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FLEXIBLE TASK COORDINATION FOR MOBILE WORKFORCE

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ABSTRACT

With the advancement of networking and mobile devices, more and more mobile business processes are automated and supported using the technologies. Mobile businesses processes are naturally exposed to uncertainty and dynamic changes that require distributed coordination. In large business organizations, the complexity of the processes also makes central control difficult due to the large number of variables to consider and mobile workers involved. To this end, this paper presents a flexible coordination mechanism for mobile workforce where multiple task assignment models are used together to adapt to dynamic changes and achieve efficiency. The overall system is flexible in that the assignment models are easily added because they are constructed as components, and the switch between assignment models are easy using manual or automated transition between the models. An example application of the model is presented using a real telecommunication organization in Europe where field workers install and repair telecommunication networks for customers.

Keywords: Business process, Mobile computing, Agent, Task Assignment Model.

INTRODUCTION

The ubiquity of network and widespread use of mobile devices allow more and more mobile business processes to be managed using the technologies. With the management of mobile business processes (mBPs), it is expected that mobile work will be performed more efficiently, delivering higher quality services to customers and business partners.

One of the unique and inherent characteristics of mobile business processes is that there is much uncertainty in mobile work compared with stationary work environment. Due to this nature, central planning and coordination often cannot reflect the frequent and dynamic changes in the mobile environment, leading to overall low efficiency of the work [1, 3, 4, 8, 10]

One of the recent trends to overcome the problem is the team-based approach wherein tasks are assigned to a team not to individual workers and the team decides who completes which tasks via a task assignment model (TAM) based on their local knowledge [7]. In line of this, this paper proposes a model of mobile task coordination that uses multiple task assignment models (TAMs) flexibly. By this approach, mobile teams can switch between different coordination methods easily, meeting the changing requirements in the uncertain environment. A novel system architecture called TeamWork is also developed where the TAMs are implemented as components so that mobile devices can receive and use different coordination mechanisms in real time.

This paper is organized as follows. The next section presents the TeamWork architecture. And then we show an illustrative example, which is followed by some details of implementation. We conclude with discussion, summary and future research directions.

TEAM TASK MANAGEMENT MODEL (TTMM)

Design Objectives of TTMM

The overall design goal of TTMM is to create a model for flexible coordination of mobile workforce. Detailed objectives are as follows:

- Multiple TAMs: The model should allow multiple TAMs to be easily created and used for coordination to meet many dynamic and distinct requirements arising in the mobile environment, because different types of mobile work or different characteristics of work environments require different TAMs. The model should also allow easy transition between TAMs so that teams can react to any changes quickly.
- Supporting mobile work: The model should incorporate modelling components that are essential for representing the common aspects of team-based mobile work, such as adjacency information between mobile teams and a pool model of skill and capabilities.
- TTMM as a meta-model: The model should be general to a certain degree so that it can be applied to many different types of mobile work environment.
- Abstraction for component-based architecture: For easy and quick deployment of TAMs, the model should have a proper abstraction that can be easily incorporated into a component-based architecture.

Formal Modelling of TTMM

A team-based task management model (TTMM) defines the structure and coordination processes for the management of team tasks. Team structure describes which roles are involved in the management and a coordination-process the flow of the

interactions among the defined team roles. Meta coordination process defines the sequences among the coordination processes in the task management. A TTMM provides all the participating agents in target system with contextual information on the team working. For the convenience of interpretation of the agents, this paper adopts XML as the basic description language of TTMM. A part of the DTD of TTMM is as follows.

