]. To achieve this aim, the project unites research in computer supported collaborative work (described in Sec. 2), formal models for graph rewriting and typed process calculi (described in Sec. 3), and design and implementation of distributed systems (described in Sec. 4). The research will be informed by challenges provided by developers working on state-of-the art distributed and mobile business applications at the industrial partner, the Mobile Applications Group at Microsoft Development Center Copenhagen, and in particular by field studies and real cases of distributed and mobile business processes.

The CosmoBiz research project is divided into a PhD project and two PostDoc projects. The PhD project was initiated in August 2007 by Espen Højsgaard under the supervision of Thomas Hildebrandt and Arne Glenstrup, and focus on the research of formalisations of mobile adaptive business process execution languages as described in Sec. 3 and providing extensible distributed implementations as described in Sec 4. The goal of the first PostDoc project, carried out by Mikkel Bundgaard, is to research types for calculi and languages for mobile adaptive business processes. The primary goal of the second PostDoc project, recently initiated by Magnus Nilsson, will be, as described in Sec. 2, to identify adequate business process execution language constructs for distribution, mobility, and evolution, based on ethnographic field studies of mobile work processes and process evolution combined with experimental prototyping. This work will be carried out jointly with Kjeld Schmidt.

During the entire project period, research assistants and student programmers will contribute to the implementation of research-based prototypes of mobile business process execution languages as described in Sec. 4.

2 Studies of Mobile Adaptive Business Processes

Research in the area of Computer Supported Cooperative Work (CSCW) has been exploring and developing advanced information technologies that may sup-

port the coordination and integration of distributed activities in complex work settings. Significant progress has been made in understanding both how cooperating actors effortlessly align their activities by exploiting their knowledge of material settings and embodied actions to be aware of the changing state of affairs [4, 5], and how they devise and employ coordination constructs such as workflow specifications to handle complex interdependencies [6, 7]. At the same time, notable progress has been made with respect to the development of advanced technologies and formal notations to support coordinative practises [8–10].

As surveyed in [11, 12], there is a visible gap, conceptually as well as technologically, between the technologies that regulate pre-defined workflows and technologies that facilitate embodied practises of improvised and adaptive coordination [13]. This deficit becomes acutely visible when mobility of actors and resources is taken into account.

Taking as starting point the previous work on computer supported cooperative work outlined above, the CosmoBiz research project aims to carry out field studies of real cases of distributed and mobile business processes, of which some will be identified by the industrial partner in the project, Microsoft Development Center Copenhagen. This will provide challenging scenarios for dynamic evolution and result in quantitative and qualitative assessments of evolution techniques. Examples of scenarios already identified are mobile and distributed processes involved in supporting mobile sales people and consultants, homecare employees [12] and construction workers.

3 Formalising Mobile Adaptive Business Processes

As mentioned in the introduction, current standards for business process execution languages are as yet only based on informal and ambiguous specifications and thus have no basis for supporting dependable dynamic (nor distributed) evolution. In the CosmoBiz project we research formal models for business process and workflow processes. These models will ensure us a sound basis for extending languages with complex primitives for process evolution and mobility. The models will also be used as a foundation for the prototypes and development of type systems.

So far, our work has been concentrated on formalising subsets of WS-BPEL, representing a current state-of-the art business process execution language [14]. Providing a formal semantics for commercially used business process execution languages is a milestone for the international research efforts on process modelling and global ubiquitous computing [15].

More specifically, we have build upon the recent formalism of *bigraphical reactive systems* developed by Milner and co-workers [16, 17] which is a promising *general* semantical framework for mobile and ubiquitous communicating processes. Bigraphs is an extensible meta-model in the sense that one may define domain specific bigraph models and benefit from the general theory of bigraphs, just as well as XML is an extensible meta-language for semi-structured data in

which one can define domain specific semi-structured data formats and benefit from general XML technologies. From the extensibility of bigraphs, we obtain the possibility to make changes in the syntax and semantics of the business process languages that we formalise. Thus bigraphs provide us with the opportunity to continuously assess and adapt our formalisation with respect to the concrete business process language under consideration. In other words, the extensibility of the bigraph model supports flexible language engineering, and in fact, provides a basis for *process language evolution*. It have been shown that bigraphs can faithfully express traditional process calculi and formalisms such as condition/event Petri Nets [18], π-calculus and Mobile Ambients [19], and recently higher-order mobile resources [20], context-dependent mobile systems [21], and typed π-calculus [22].

In the paper [23] we propose and formalize a higher-order WS-BPEL-like language called *Higher-order mobile embedded BPEL* (HomeBPEL), where processes are values that can be stored in variables and dynamically instantiated as embedded sub-instances. A sub-instance is similar to a WS-BPEL scope, except that it can be dynamically frozen during a session and stored as a process in a variable. When frozen in a variable, the process instance can be sent to remote services as any other content of variables and dynamically re-instantiated as a local sub-instance continuing its execution. This conceptually relatively simple idea results in a very powerful higher-order business process language allowing to express a nested hierarchy of processes and business process management processes.

We exemplify the use of HomeBPEL by an example of pervasive healthcare, where instances of treatment workflows are moved between and executed locally on mobile devices belonging to either the doctor or the patient, depending on whether the treatment workflow requires actions by the doctor or it prescribes actions carried out as self-treatment by the patient.

