Context-Aware Content-Centric Collaborative Workflow Management for Mobile Devices

Anna Kocurova, Samia Oussena, Peter Komisarczuk
School of Computing and Technology
University of West London
London, UK
Anna.Kocurova,Samia.Oussena,Peter.Komisarczuk@uwl.ac.uk

Tony Clark
School of Engineering and Information Sciences
Middlesex University
London, UK
Email: T.N.Clark@mdx.ac.uk

***Abstract*—The paper examines mobile context-aware content-centric workflows. With the proliferation of mobile devices, distributed collaborative teams can communicate, share content and remain productive while working out of the office. The collaboration process can be enhanced, more dynamic and efficient by using a workflow management technology that responds to collaborators' requirements, supports coordination of a teamwork and is adapted for context-aware content manipulation. This paper discusses context awareness and proposes to extend the existing collaborative workflow approach by a context-aware content lifecycle in order to make workflow processes more adaptive to collaboration needs.**

***Index Terms*—mobile; peer-to-peer; context-aware; content; workflows.**

I. INTRODUCTION

Collaborators use mobile computing in everyday life and expect to have the same or better services as traditionally available in desktop computing. In contrast to traditional computing, systems targeting mobile devices face a number of constraints in terms of location variability, context changes, network data connectivity and resource sharing [1]. Mobile devices reside in extremely dynamic contexts and mobile systems with the ability to react to frequent context changes can be more flexible and adapted to user needs.

Collaborative workflow management is a technology that supports coordination of geographically distributed collaborators and content manipulation, and can be used in a mobile setting. In order to utilise workflows in ubiquitous environments, adaptability and context-awareness are the features that should be included in the workflow mechanism [2]. Context awareness might have a number of meanings based on the domain to which it is applied. In this work, context is related to two workflow concepts: context-aware content and context driven workflow execution.

A. Context-Aware Content

Context information can semantically enrich a piece of mobile content. Content such as a picture, document or audio file is usually user-generated or adapted for use on mobile devices. For example, context-aware content can be a picture associated with information about the physical location, the time when it was taken or a certain user preference. From creation to disposal, content pass through various stages of its lifecycle. Context information can be added or changed in any stage of its lifecycle. So sharing of context-aware content between workflow participants and managing its lifecycle over a number of devices is challenging, especially if one task can be completed by a number of collaborators. Existing process-centric workflow approaches provide only a limited support for the recognition of a context-aware content lifecycle.

B. Context-Driven Workflow Execution

A context change can control start and termination of tasks or drive the overall workflow execution. How context is integrated in workflows depends also on an underlying management topology. In case of a centralised management topology, only light-weight workflow process support is provided on mobile devices. Decisions made by one or more servers with deployed workflow management system do not consider contexts in which the collaborating devices currently reside. Moreover, this topology is impractical for small-scaled workflows, especially in situations in which servers are not available or in business meetings when colleagues want to share private information. The need for mobile device workflow centric process operating in a completely distributed manner has been recognised [3]. Only in a peer-to-peer (P2P) management topology, management decisions can be based on the device's local, context-related information and workflows can become more context-oriented processes adapted for current collaborators needs.

This paper shows a work in progress and describes a research idea for integrating a context-aware content-centric perspective and context awareness into mobile collaborative P2P workflow management. The combination of the concepts offers promising opportunities which can enhance mobile collaboration. The presented idea is accumulated through an experimental construction of the following artefacts: a meta-model for workflow definition and software prototypes. The structure of the paper is as follows. Related work is discussed

 ISBN: 978-1-61208-206-6

in Section 2. Section 3 describes a case study. Section 4 discusses domain analysis. The research idea is outlined in Section 5. The final section 6 summarises the work in progress.

II. Related Work

This section describes work related to workflow contextualisation and artifact-centric workflow approaches. Workflow meta-models should support context modelling and its use in workflows [4]. Various frameworks for context modelling and management have been designed [5][6]. A number of works address workflow contextualisation [7][8]. These works rather offer general approaches for a wide spectrum of workflows. From our perspective, context awareness should be adapted for the problem it is applied to. Although no new context-related concept is introduced in this work, different approaches to context management and workflow contextualisation are proposed.

Focus on key business-relevant objects, their lifecycles and how services invoke on them has emerged [9]. However object-awareness in process-centric workflows is still very limited [10]. Entity such as content or business artefact is incorporated in an activity-based workflows as an input or output of an activity and the effects of how performed activities influence entity's behaviour are not visible [11]. Our goal is to integrate a context-aware content-centric perspective into workflows.

So, in summary, there is no existing mobile workflow management approach that would support context-aware content management, have a context-aware content lifecycle integrated and operate in a P2P context driven manner.