<!ELEMENT ttmm (team, tam+, ttr+, adj-team+, def-tam)>

<!ELEMENT team (id, name, area)>

<!ELEMENT tam (tlm, role+, service+)>

<!ELEMENT tlm (ini-stat, status+, trans+)>

<!ELEMENT trans(pre-sta, service, post-sta)>

<!ELEMENT ttr (cond+, tam)>

<!ELEMENT cond (attr, value)>

<!ELEMENT adj-team (team-id+)>

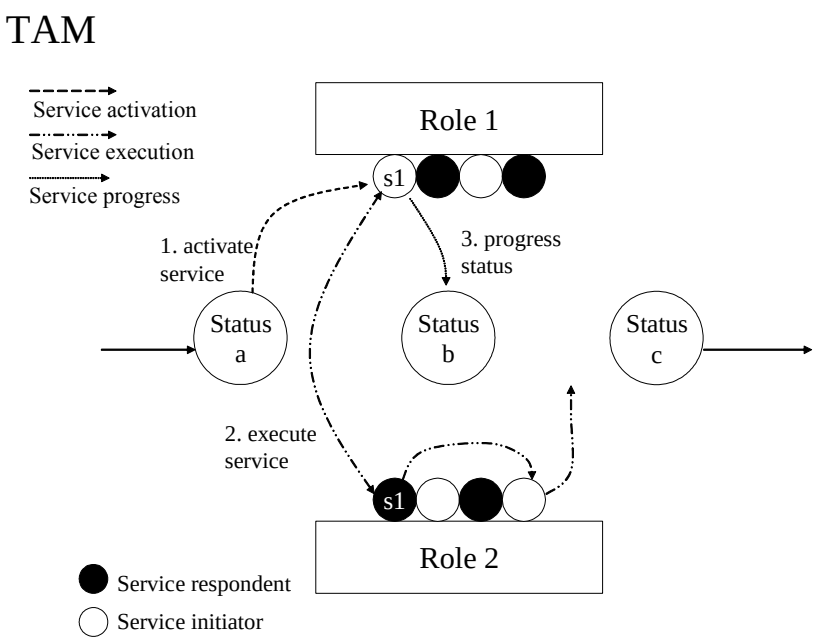


Figure 1 A diagram for a task assignment model (TAM)

A ttmm is described with team information such as team id, name and responsible geographical area; adjacent teams (adj-team); task assignment model (tam) that specifies the task delivery path through the roles and related rules defined in the team; default tam (def-tam) that is the default tam that is used when a team starts a working day; and exceptional rules that enforce tasks having specific attribute values are assigned by predefined tams rather than default tam. A tam is described with task lifecycle model (tlm), participating roles and allowed services that are necessary for the management of tasks. A tlm defines the possible transition paths of task status and described with initial status (ini-stat), a set of possible task status (status) and a set of transition (trans) that defines which service can be executed when a task reached to a status and make it progress into which task status. A ttr represents a TAM transition rule where each rule is specified with a condition and a target tam. A tlm provides useful information in determining which services should be accessible by a team member or the leader. For example, in Figure 1, if the status of a task reaches "Status a", the model informs that any team members who are in charge of role "role 1" can start a coordination service "s1". Once any instance of role "role 1" starts the coordination service "s1" this may trigger another service "sn". Once the coordination service is completed, it may update the task status into "status b". A cooperative service (service) is described with cooperative service components (ccom) and their sequences (seq). The sequence of ccoms is defined by a priori ccom (pre), a posterior ccom (post) and conditions (cond) for the transition from pre to post.

APPLICATION TO A REAL EXAMPLE

A telecom company B in Europe operates about 24,000 field forces to install and manage telecommunication networks. The tasks performed by the workers are diverse, but basically consists of two types, installation and repair. The tasks are further specified by specific requirements by customers and types of errors. Currently, the company is running a centralized WFMS for scheduling and assigning tasks.

The centralized system has, as discussed earlier, the following limitations. First, the central planning and control does not consider incentives to those workers who are more skilled and productive. Second, the central planning is rigid in that the

planning cannot be changed easily at local level to variable local situations, which may lead to overall inefficiency.
For this reason, the company is considering the adoption of decentralized team-based management of field tasks. The goal of the decentralized scheme can be briefly described as follows:

1. There are teams and each team has a leader.
2. Teams are usually responsible for tasks within a geographical area.
3. Team managers encourage team members to work more efficiently, but at the same time, tries to improve the overall performance of the team so that purely competitive task allocation may not lead to decrease in the overall team's performance.

For the above scheme, three TAMs were designed as presented in Figure 2. Firstly, they can use existing centralised WFMS. The use of the centralised WFMS can be done in direct-gateway or indirect-gateway-mode. In indirect-gateway-mode, all the tasks are assigned to the team members by the WFMS but the team leader should publish the assignments to make the tasks visible by the team members. Also, the team leader can modify the assignment based on his local knowledge before the tasks are published. In direct-gateway-mode, the assigned tasks by the WFMS are made visible by the team members without the interference (publication) of the team leader. Secondly, the teams can use the first-come-take rule for the team task assignments. In this mode, team tasks are put into the team task pool without any provisional assignment by the centralised WFMS. Every team member has the equal view on the task pool and can reserve any tasks they want to perform based on the first-come-take rule. The team leader can give restriction to this mode, for instance, setting the maximum number of tasks a member can reserve in a day. The team leader should be able to change from one mode into another based on the team's situation. For example, a team leader may become unavailable for a short term. In this case, s/he can either delegate his team leader role to one of the team members or change the working mode into first-come-taker mode. Furthermore, the team leader can use the two or three modes at the same time for different task instances. For example, s/he can configure the team operation so that tasks that have been retained by a team member are delivered to the team member next day via direct-gateway-mode while other tasks are assigned to team members via indirect-gateway-mode.

