Role-Based Collaboration Extended to Pervasive Computing

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***Abstract*—computer supported Collaborative Work (CSCW) has been a hot point in researches for some decades. Recent advances in software and hardware technologies have allowed the use of more and more advanced applications and services. It also brought computing capabilities to mobile devices such as smartphones and laptops. This has led to an extensive use of computers to collaborate in some unexpected manners. To support this collaboration, numerous models have been designed and tried. Among these models, some particularly caught our attention: models based on the description of tasks, role-based models and collaboration's context models. Simultaneously major advances were made in the young pervasive computing domain. We propose a role-based model, which aims at modelling the cooperation between devices to support pervasive collaborative work. Leading to the emergence of the Pervasive Computing Supported Collaborative Work (PCSCW).**

Keywords-component; pervasive computing; collaborative work modeling;role based collaboration model

I. Introduction

In the past few, computer supported collaborative work (CSCW) has became an unavoidable aspect of everyday's life of most companies. Actually, computers can channel the collaboration between people in many ways; they facilitate many tasks and allow monitoring and regulating of the collaboration. Most simple tools for collaboration already exists, even if those are still young and lack of maturity they offer the basis for simple collaboration. However, to provide more advanced collaboration features and opportunities, it is necessary to go deeper in this research field.

Research in CSCW is an "old" domain (relatively to computer sciences history) and many researchers have focused on the design of collaboration model with the final objective to allow a better management and understanding of collaboration. Thus many interesting models have been carried out in the history of collaborative software, but as for now none of them have ever really be able to overcome others and to solve all issues. However we think that some models are more relevant and promising. This is the case for role-based models. These models focus on the simple but still unavoidable concept of roles in collaboration. A role can be defined in terms of responsibilities and rights where responsibilities are actions a role player must perform and rights are actions he can perform. Zhu and Seguin [13] characterise a role in collaboration as follows:

- role is independent of persons;
- A role should consider both responsibilities when the human player is taken as a server and rights when the human player is taken as a client.
- A role cannot accomplish the tasks specified by the responsibilities.
- A role can be performed by one or many human players at the same time. A role can be created, changed and deleted by a human user with a special role.

Another evolution we can observe nowadays is that electronic devices are becoming more and more common, compact, smart and autonomous. Thus, the digital environment is taking each day a greater part in our world, leading us to a digital augmented environment. In this vision, the pervasive computing paradigm is a major domain, it aims at making all these smart electronic devices spread in our environment collaborate to provide us a seamless interaction with the digital world.

A natural extension for CSCW is then to be more suited for this kind of environment where the number and the type of devices is nothing more than a variable to which you have to be able to adapt. In this perspective, an interesting challenge for CSCW is to know dynamically and efficiently how to take advantages of this technology to improve the collaboration between humans. Potential advantages are various, we can think to simple mechanisms such as smart device control via a computer until complex mechanisms of collaborative context awareness.

However, only few advances have been made toward the better integration of pervasive features in CSCW systems. As we will see in the next sections, we explore this aspect of the CSCW domain by proposing an extension of a role-based model to support pervasive computing as a native feature of the collaboration.

In the remainder of this paper, we present our role-based model for pervasive computing supported collaborative work. Section 2 describes collaboration models for CSCW. Section 3 presents role-based model. Section 4 describes our PCSCW model which is followed by a use case in Section 5. Section 6 is dedicated to the presentation of the simulator we're designing. Finally we discuss and try to draw some perspectives.

II. COLLABORATION MODELS FOR CSCW

The main purpose of CSCW systems is to handle the collaboration between users. To do it they can rely on technical evolutions and tools adaptation for multiple users. But collaboration raises problems that are going far beyond technical issues. Indeed, the main problem of CSCW is collaboration itself, how a system can effectively support collaboration patterns and how it can be aware of the current collaboration status. To tackle these problems models of collaboration have been proposed. Among them, some kinds sounded more promising: tasks models, roles models, groups' models and the refined collaborative awareness models. In the following we will illustrate these models by presenting some of their related researches.