The flexibility offered by mobility and dynamic distributed evolution makes the construction of correct business process descriptions more complex. We propose to address the complexity by adding type systems to the languages controlling aspects such as proper composition of processes [24–26], invocation of sub-processes, mobility of processes [27] and their access rights [28]. Not only do type systems play an increasingly important role for calculi for concurrency and mobility, they have also become more expressive; whereas original type systems ensured the absence of runtime type errors, contemporary behavioural type-and-effect systems ensure behavioural properties, such as deadlock-freedom [29]. We also plan to examine the approaches done for Boxed Ambients [30] and for the higher-order π-calculus [31] on the safe integration of higher-order mobility and sessions. Initial work on types for bigraphical reactive systems is presented in [32].

In the following section we will briefly outline the use of the bigraphical formalisation of the business process language for business process language design and prototype execution engines.

4 Implementing Mobile Adaptive Business Processes

One of the aims of the CosmoBiz project is to provide an implementation of a generic *process execution engine* that supports process language evolution as well as executing and evolving processes on a large number of mobile clients even in the presence of device disconnections. The challenges implementation-wise is to support *wide-scale distribution* of the processes and *lightweight engines* suitable for resource-constrained devices and *disconnected operation*.

The layers of the proposed implementation is shown in Fig. 1. We expect to explore possibilities for basing the implementation upon a value-oriented peer-to-peer distributed persistent storage middleware for storing XML documents, called XML Store [33]. On top of XML Store, we build an engine, called Distributed Reactive XML [34], which is a distributed implementation of an extensible distributed process calculus based on bigraphical reactive systems [16, 17]. The engine stores versions of XML documents representing the state of the execution (a bigraphical representation in XML of process as well as data) of the processes in the XML Store and executes the processes by distributed concurrent rewriting of XML documents with optimistic concurrency control. Finally, the engine allows us to capture the semantics of business process execution as bigraphical reaction rules represented as XML (demonstrated for a subset of BPEL in [35]), providing support for language engineering simply by changing the rewrite rules.

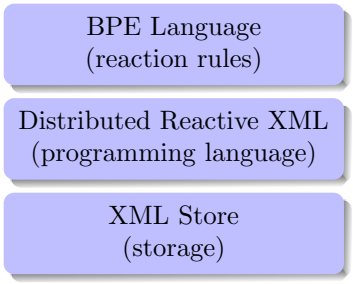

Fig. 1. The layers of the proposed implementation.

XML Store, by virtue of its peer-to-peer distributed storage layer, supports wide-scale distribution. The distribution will typically involve a number of more static peers which are more or less always available and a number of dynamic peers, laptops, PDAs, etc., which have intermittent connectivity and thus are expected to join and leave the storage layer regularly. Mobile clients thus may opt to directly be part of the storage layer as normal peers, or, in particular for resource-constrained clients, to be clients of the storage service rather than being peers.

One may obtain relatively lightweight execution engines by basing them on XML rewriting. Rather than using a database with a proprietary schema for storing process instances, we propose to simply store XML documents representing the state of each instance. For resource-constrained devices, we store only the parts of the process necessary for the (owner of the) the device; for example, for a mobile worker, only the state needed to carry out the work processes of the day. We are in the progress of implementing an execution engine suitable for mobile devices.

For mobility, supporting disconnected operation is essential. We cannot expect a mobile device to be continuously connected to the XML Store. However, XML Store is value oriented, which means that data items, once stored in XML

Store, do not change, and this allows us to aggressively cache or replicate parts of the overall state on each mobile device (as above only the necessary parts). By constructing a lightweight execution engine, we allow the mobile device to continue executing its processes with respect to its local state. Once connected again, optimistic concurrency control tries to reconcile local changes to the state of the overall system. Of course, it is necessary to investigate different strategies for handling conflicts during reconciliation.

So far the work on the implementation has been focusing on exploring the Mobile Development Framework [3] developed by the industrial partner at Microsoft Development Center Copenhagen since the start of the research project. The framework introduces a new simple XML-based orchestration language allowing to build customized workflow-driven applications for accessing the ERP systems Microsoft AX and NAV. Essentially an application consists of a set of tasklets, implementing simple services running on the PDA allowing for e.g. creating new orders, customers or looking up previous sales statistics. The tasklets are then orchestrated to fit the workflow of e.g. the mobile salesman.

A prototype business process orchestration engine has been implemented by student programmer Tijs Slaats, that can be executed on the windows mobile platform and orchestrate the tasklets used in the Mobile Development Framework. We expect to use this as a basis for experiments and prototype implementation of a general engine on the windows mobile platform based on XML-rewriting.

Recently, research assistant Tim Hallwyl has been working on developing a prototype engine for WS-BPEL based on XML-rewriting. We expect to use this as a basis for experiments and prototype implementation of a general engine for WS-BPEL based on XML-rewriting.

5 Conclusion and project plan

To summarize, the CosmoBiz project addresses the challenge of providing flexible process languages and models that allow seamless and trustworthy adaption, distribution, and mobility of workflows and business processes.

So far the project has been focusing on *imperative* process languages extended with primitives for higher order mobile embedded processes and formalized as bigraphical reactive systems. This has resulted in a proposal and formalization of HomeBPEL, forming the foundation for further studies of type systems for higher order processes.

For future work we expect to be considering the use of *declarative* process languages, which are being proposed as basis for dynamic and flexible business processes. Initial studies of uses of a declarative process model and its formalization as LTL has been carried out in [36, 37] in relation to the TrustCare research project [38]. While declarative process languages have been proposed as a means to achieve more flexible process descriptions with respect to the *logical* ordering of actions, we intent also to explore their use to achieve more flexible process de-

scriptions with respect to the *spatial* distribution and truly concurrent execution of actions.

Finally, we expect to contribute to the study of projections from global descriptions to local end-points and interfaces, in particular in researching how to support changes to processes, dynamic generation and verification of interfaces, and the generation of human user interfaces.

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