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Requirements for Distributed Event-based Awareness in P2P Groupware Systems

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***Abstract*—One of the major premises of P2P systems is to enable fully decentralized collaborative functionalities for supporting work teams and P2P communities. Within collaborative systems, *tracking* and *awareness* are vital aspects for a successful collaboration. Despite the experience of using awareness in web-based applications, there has been little research in endowing P2P collaborative systems with generic, application-independent awareness mechanisms to fully support collaboration.**

In this work we present a distributed event-based awareness approach for P2P groupware systems. Unlike centralized approaches, several issues arise and need to be addressed for awareness in P2P groupware systems, due to their large-scale, dynamic and heterogenous nature. In our approach, the awareness of collaboration will be achieved by using primitive operations and services that are integrated into the P2P middleware. As a first step, we identify the major requirements for such an event-based awareness approach, including dynamics of events, genericity of events, lightweight mechanisms, automation via the use of rules, as well as event transformation, presentation, propagation and notification services in order to fully support timely awareness of collaboration activity. We then propose an abstract model for achieving these requirements and we discuss how this model can support awareness of collaboration in mobile teams.

***Index Terms*—P2P systems, Events, Awareness, Collaboration, Replication, Middleware, ECA rules, Queries.**

I. Introduction and motivation

P2P computing has emerged as a new large scale distributed paradigm. Typically, P2P technologies enable deployment of large-scale, self-evolving infrastructures, without the need for centralized management. The P2P paradigm is thus becoming a focus for the development of new classes of applications that can effectively provide services over the Internet to a large number of users, teams and virtual organizations.

A major premise of P2P systems is to enable fully decentralized collaborative systems by supporting different forms of collaboration. Collaborative work through virtual teams is a significant way of collaborating in modern businesses, online learning, etc. Collaboration here refers to both data sharing among the group members as well as sharing of group processes. The later includes coordination, interaction and the internal group relationships that are needed for accomplishing common tasks through a shared workspace environment.

Awareness is a key feature of groupware systems. In its simplest terms, awareness can be defined as the system's ability to notify the members of a group of changes occurring in the group's workspace. More generally, awareness refers to the knowledge provided by the system to group participants about what other participants are doing at the same time and what they did in the past [8]. Groupware systems were among the first multi-user systems to implement such functionality; this was later addressed also by active databases [21], with event monitoring schemes through event-condition-action (ECA) rules, and by web notification services.

However, group awareness is not just about notification as it aims to support group processes by overcoming shortcomings such as: (a) inefficacy due to limitations of information and communication provision; (b) availability of possibly overwhelming amounts information; (c) difficulties in extracting monitoring and progress reports; and, (d) achieving better use of group resources based on awareness of resource availability. As group work usually takes place throughout the lifespan of a project, the time dimension is also very important to group processes. Group processes can benefit from awareness in order to decrease the time needed for completion of tasks by enabling faster information and knowledge transfer between group members. Supporting interaction among group members in order to enable timely decision support is also a necessity in our setting, as opposed to the simple "office communication" of a group of people not requiring much interaction. An additional requirement arises from the space and time distribution of group members, which imply that group activity should be achieved through decentralization of both data and group processes (control, task completion, scaffolding, etc.).

Awareness systems for online collaborative work have been proposed since in early stages of Web technology [1], [24], [25]. Such proposals started by approaching workspace awareness, aiming to inform users about changes occurring in the shared workspace. More recently, research has focussed on using new paradigms, such as P2P systems, to achieve fully decentralized, ubiquitous groupware systems and awareness in such systems. In P2P groupware systems group processes may be more efficient because peers can be aware of the status of other peers in the group, and can interact directly and share resources with peers in order to provide additional scaffolding or social support. Moreover, P2P systems are pervasive and ubiquitous in nature, thus enabling contextualized awareness.

However, several challenges arise in developing groupware and awareness mechanisms in fully decentralized P2P systems as it is more difficult to achieve a consistent view of the

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groupware global state from the local states of the group members. Also, P2P systems are primarily aimed at supporting explicit peer-to-peer communication, while group collaboration should support the many-to-many mode. Furthermore, issues inherent to P2P systems such as their large scale, dynamics and heterogeneity need to be dealt with.