The task model is now widely accepted by the CSCW community to be one of the basis to represent collaborative work. It has been the subject of many articles and is still an active research field. Penichet [9] proposes a task model for CSCW based on the use of several well known task modelling aspects. Their model is aimed at describing “the tasks that should be performed to achieve the application goals” by giving them a good characterization. This model is aimed at designers that have to design groupware systems. What they propose is not a complete new model of tasks but a new “composition” of existing tasks models in order to have a better, more complete and more effective task model. Their approach is based on the description of tasks that are realised in groupware systems keeping in mind more classical aspects and mechanisms to analyse them. They argue that classical CSCW features or time-space features are not enough to correctly describe a groupware, but that a well done combination of them can do it.

Yan and Zeng [10] propose an original model for group awareness inside CSCW systems. They assume that there are mainly two aspects in group awareness: “group awareness model” and the “method of realization”. They point out the fact that for now, the main problem is still the construction of a robust model.

What they want to do to solve the resisting problems is to analyze basic elements of group work: “task”, “action” and “role”. One of the main aspects to consider in this article is that the authors assume that “*task has a thinner granularity in describing the group awareness*”. They demonstrate this by saying that if the role changes, so does the task. But if the task changes, the role does not necessarily change. Moreover, a change on the action may change the task but does not alter the associated role. It is why they put the task on the foundation of their awareness model. The proposed “Task-Based Group Awareness Model” is subdivided in two parts: information management and information forming.

The application they developed is composed of a set of modules, each one dedicated to a specific goal, but the more interesting of them is obviously the task disassembling one. The elementary definition here is the formal definition of a task as a triplet *T: (Role1, Action, Role2)* where T is the task, Role1 and Role2 are roles associated with the task. Role2 is only mandatory when Role1 cannot complete independently the Action. So, to disassemble a task, the system recursively disassemble Role1, Action and Role2 until it can’t divide any more. When it reaches this state, the task is defined as “atomic”. They also define a set of rules for disassembling in order to avoid inconsistent state. Moreover they notice that task disassembling is time consuming and then propose to pre-process most common tasks categories into task tree templates.

Thus they provide templates to represent tasks and then user’s activity, allowing them to have an interesting description of current collaboration.

Task models are interesting, because they can be easily understood by humans as they represent “classical” organization of collaborative work. But some models take different ways to represent the collaboration, making them interesting by the simple fact that they have new points of view of the collaboration.

Benford and Fahlen [11] proposed a spatial model of group interaction in virtual environments. The model is based on joining and combining objects of the focus space of participants. The model defines the key concepts: medium (audio, visual, object specific interface), aura (is defined to be a sub-space which effectively bounds the presence of an object within a given medium and which acts as an enabler of potential interaction), awareness, focus, nimbus and adapter objects.

Rodden proposes a model of awareness for cooperative applications [12], this model measures the awareness intensity by the flow of information between application programs. If these two models success in describing group awareness characteristics, they do not really include group structure into their measure [10].

Ellis and Wainer [4] propose a conceptual model to characterize groupware systems based on three aspects: objects and operations on such objects, dynamic aspects, and the interface between the system and the users and amongst users. This characterization describes a groupware system from its users' point of view.