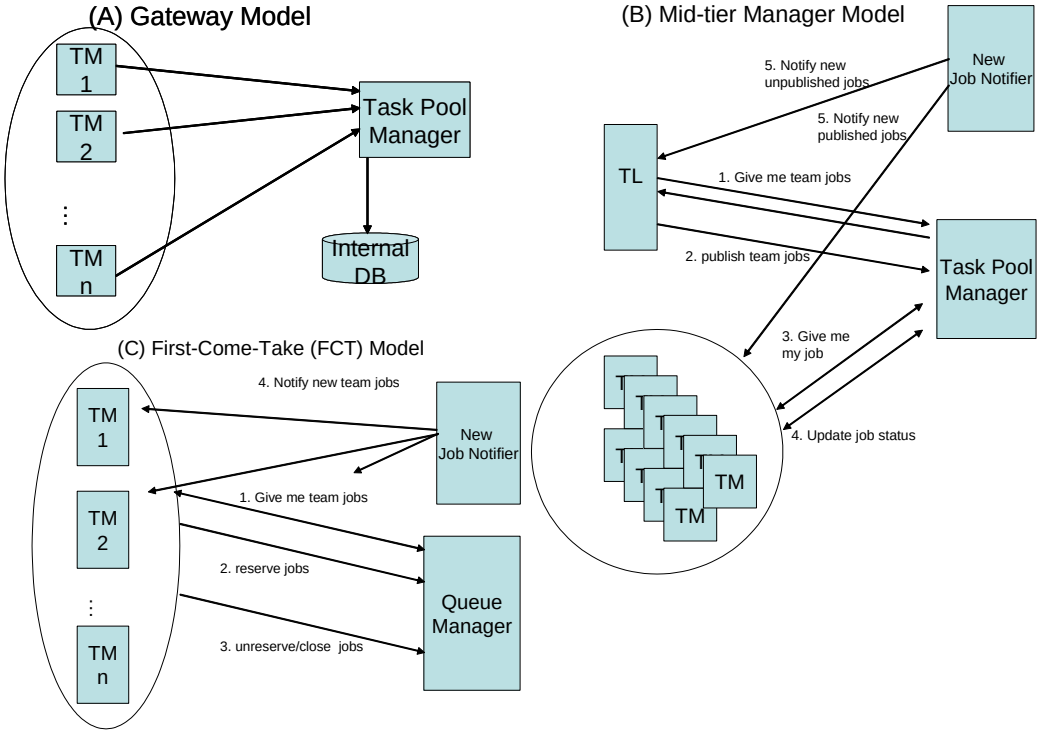


Figure 2 Three Example TAMS the Field Workforce for a Telecommunication Company

IMPLEMENTATION

TeamWork is a distributed architecture that can be used by a team of workers to mange team tasks. The core of TeamWork is a task management model that describes how a set of team tasks can be assigned or re-assigned to team members via cooperation. As a result, TeamWork consists of a task management model, participating role model and their interaction models. In TeamWork, team members can determine a task assignment model, switch to another or change rules of the model flexibly.

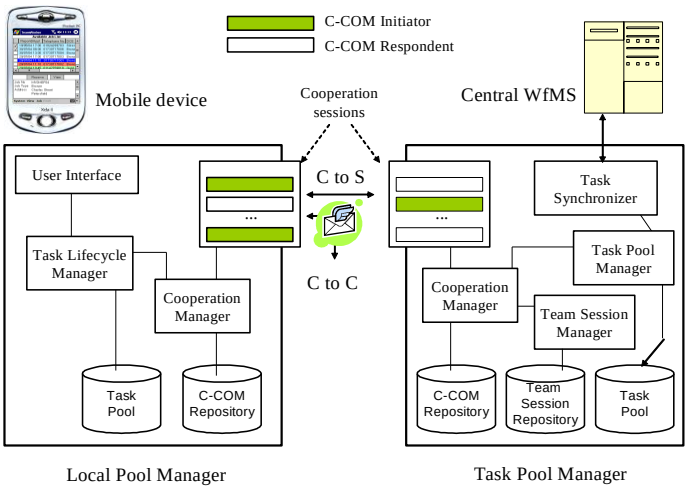


Figure3 Components and their interactions in TeamWork

Two major components of TeamWork are task pool manager (TPM) and local pool manager (LPM). TPM is normally located in the server side and responsible for the management of all the tasks and team members for a mobile business process. On the other hand, LPM is normally located in a mobile device and represents a process actor's view.