This work is motivated by the need to provide P2P groupware systems with awareness functionality in order to fully support groups' activities. We focus on the awareness needed to support the completion of common tasks through interaction and information transfer in a fully decentralized P2P shared environment. The objective is thus to overcome limitations of existing approaches in which the awareness functionality is part of the groupware application itself. To this end, we propose primitive operations and services for awareness to be integrated into the P2P middleware, on top of which specific groupware applications can be developed. Service-based middleware approaches scale much better than do monolithic approaches and also provide greater flexibility as well as raising the level of abstraction of the interfacing with applications. The primitive operations and services for awareness are conceived primarily as supporting basic awareness information. They are also intended to support other features of awareness, such as provision of lightweight mechanisms for pervasive awareness as well as enabling the extraction of awareness to the desired detail of information over time. The objective is to deal efficiently and effectively with the possibly overwhelming amount of information generated in a group workspace. Thus, unlike existing approaches that provide awareness information directly from streams of events, we propose *event transformation* capabilities to achieve presentation of information in different formats, tailored to group members' needs and to their computational resources.

The rest of the paper is organized as follows. We briefly review some related work in Section II. The awareness model considered in this work is specified in Section III. In Section IV, we present the main requirements for event-based group activity awareness in P2P groupware systems. The abstract model to support the identified requirements is given in Section V. We briefly outline how our model can support awareness of collaboration in mixed P2P systems (including mobile peers) in Section VI and we end the paper in Section VII with some conclusions.

II. Related Work

During the last decade, attention in collaborative applications has shifted to using P2P systems, which can truly achieve the fully distributed nature of such applications. Some research has also addressed the use of P2P systems specifically for supporting teamwork. It should be stressed however that in existing proposals of P2P groupware systems, awareness has been considered little or not at all. Below we briefly review the use of P2P technologies in the context of groupware systems for eLearning and teamwork.

Several research works have discussed the benefits of using P2P technologies to education. One such benefit is the use of P2P technologies for sharing learning resources. Edutella [17], [23] used a P2P architecture for exchanging RDF metadata by building upon Semantic Web techniques and the JXTA middleware, with the purpose of making the reuse of globally distributed learning resources easier. In [3], the authors proposed to use P2P technologies for large scale distribution of learning objects that will enable the creation of collaborative learning communities. The SeLeNe system [11] proposed a P2P network to support distributed learners in sharing learning resources in a peer community; and it envisaged using ECA rules to provide the change propagation and notification services required by such learners. P2P technologies may also be useful for enabling eLearning environments to be more efficient, scalable, mobile and versatile [7], [9], for supporting group cognition processes in problem-solving environments [6] and for enabling integration with the new paradigm of personal knowledge management [2].

On the other hand, proposals for specifically supporting group work have also been proposed. Busseta et al. [4], [22] proposed an approach to integrate P2P systems with so-called active environments in order to provide intelligent, pervasive support for group work. Their proposal is an agent-based and one of its aims is to provide mechanisms to know if a group's activity is progressing as expected. Parker et al. [20] use collaborative computation to achieve three basic objectives of P2P collaboration, namely, achieving global shared knowledge, sharing of computation, and coordination of activities. The authors propose JXTASpace, a P2P framework for enabling applications to collaborate on top of a JXTA based architecture by using the Tuple Space mechanism.

Other proposals for supporting teamwork using mobile and pervasive computing have also been reported. For instance, in [12] the authors presented Omnix, a P2P middleware that aims to be topology independent. The middleware services it provides include support for mobile teamwork allowing different connectivity modes, support for access to various devices, and query services for distributed search and subscriptions.

The above-mentioned proposals are mainly concerned with asynchronous collaboration. Some P2P-based applications have been specifically designed to support synchronous collaboration [10], [13]–[15], [18]; however, they do not address awareness of the collaboration activity.

A few software projects using P2P technologies have also been proposed for supporting collaborative work. Among them are Groove, Collanos Workplace and PeerWare. Groove is among the first collaborative applications using P2P technologies and it allows its users to communicate, share their contents and accomplish joint activities in a decentralized way. It is claimed that collaboration can be achieved also by using PDA devices. Collanos Workplace is another software for supporting teamwork. It is claimed that the software gives support to "any time, anywhere" paradigm. Awareness however is implemented using the traditional forms of instant messages to team members and alerts on updates. Finally, PeerWare is P2P platform for the development of applications for distributed and mobile team work in enterprise scenarios.

In this platform, awareness is implemented using notifications.

In the above-mentioned proposals, the awareness mechanisms are implemented as part of applications, having thus the limitation of being fully-coupled within the applications. Moreover, our objective here is not only to provide information about others' activities (e.g. in the form of simple notifications) but, more importantly, to support group processes, that is, to link information to group member's actions.

III. Group Activity Awareness model

The awareness model considered here focuses on supporting group activities so to accomplish a common group project, although it can also be used in a broader scope of teamwork. The main building blocks of our model (see also [8], [25] in the context of web-based groupware) are described below.