Researches often want to be as generic as possible, in order to produce a model able of representing any kind of collaboration. Thought, generic implies less coupling with the domain, then most of the times it is necessary for models to focus on a specific domain. In this perspective, Qui et al (Qui et al, 2008) propose a task-based government organization collaboration model (TBGOCM). The model integrates resource and collaboration organization unit from the perspective of tasks and organization function. This model is constituted of five parts: Collaboration Organization Unit Layer (COUL): the basis of the entire framework, Resource Layer (RL): provides resource guarantee for the implementation of activities, Activity Layer (AL): is the instance of a task execution, Task Layer (TL): describes the coordination relationship between the sub-task and Coordination Layer (CL). TBGOCM is defined as a tuple that have five basic elements: <COU, Resource, Activity, Task, Coordinators>. *COU*: "Collaboration Organization Unit" is constituted by three parts<Ct, Relation, Agreement>. *Resource*: includes human resources, information resources, application system and entity resources. *Activity*: is the key cell of task having one or more activities with a certain sequence to reach the aim of collaboration. *Task*: it is decomposed into sub-tasks by coordinator based on certain strategies and rules. *Coordinators*: for determining collaboration target, strategies and time constraint, decomposing task and establishing collaborative relations, selecting collaboration organization, monitoring implementation of sub-task, being responsible for communication between COU, finally involving in authorization and so on.

We are reaching the roles models, which are the ones that motivated use for this research. Roles can seem simple, but describing them correctly with all their characteristics is a really complex issue.

III. ROLE BASED COLLABORATION

Role Role-based collaboration (RBC) is a methodology to design and implement new computer-based tools. It is an approach that can be used to integrate the theory of roles into CSCW systems and other computer-based systems. It consists of a set of concepts, principles, mechanisms and methods [1]. RBC is intended to provide some benefits to long-term collaboration: identifying the human user "self", avoiding interruption and conflicts, enforcing independency by hiding people under roles, encouraging people to contribute more and removing ambiguities to overcome expectation conflicts. It is also intended to provide benefits to short-term collaboration: working with personalized user interfaces, concentrating on a job and decreasing possibilities of conflicts of shared resources, improving people's satisfaction with more peoples' playing the same role during a period and transferring roles with requirement of a group. Finally, in management and administration, it helps at decreasing the knowledge space of searching, creating dynamics for components and regulating ways of collaboration among parents.

Some CSCW systems have indeed applied the concept of roles. Barbuceanu et al [6] have proposed role based approaches to agent coordination. This approach includes a "practical, implemented coordination language for multi-agent system development" that defines, agents, their organization and roles. Agents play roles in an organization, and a role is defined by its major function, permissions, obligations, and interdictions. A role's permissions include agents under its authority and its acquaintances. An agent's beliefs and reasoning are partitioned on the basis of the roles it plays to facilitate context switching [6]. A combination of events leads to a situation for the organization, with each agent member in a given local state. An agent's behavior in a situation is determined by its conversation plans, and these are usually specified to be between a particular pair of roles.

Edwards [7] propose a system that can implement a variety of useful policies in collaborative settings, particularly in the areas of awareness and coordination. This system uses the notion of roles to associate categories of users with particular policies. Intermezzo roles can represent not only groups of users, but also descriptions of users in the form of predicates evaluated at runtime to determine group membership. Dynamic roles, in particular, expand on one of the central themes in this work: by bringing information about users and their environments into the system, it can make computer augmented collaboration more responsive, and can free users of many of the implicit burdens in working with today's collaborative systems.

In a more recent article, Zhu [2] proposes his view of collaborative authoring based on the use of roles. He points out the fact that collaborative systems should not only support virtual face-to-face collaboration between distant people, but should also improve physical face-to-face by providing mechanisms to overcome drawbacks of face-to-face collaboration. They notice that WYSINWIS (What You See Is Not What I See) can be an efficient model for the development of collaborative systems. Thus WYSINWIS systems can allow different users to have different views of a shared document according to their roles inside the collaboration. This kind of interaction is not totally new, and such systems exist for a long time, but what they propose is a mechanism based on the precise role definition and specification to allow roles to be dynamically tuned and managed in the system.

Furthermore, Zhu and Tang [3] propose a role based hierarchical group awareness model (RHGAM). Firstly RHGAM constructs a group cooperation environment (GCE), and then GCE is extended by group awareness content, awareness hierarchy, the task decomposition rule. The model divides the awareness information into four levels by decomposition and recombination using a role-task graph and the thinking of group structure. In RHGAM, role is the basic of group cooperation; with the different group structure and task relation, the awareness information is shared between roles hierarchically.