III. Case Study

The concept introduced in this paper is illustrated by using the following case study. A team of ten designers work on interior design of buildings. Designers often work out in the field using smart phones to communicate and directly share pictures. Although each design project is assigned to a particular designer, design decisions are never done by a single person. The following work pattern is used to complete projects. Based on client's requirements, a designer redesigns the room interior and takes a picture of the new room's look. The designer sends the picture to his fellow team workers in order to obtain at least two reviews within a short period of time. Often no more than few colleagues are at work at that particular moment and moreover, only some of them are able to review the picture within the required time. Ideally, the picture should be sent only to those colleagues who can review it. When two reviews are obtained, the designer is able to assess their comments and send the picture for final approval to client.

In addition, a simple rating system is used to aid in processing the pictures. Designers can add rating to the picture in a range between 1 as 'satisfactory' and 5 as 'not sure'. A designer can set up a preference specifying that only pictures with rating greater than 2 need to be sent for review. Other pictures do not need to be reviewed at the time. However, the preference can be changed anytime.

IV. Domain Analysis

In this section, domain characteristics are discussed.

A. Peer-to-peer workflow management

Without a centralised management unit, there are many challenges introduced. First of all, efficient resource sharing might be an issue. Secondly, each participating device needs to be aware of the workflow process definitions and also all multiple workflow process instances the device participates in. Each device executes only an allocated partition of the workflow and no single device has a complete view of the global workflow state. Finally, no fixed network infrastructure imposes challenges in identity and communication management.

B. Context Definition

Context describes the current situation of a user, a device or an environment regarding a specific purpose. User context can be a user preference, current activity or interest. Device's context might be its connectivity or battery level. Examples of environmental context might be the current time, the actual location or surrounding devices. Social context awareness, a core context to establish cooperative effort, relies on knowing the work context of fellow collaborators, such as their availability, current activity and location [13].

Workflow related context information can be categorised as case independent, case dependent with a priori knowledge and case dependent with no a priori knowledge [14]. In this work, only first two types of context information are considered. An example of case independent contextual information is connectivity. Information about connectivity is important anytime when a device needs to send a task, content or information to another device and is relevant to all collaborative workflow cases. On the other hand, user preferences or work context are information that are workflow case dependent with a priori knowledge. Each workflow case needs to have a predefined set of contexts which influence its execution. In addition, context definition is role-specific, therefore, specified for all roles involved in workflow cases.

C. Context Acquisition and Aggregation Mechanism

Context information that influences workflow execution may depend on a number of other contexts. All context information needs to be gathered and composed beforehand, see Figure 1. For example, *Connectivity* context depends on the current

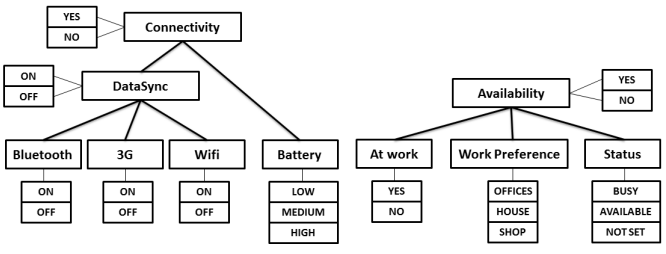

Fig. 1. Context Aggregation Example - Connectivity and Work Context

state of *Bluetooth*, *WiFi* or *3G*. If a context value of any of these contexts is *ON*, then data or content can be transferred. Sending content might be time consuming so it should be ensured that the device's *Battery* level is not *LOW*. The context value of the *Connectivity* is set to *YES* if *DataSync* is *ON* and *Battery* is either *MEDIUM* or *HIGH*.

Another example can be work context. Workflow execution is influenced only by the context value of reviewer's availability: *YES* or *NO*. Whether reviewer is available can depend on reviewer's work status, work preference or current availability. If the reviewer is at work, the picture theme belongs to his work preference and the status is set to *AVAILABLE*, the context information for *Availability* is set to *YES*.

Clearly, context acquisition and aggregation are concepts independent from workflow execution. The workflow management system does not need to know all context values because only the aggregated, final context information influences workflow execution. Therefore, context acquisition and aggregation can be separated and handled by a generic standalone context engine which is used to monitor, manage, aggregate and disseminate contextual information to the distributed mobile workflow management system as already presented in our previous work [15].

D. Context Adaptation

A context adaptation mechanism need to be integrated within the workflow management system. Both synchronous and asynchronous communications must be supported. An asynchronous communication mechanism is needed in order to receive all context information broadcasted by the context engine. Consequently all workflow instances which execution depends on that particular information are informed. In case when the context engine needs to be queried, a synchronous communication mechanism is used.