The major roles of TPM are to collect tasks from an external source for the team, initiate a task assignment model, notify any new or urgent tasks to the team and update any changes on the attributes of the tasks such as task owner or status. At its launching time, TPM reads a TTMM provided by an administrator and initialises team settings and the task pool. Task synchronizer is a sub component of TPM that connects to an external task source such as a WFMS and collects all the tasks for the team. It has been designed to use a standard interface defined by the WfMC (workflow management coalition) so that it can be integrated with heterogeneous WFMSs. Task synchronizer passes any tasks collected to task pool manager that checks the attributes of the tasks and attach a TAM to each task according to the default TAM value and exceptional rules in the TTMM. During this process, the task pool manager contacts team session manager to have the current default TAM of the team and any changes on the exceptional rules. The team session manager maintains team session repository that keeps all the history information with regard to the team configuration. Once each task is attached with a TAM, the task pool manager executes the TAM so that the task is assigned to a worker. For this purpose, the task pool manager contacts the team session manager to get the contact information of the current team leader or any delegated team member in the absence of the team leader. After that, the execution of the TAM is managed by coordination manager. In TeamWork, all coordination among team members including the team leader is performed via C-COMs [7]. A C-COM is a software component that automates coordination processes among organizational roles. It consists of two or more role components that implement the logics of the roles participating in the coordination process. For example, a C-COM implementing the auction process for a distributed task assignment will consist of two role components: auction manager and auctioneer. The auction manager role component is installed within the C-COM repository of the TPM while auctioneer role component is installed within the C-COM repository of the LPM. The coordination manager gets an instance of the auction manger role component and put into the cooperation session that executes the role component. The execution of the role component triggers a series of message exchanges with counter role components (auctioneer) in mobile devices of the workers.

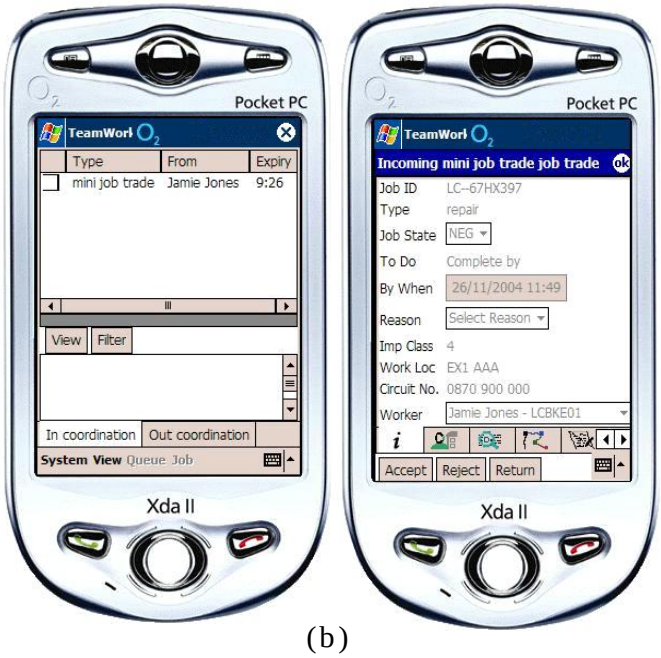
An LPM is responsible for the interactions with a TPM for the collaborative management of team tasks. At its launching time, it reads the profile of the worker which specifies the worker's team profile and the roles of the worker. Based on the worker profile, it initialises C-COM repository and a task pool that contains tasks that the worker is interested in. Initialisation of C-COM repository includes selecting C-COMs based on the user role and installing corresponding responding role components of the selected C-COMs. Tasks in the task pool are largely classified into two categories: tasks already assigned to the worker and tasks in the middle of an assignment process. The worker has different views on the two types of the task on the user interface. The tasks in the task pool can have different statuses according to the task lifecycle models they are attached to. The tasks and status information are displayed on the mobile device via a user interface. Any messages from TPM are handled by the cooperation manager within the LPM. The cooperation manager identifies the relevant task of the cooperation message, and checks the progress of the cooperation process for the assignment of the task. If the message is about new task which need to be assigned to a worker, then task lifecycle manager is informed with the task information along with the TAM used so that it can create a new TLM history. Once the TLM is settled down (that is, the task is assigned either to the worker or others), then the task is either transferred into his personal task pool or removed from the pool. The message exchanges can happen between an LPM and a TPM (C to S) or two or more LPMs (C to C) depending on the used TAM.