III.A. Activity awareness

Activity awareness refers to awareness information about the project-related activities of group members. Project-based work is one of the most common methods of group working. Activity awareness aims to provide information about progress on the accomplishment of tasks by both individuals and the group as a whole. It comprises knowing about actions taken by members of the group according to the project schedule, and synchronization of activities with the project schedule. Activity awareness should therefore enable members to know about recent and past actions on the project's work by the group. As part of activity awareness, we also consider information on group artifacts such as documents and actions upon them (uploads, downloads, modifications, reading).

Activity awareness is one of most important, and most complex, types of awareness. As well as the direct link to monitoring a group's progress on the work relating to a project, it also supports group communication and coordination processes.

III.B. Process awareness

In project-based work, a project typically requires the enactment of a workflow. In such a case, the objective of the awareness is to *track* the state of the workflow and to inform users accordingly. We term this process awareness. The workflow is defined through a set of tasks and precedence relationships relating to their order of completion. Process awareness targets the information flow of the project, providing individuals and the group with a partial view (what they are each doing individually) and a complete view (what they are doing as a group), thus enabling the identification of past, current and next states of the workflow in order to move the collaboration process forward.

III.C. Communication awareness

Another type of awareness considered in this work is that of communication awareness. We consider awareness information relating to message exchange, and synchronous and asynchronous discussion forums. The first is intended to support awareness of peer-to-peer communication (when some peer wants to establish a direct communication with another peer); the second is aimed at supporting awareness about chat room creation and lifetime (so that other peers can be aware of, and possibly eventually join, the chat room); the third refers to awareness of new messages posted at the discussion forum, replies, etc.

III.D. Context awareness

In early approaches to awareness, context awareness was simply defined as information on the *workspace* where actions on objects (documents, notes, etc.) were generated. In other words, this is a kind of context of origin. However, context awareness is broader than just workspace information. Full implementation of group processes requires a definition of group context in terms of interrelated conditions and constraints over time and location under which group members perform actions. This concept is becoming increasingly relevant to the emergence of pervasiveness features of contemporary networking systems. Context also includes the individual profiles of group members, leading to the concept of *pervasive* context awareness. Recent work (see e.g. [16]) is providing evidence that context provides an effective basis for personalization in a group environment to exploit the power of P2P and mobile technologies. In early definitions, context was identified with information on "location, identity, environment, and time". However, in a networked environment, other features are also relevant, including network connectivity, communication costs and bandwidth, and even the social situation of actors (individuals, groups, and computational and physical objects). Moreover, in our approach, context is further extended by the task context, that is information on members' actions relating to the tasks of the project workflow.

III.E. Availability awareness

Availability awareness is useful for provide individuals and the group with information on members' and resources' availability. The former is necessary for establishing synchronous collaboration either in peer-to-peer mode or (sub)group mode. The later is useful for supporting members' tasks requiring available resources (e.g. a machine for running a software program). Groupware applications usually monitor availability of group members by simply looking at group workspaces. However, availability awareness encompasses not only knowing who is in the workspace at any given moment but also who is available when, via members' profiles (which include also personal calendars) and information explicitly provided by members. In the case of resources, awareness is achieved via the schedules of resources. Thus, both explicit and implicit forms of gathering availability awareness information should be supported.

IV. Requirements for Event-based Group Activity Awareness in P2P Groupware Systems

In this section we present the main requirements for a distributed event-based awareness approach to support group activity in P2P systems. These requirements will serve as a

basis, in our future work, for the design of the necessary primitives and services within the P2P middleware.

IV.a) Distributed awareness: Unlike centralized approaches, in which awareness information is kept at a central server, in a decentralized P2P groupware system the information upon which awareness is built is distributed among different peer sites. In server-based approaches, event processing takes place at the central server, which stores event information within a history database and provides a query interface for extracting the event data of interest. In a P2P groupware system, the storing, processing, and querying of event data needs to be done in a distributed fashion.

IV.b) Dynamics of events: P2P systems are dynamic in nature. Peers (i.e. members of a group) can join and leave the system dynamically. The awareness functionality should be able to handle such dynamicity. Synchronization and consistency of information at different peer sites are crucial, in contrast to server-based approaches in which consistency of data is more easily achieved. The awareness functionality thus needs to provide appropriate mechanisms, such as propagation and replication of information, to ensure provision of awareness under dynamic constraints. P2P ECA rules [19] are one possible mechanism for achieving consistency of information within the group at each peer site.

IV.c) Genericity of events: Events can be of many types. Their representation within the P2P middleware should be as generic as possible, e.g. using an XML or RDF-based representation, so as to allow encoding of any application-specific information about event occurrences that is required to enable efficient querying of event information of relevance.