E. Content Sharing

Content sharing between devices might be a time consuming and costly operation, especially when one collaborative task may be accomplished by a number of actors with the same role but only few of them might be able to perform the task. Sending the piece of content to all of them would be inefficient in terms of transfer cost, device's resource usage and user's time consumption. A workflow management system running on each device would need to cope with the incoming content, store it and trigger an according action. Every participant would be informed about the task despite the fact that he might not be able to accomplish it within the required time.

F. Context-Aware Content and Lifecycle

A workflow process includes tasks that require interaction with content. At any given instant of time, content is in a specific state that is defined by values of ordinary metadata and context information. For example, after a picture is reviewed, it can be labelled as *Reviewed*. Collaborators often directly retrieve all pictures that are stored on mobile devices and would like to know in which content state the picture currently is. Content lifecycle can be described by a set of states and transitions between the states. Transitions between content states can be associated with context driven conditions. These conditions can influence content's behaviour and workflow execution. For instance, a designer decides to increase rating for a particular picture. Designer's preference determines that only pictures with rating higher than 3 can be proceed further in workflow and be sent to fellow participants. So this context change influences the execution of workflow at runtime. In order to sufficiently cope with the events at run-time, the context definition and its association with process definition must be expressed at build time. Moreover, there are two types of context information: workflow active and workflow passive. The workflow active context has an influence on the workflow execution whereas the passive context does not. The changes of context values might trigger certain actions.

V. Context-Aware Content-Centric Collaborative Workflows for Mobile Devices

A simplified example of the proposed adaptation of collaborative workflow for mobile devices is outlined in Figure 2. The collaborative work pattern presented in the case study can be abstracted into the workflow process presented in the middle and carried out by a distributed workflow management system deployed on mobile devices. A picture lifecycle can be integrated with the collaborative workflow process. Each activity that interacts with the picture is associated with a particular content state. Context driven conditions are placed on transitions between two content states. For example, the picture can go to the *Reviewed* state only if the value of added rating is larger than current *User Rating Preference*. Or the picture can go to the *Assessed* state only if the number of obtained reviews is more than the current *User Preference for Number of Reviews*. It is also depicted that the aggregated context values such as *Connectivity* and *Reviewer's Availability* can influence communication activities. Our assumption is that context driven conditions in the content lifecycle and coordinated social context-dependent workflow activities can effectively mediate the constraints of content sharing between workflow participants.

Currently, experiments have been conducted and a solution is under construction. The aim is to express the workflow definition at a metamodel level. A metamodel represents a language independent workflow ontology. An existing workflow process metamodel will be extended by three parts: context definition, context adaptation, and context-aware content lifecycle. A context definition defines the contexts, their aggregations and possible context values which influence the workflow execution. The context-aware content lifecycle part defines context information, states, transitions and context driven conditions for content handled in workflow. The context adaptation part expresses the adaptation itself. The knowledge is also mapped to an XML schema. Each context-aware content-centric collaborative workflow process definition can be described by an XML document that conforms to the XML schema and serves as a software input.