In a relatively different perspective, Ahn et al [5] implemented a role-based delegation framework to manage information sharing (FRDIS) for collaborating organizations. Their central idea is to use delegations as a means to propagate access to protected resources by trusted users.

Role models propose a "natural" approach to collaboration; with the help of task models it is possible to have an accurate description of user's collaborative work. Still we want to go further and properly consider devices as part of the collaboration. To do it we propose our model based on the description of roles, tasks, actions, resources to perform them and available devices resources.

IV. PCSCW COLLABORATION MODEL

Keeping in mind the works that have been done in the different domain we're interested in, we propose our own model relying on some simple concepts: tasks, actions, roles and resources. We'll now describe these main aspects.

A. Task

The first concept to define is the task. This concept is one of the most popular of the recent researches in collaboration modelling. A task can be defined as a set of actions to be performed in a specified or unspecified order to fulfil the task objective. In addition, a task is not always (and in fact most of the time is not) an atomic one, meaning that it can be composed of several sub-tasks with their own actions and objectives. Moreover, we can point out that the collaboration of people takes place when they need to perform a task they can't or shall not do alone. If this task has to be performed by more than one person, it can be considered has a "shared task" or a "common task".

B. Actions

Actions can be seen as tasks components. In some perspective they could be considered as atomic tasks, however we think that a task carries its own meaning, actions don't, and that's why we should consider them as sub-atomic tasks. To illustrate this idea we can figure that the action "opening a web browser" has no "meaning", but opening a web browser and writing a word in a search engine has its own meaning, it is the task of "searching on the web".

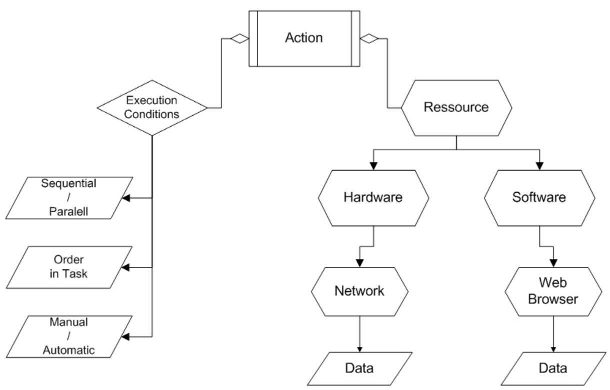

Figure 1. Action Specification

C. Role

As we have seen previously, a role can be defined as a set of tasks to be performed by a single entity, giving it responsibilities, rights and duties. A role is not reserved to persons; it can also be played by a group of persons or by an entire organization. Besides, in the same way as a role can be designed for more than one person, a person can play several roles at a time. This is particularly true in the case of a person belonging to multiple groups (for example a work team and a sport club). In addition, a role can have a specific "cardinality" inside of a group, meaning that you can have several people in the same group playing the "same" role. This aspect of the role concept can be confusing if you consider that two people never do the exact same work, that's why roles have not to be confused with peoples.

D. Resources

If you intend to model the context of people in order to develop context awareness mechanisms, at some point of your reflection you will have to face the representation of users' resources relevant for the part of context you're interested in. Obviously in our model, we can't avoid this part, it is in fact one of the most interesting point we want to explore. Indeed, we argue that the description of tasks should be made through the representation of resources required to perform it. Going even further we could describe facultative resources that can be effective to perform the task but which are not mandatory. Thus, considering that you've got a fine description of the task a group is performing, you can have accurate indicators of the state of the task. This could lead to a fine monitoring of the task and then to a fine collaboration awareness mechanism.

E. Smart devices

By extension of the precedent aspect of our model, we propose to associate tasks to (smart) devices. To do it we have to figure out that smart devices are parts of the available resources. Furthermore, it is necessary to have a description of devices capabilities. For instance, if you consider that a high-speed connection to the Internet is required for your task, the best device to support it can be quickly identified by a simple query to available ones or by a more efficient request to some kind of a context manager. Such a mechanism is particularly effective, as it can make several devices cooperate seamlessly.