TeamWork has been implemented as a part of mPower project [7] that aims to develop an application framework for agent-based workflow systems for mobile business processes. The major players of the framework are Personal Assistant agents that are installed on mobile devices to support mobile workers and Information Agents that collects tasks or relevant knowledge for the execution of the tasks. Local Pool Manager has been implemented within the Personal Assistant agent for the cooperative task management and Task Pool Manager is one of the core components of an Information Agent. Jade [2] has been used as the implementation platform of the agents. The user interface on mobile devices has been implemented using SWT (Software

Widget Toolkit) to enhance the performance of the overall system.
Figure 4 (b) shows the screenshots of the implementation based on the specification. The first screen shows the coordination status window which displays all the incoming or outgoing coordination items with regard to team tasks management. In the figure, the incoming coordination window has a mini-trading offer from a colleague (Jamie Jones) and it should be responded within about nine and half minutes. If the user selects the item and clicks the "view" button, the systems displays the detail of the trading offer including task information and available choices for the offer (accept, reject or return).

```
<ttmm>
<team id=suffolk>
<default-tam id=indirect-gateway-mode>
<tam id=indirect-gateway-mode>
<role id=TL \>
…
<service name="Job trading">
<ccom id=mini-trade role=ini-resp \>
<ccom id=maxi-trade role=ini-resp \>
<seq><pre>mini-trade</pre>
<post>maxi-trade</post>
<cond><attr>output</attr><val>failed
</val></cond></ service></ tam>
<tam id=first-come-take-mode>
   …
<rule><attribute id=max-no-daily-
reserved-job />
<value>10</value></rule></tam>
<exception>
<cond><attr>status</attr><val>retained
</val></cond><tam-id>direct-gateway-
mode</tam-id></exception>
…
</ttmm>
```

(a)



(b)

Figure 4 (a) The team-based task management policy of B Company (b) the screenshots of the application based on the policy

CONCLUSIONS

The importance of mobile work continues to increase as more technologies and stronger network infrastructure become available. The distributed and mobile work environment requires flexible management of team tasks according to changing and uncertain situations. This paper addressed this problem by suggesting TTMM, Team Task Management Model, that flexibly switches task assignment models according to changing situations. The key contribution and novelty of this paper can be summarised as follows. Firstly, to the authors' knowledge, TeamWork is the first attempt to allow multiple TAMs to be interchangeably used for assigning tasks to workers. Secondly, the TTMM is the first model that abstracts the team dynamics including cooperative role and TAM management. Thirdly, this paper showed how TeamWork can be implemented using a distributed computing platform (a multi-agent platform). Further research issues include supporting easy design, creation, and management of TAMs by field workers and managers.

REFERENCES

Bauer, T. and Dadam, P.(2000) "Efficient Distributed Workflow Management Based on Variable Server Assignments". *Lecture Notes in Computer Science*, Vol. 1789, pp. 94-109.

[1] Bellifemine, F. et al.(2003) "JADE—A White Article", *Telecom Italia Lab J. Exp*, Vol. 3, No. 3, pp. 6-19..

[2] Davis R. and Smith R.G. (1973) "Negotiation as a metaphor for distributed problem solving", *Artificial Intelligence*, Vol. 20 , pp. 63-109.

[3] Geppert, A. Kradolfer M. and Tombros, D. (1998) "Market-Based Workflow Management", *Lecture Notes in Computer Science*, Vol. 1402, pp. 179-191.

[4] Graves, S. C.(1981) "A Review of Production Planning", *Operations Research*, Vol. 29,No. 4, pp. 647-675.

[5] Harchol-Balter, M.(2002) "Task Assignment with Unknown Duration", *Journal of the ACM*, Vol. 49, No. 2 , pp. 260-288.

[6] Lee, H., Mihailescu, P. and Shepherdson, J. (2003)"Conversational Component-based Open Multi-agent Architecture for Flexible Information Trade", *Lecture Notes in Artificial Intelligence*, Vol. 2782, pp. 109-116.

[7] Lesaint, D., Voudouris, C. and Azarmi, N.(2000) "Dynamic Workforce Scheduling for British Telecommunications plc", *Interfaces*, Vol. 30, No. 1 , pp. 45-56.

[8] Sandholm, T.(1995) "An implementation of the Contract Net Protocol based on marginal cost calculations", *Proceedings of the Eleventh National Conference on Artificial Intelligence*, Washington, D.C., AAAI/The MIT Press, Menlo Park, CA.

[9] Tan, J.C. and Harker, P.T.(1999) "Designing Workflow Coordination: Centralized Versus Market-Based Mechanisms", *Information Systems Research*, Vol. 10 , No. 4, pp.328-342.