 ISBN: 978-1-61208-206-6

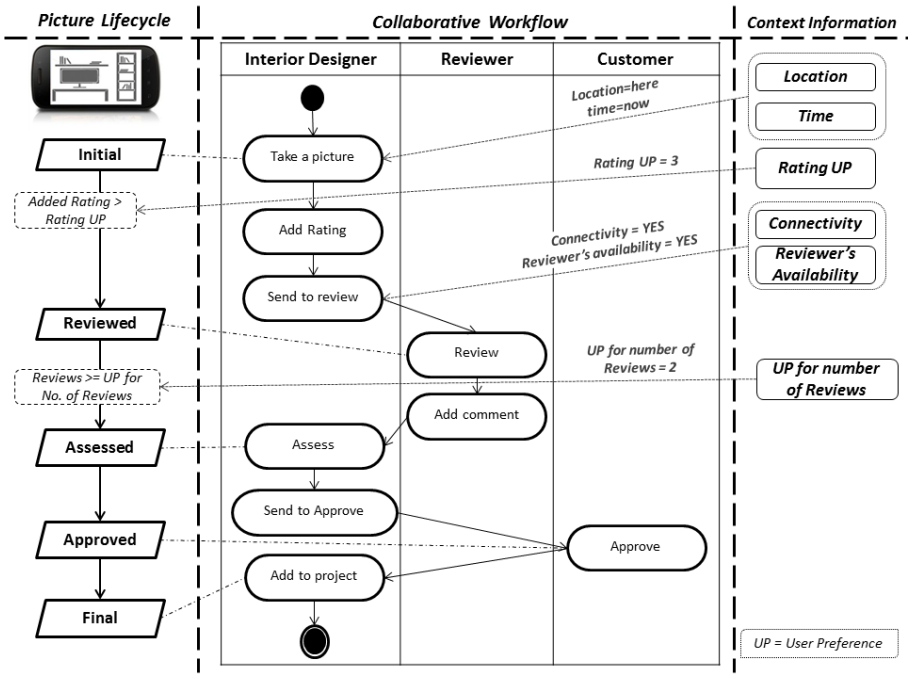

Fig. 2. Context-Aware Content-Centric Collaborative Workflow for Mobile Devices

VI. Conclusion and Future Work

The research aim is to adapt the collaborative workflow technology to mobile platforms with the objectives to achieve better mobile collaborative workflow management capable of processing contextual events and context-aware content manipulation. The proposed adapted workflow is a technology-based solution for mobile P2P collaboration and should have a positive impact for developers of certain classes of mobile applications.

A formal workflow model for context-aware content-centric collaborative workflow definition, management and execution is built. The model contains all necessary information about the adapted workflow process definition, management and execution. Prototypes of a context engine and a distributed mobile workflow management system capable of executing such workflows are under development on the Android platform. The context engine has been released as an open source software [16]. Future work includes finalising and evaluating of the workflow model and software prototypes.

References

[1] Q. H. Mahmoud, Middleware for Communications. John Wiley and Son, 2004.

[2] S. Smanchat, S.Ling and M. Indrawan, "A survey on context-aware workflow adaptations," in Proceedings of the 6th International Conference on Advances in Mobile Computing and Multimedia, 2008, pp. 414-417.

[3] L. Pajunen and S. Chande, "Developing workflow engine for mobile devices," in Enterprise Distributed Object Computing Conference, 2007.

[4] M. Wieland, O. Kopp, D. Nicklas, and F. Leymann, "Towards Context-aware Workflows," in CAISE 07 Proceedings of the workshops and doctoral consortium, 2007, pp.11–15.

[5] R. Reichle, M. Wagner, M. Khan, K. Geihs, J. Lorenzo, M. Valla, C. Fra, N. Paspallis, and G. Papadopoulos, "A comprehensive context modeling framework for pervasive computing systems," in Distributed applications and interoperable systems, 2008, pp. 281–295.

[6] J. Bardram, "The Java Context Awareness Framework (JCAF)a service infrastructure and programming framework for context-aware applications," Pervasive Computing, 2005, pp.98–115.

[7] M. Rosemann, J. Recker and C. Flender, "Contextualisation of business processes," in International Journal of Business Process Integration and Management 3(1), 2008, pp. 47–60.

[8] O. Saidani and S. Nurcan, "Context-awareness for adequate business process modelling," in Third International Conference on Research Challenges in Information Science, RCIS 2009, IEEE, 2009, pp. 177–186.

[9] R. Hull, "Artifact-centric business process models: Brief survey of research results and challenges," On the Move to Meaningful Internet Systems: OTM 2008, pp.1152–1163.

[10] V. Künzle and M. Reichert, "PHILharmonicFlows: towards a framework for object-aware process management" in Journal of Software Maintenance and Evolution: Research and Practice, 2011.

[11] K. Bhattacharya, R. Hull and J. Su, "A data-centric design methodology for business processes" in Handbook of Research on Business Process Management, 2009, pp. 503–531.

[12] I. Vanderfeesten, H. Reijers and W. van der Aalst, "Product based workflow support: dynamic workflow execution" in Advanced Information Systems Engineering, 2008, pp.571–574.

[13] J.E. Bardram and T. R. Hansen, "The AWARE Architecture: Supporting Context-mediated Social Awareness in Mobile Cooperation," in Proceedings of the 2004 ACM Conference on Computer Supported Cooperative Work, Chicago, Illinois, USA, 2004, pp. 192-201.

[14] M. Adams, A. Ter Hofstede, N. Russell, N. and W. van der Aalst, "Dynamic and context-aware process adaptation" in Handbook of research on complex dynamic process management: techniques for adaptability in turbulent environments/Ed. MM Wang, Z. Sun, 2009.

[15] D. Kramer, A. Kocurova, S. Oussena, T. Clark and P. Komisarczuk, "An Extensible, Self Contained, Layered Approach to Context Acquisition" in Proceedings of the Third International Workshop on Middleware for Pervasive Mobile and Embedded Computing at Middleware 2011, Lisbon, Portugal, 2011.

[16] https://github.com/deankramer/ContextEngine, 11.04.2012

 ISBN: 978-1-61208-206-6