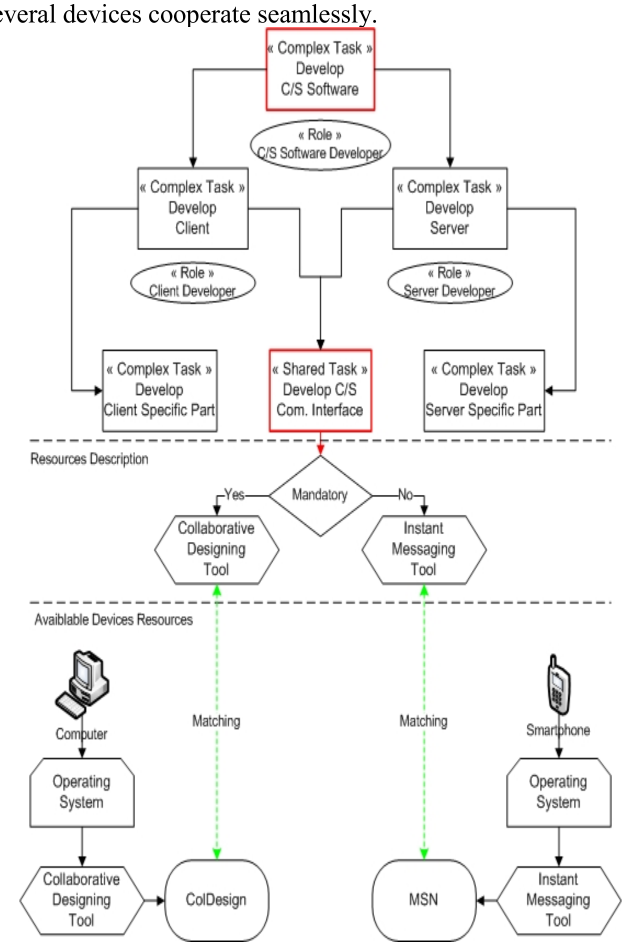

Figure 2. PCSCW Model, Example of Application

F. Roles for devices

As a refinement of devices description, we propose to define their roles in the collaboration process and more precisely for a task. Thus, a task becomes the natural link between peoples and devices via the description of roles for both of them. As for "Human Role", the role of a device describes its responsibilities and rights. To take a simple example a device can have a role in a collaboration process giving the responsibility of providing the Internet connection for a given user. With this example we can point out a major difference between human roles and devices roles, humans' roles are based on actions performing while devices roles are based on resources providing. The Fig.2 sums it up. On this figure we quickly modelled a simple, but common task: the development of a client-server application which implies the development of a shared object: the communication interface between the client and the server. For this task we need a Collaborative Design Tool and an Instant Messaging Tool, which is not mandatory but can improve the collaboration. An interesting point here is that the model can enhance the collaboration by proposing optional resources such as, in this case, a messaging tool. Furthermore the model itself can be refined by describing precise rules for the messaging tool to be proposed and used; in some cases it can be preferable not to use it. The designing tool is provided by a computer while the messaging one is available on the smartphone. Thus we can say that the computer plays the role of "Heavyweight application provider" while the smartphone has a "Messaging application provider" role.

G. *Devices collaboration rules*

All devices don't natively support collaboration with others. In order to solve this kind of issue we argue that the definition of device collaboration rules could be of great help. These rules intend to define tasks that could be automatically performed by devices to collaborate in order to allow a user to do its own task. The main idea behind this is the following: a user needs two (or more) resources to complete an action related to a task; these resources are not available on a single device, but the combination of several of them can supply the resources. Thus, device collaboration rules define what actions can be performed by devices to collaborate, finally providing required resources to the user. These collaborations can be of various kinds: network access sharing, heavy computing task delegation and notification of events, anything you can imagine to make several devices cooperate.

These Device Collaboration rules will be illustrated in the following section.

V. PCSCW IN ACTION A USE CASE

To illustrate our model, we can consider a use case that we already mentioned in [8]. This example relies on the Pervasive Brainstorming systems we developed in this previous article and can be described as following:

The manager of a team wants to have the opinion of its team members about a specific topic (for example about a project he's planning);

As his team is often spread over different locations, he can't meet each of them physically;

To solve issues they can encounter for this collaboration, we proposed a service based on the use of mails and forum to channel the opinion of the team and provide efficient synthesis of the group opinion;

The system itself is based on the automatic publication of multiple-choice questionnaires which can be sent by mail to a dedicated mailbox, mails are then analyzed and contained questionnaires are published on a forum where team members can vote and give their opinion.

If we consider this use case with our model we can distinguish two roles: the manager role and the basic team member role. The manager role has a cardinality of 1 while the team member role has an unspecified cardinality for this group. The team itself is mapped to a "Group Role" with its own set of tasks. The manager role allows its player to perform a "Send New Questionnaire" task while team members are allowed to perform the task "Answer a Questionnaire".

Let's consider the case where a member of the team, Bob, is equipped with a laptop and a cell-phone, both switched on. His laptop has only a Wifi and an Ethernet adapter without available network in range. On the contrary, his cell-phone is connected to a HSDPA network and has its own Wifi adapter (but as for the laptop, without access point available). Bob's manager has just sent a new questionnaire; an automatic mail is sent to him with a link to the published questionnaire. In the traditional case, Bob should open the mail; go on the forum and access to the questionnaire on his phone. We suggest that this interaction could be dramatically improved. Let's consider that Bob is deeply focused on his laptop and that his cell-phone lies at some distance of him. Here a simple but still efficient device collaboration rule can take place:

- When receiving a new mail on cell-phone;
- If User is working on superior ergonomics device (Computer, Laptop …) which can be connected with cell-phone;
- Then perform tasks: establish a bridge connection from cell-phone to computer and notify user of the new mail.

Fig.3 represents what resources are necessary to perform the "Bridge Connection" task.

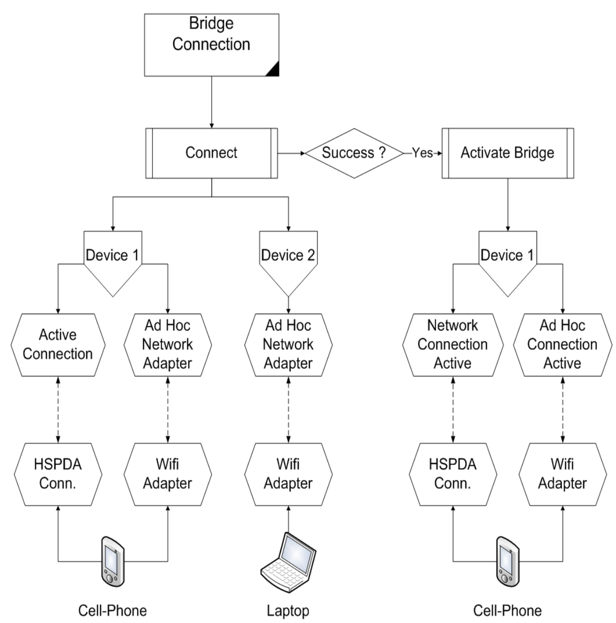

Figure 3. Device Collaboration, Connection Bridging

As we can see on the previous figure our model serves at representing resources of users' task to find matching devices but also to determine if those devices can cooperate to supply the desired resources. Indeed to perform the connection bridge between two devices we have defined the required resources: an active connection on the device that have to bridge it; and a network adapter of the same type on both of devices. In our case the available connection can be found on the cell-phone as the HSPDA one while common network is supported by Wifi adapters. Once the cell-phone and laptop are connected the bridge can be activated.

This quite simple scenario shows how our model enables the efficient cooperation of surrounding devices to enhance the collaboration of users. Besides, this type of scenario can be extended to multiple users and devices, creating a real "pervasive and collaborative network".

VI. SIMULATOR

For now we have presented our model. However this model has not been tested in real conditions yet. In order to evaluate it we're currently developing a simulator that will help us in this long work. This simulator relies on some choices and principles: as it has to represent a multi-agent system we decided to rely on the well known JADE Framework (Java Agent DEvelopment Framework). Thus, each person and device of the simulation will be represented by its own agent. Direct interactions between agents will be done by JADE agent messaging while the interaction with the outer environment (the agent's access to the world) will be managed by a unique object. Still, as an agent hasn't a perfect knowledge of its entire context, they will store their representation of the world individually. In addition to these "classical" multi-agent features we incorporate a behavior manager to each agent. This module has to handle the current behavior but also the start of a new behavior according to evolving context, changes due to an agent or to the environment. Besides these considerations, we have some constraints to handle: support for roles, actions, resources, human, resources, groups and interactions.

In order to conduct our evaluation of the model we have decided to intensively use scenarios. These scenarios will be composed by an initial state of the world with a given set of agents and by some events that will, we hope, trigger collaboration rules among devices. Moreover, we will trace the execution of the scenario and the different actions made by agents, in order to be able to replay and analyze them. Thus the simulator will be a real laboratory to construct and improve devices collaboration rules.

VII. DISCUSSION

The model we propose does not come out of nowhere, it relies on robust researches that inspired us and guided us to develop it. As it has been intensively mentioned, our model is based on the notion of roles, for people and for devices. In a moral consideration, the representation of roles is not a substitution of the representation of a person, it is only a part of a person, otherwise one can quickly come to the conclusion that only roles matters and peoples don't. But from a model perspective taking into account the role as a variable can help to apprehend the complexity of a pervasive environment. In such context, roles or resources can vary depending on spatial, temporal or collaborative constraints. Having a model in which the "efficiency" of the collaboration can be estimated can be used for designing purpose.

Our approach can seem very descriptive, detailed and requiring great efforts to be used. But we want to take an advantage from this issue. In fact, all awareness mechanisms do not require the same level of description. For some of them, only the top levels are relevant. This is why we argue our model is able to describe and reason on different granularity levels, from a simple description of devices until a fine description of each object manipulated by an application on a virtualized operating system. Thus, we can say that our model naturally supports the scalability of awareness mechanisms by its adaptability to the description of resources. This scalability can even bring an abstraction capacity by allowing designers to represent high-level information and reason on it. Besides, this scalability advantage is twofold, it allows the description of resources with various granularity, but it also offers the possibility to reason with few context information and then when computing resources are limited or information are hard to obtain.

This work relies on two main aspects: the representation of required and available resources and the description of device collaboration rules. Still we know our work has its own disadvantages. One of the mains is the need to create these rules. Indeed to adapt to a specific context it requires having a more or less generic set of rules. Even if this particular point can seem annoying it can be a source of improvement. Despite rules have to be written before the use of the model, they can also be derived from user's activity, preferences and constraints dynamically. As for now we don't have dig deeper in this way as it was not our main focus, but in future works we'll need to explore potential way to automatically generate and adapt rules.

We think our model is a good basis to develop interactions between smart devices. Besides the collaboration supported is threefold: collaboration between users, collaboration between devices and collaboration between users and devices.

Still, we know that our model certainly needs some improvements, and that without implementation and in-depth evaluation it is only theory. From all we've said until here we can draw some conclusions about what we'll be our future works. In a first time we need to implement a prototype coupled with a simulator in order to evaluate the efficiency of our model. The simulator should allow us to lead interesting tests and researches about device collaboration rules: which one are relevant and how should they be adjusted. In essence the prototype has to provide us a platform to evaluate users' experience with collaborating devices. Furthermore it is an unavoidable laboratory to explore interactions and find new device collaboration rules with the help of users. Finally it will allow us to evaluate our model in real conditions.

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