IV.d) Lightweight mechanisms: Lightweight mechanisms are indispensable for both reducing the overhead caused by event generation, processing, notification, etc. as well as for supporting awareness for peers with limited computational resources.

IV.e) Automation of event processing using expressive rules: Most event-based approaches rely on triggering when events of interest occur and on the system processing event-related information for awareness purposes. However, awareness needs to support both this "passive" kind of awareness (from the user's perspective) and also "active" awareness explicitly initiated by the user (see paragraph on Awareness Delivery below).

IV.f) Event transformation: In most existing approaches in the literature, log files of events are maintained and are used to provide the group with chronological presentation of awareness information. However, in many situations, the chronological representation of a temporal stream of events is not sufficient to support group work, and event *transformation* may also be necessary. Transformation here refers to either refining the event information (e.g. by adding conditions on parameters exposed by the event or on values computed from the context) or to composition of events yielding new, composite, events. Event transformation is thus particularly useful for implementing context-awareness as new, more complex, contexts can be created through the combination of events from simpler contexts.

IV.g) Advanced event query processing: Group work has a time dimension, that is, short-term, mid-term and long-term objectives are to be accomplished during group activity. Therefore, the awareness should be adapted to such objectives. While short-term objectives, say for everyday work, can be supported by short-term awareness, mid and long-term objectives require more relevant information to be extracted by processing the streams of events generated in the group environment. However, the volume of information on streams of events may be overwhelming. For instance, suppose that a group member is not connected to the group environment for a certain time. If the member were to receive unprocessed event information upon reconnecting (i.e. a full report), that could make it very difficult for the member to find out the relevant information that they had missed. In fact, studies in the groupware literature have shown that the awareness on medium-term and long-term activities are of high significance.

One important requirement is thus to provide advanced query processing mechanisms that would enable members of the group to extract awareness information tailored to their needs and, as we will discuss next, at a desired level of detail ranging from simple summaries to full reports.

IV.h) Event-based awareness granularity of presentation: Awareness approaches are usually concerned with providing full information to group members. As group activities typically span rather long time periods, awareness should provide more than temporal streams of events. Providing meaningful awareness information is thus indispensable. To achieve this, the awareness system should provide mechanisms to present the awareness information at different levels of granularity: from overviews and summaries to full reports. Therefore, users can receive according to their preferences the awareness to the detail that best fits their current needs and goals and thus can adapt their actions to the situation in the group environment. For instance, for a latecomer to the group it is more useful to receive overviews and summaries on group activity to date rather than full reports.

Moreover, different granularities of awareness presentation would have the potential to overcome the temporal fragmentation which is commonly found in group work (i.e. the point in time when an action takes place is separated from the point in time when an observer perceives it). In particular, a coarse-grained presentation (overviews and summaries) would allow adaptation to the peer's computational resources, especially to limited computational devices.

IV.i) Awareness delivery: The provision of awareness should be supported in several modes so as to enable highly configurable awareness mechanisms. Awareness delivery could be "passive" or "active". In a passive mode, the awareness information is delivered to group members without requiring any specific actions on their part. Passive delivery is most suitable for time-sensitive awareness information as it can be configured to generate timely awareness information, including context (e.g. member availability, location or show up in a workspace). Passive delivery has nonetheless some limita-

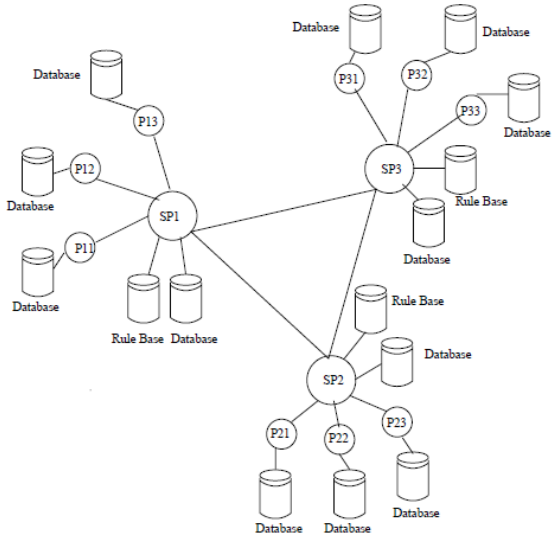

Fig. 1. P2P group-based model

tions. First, group members receive the awareness information according to an *a priori* configuration. Second, group members may be overwhelmed by too much information, which could in some situations be intrusive to group work. Thus, the passive mode should be complemented with the active mode, which requires group members to take specific actions to request awareness information. In fact, passive and active modes, as well as types of awareness information and frequency of its delivery, can be seen as aspects of awareness customization.

IV.j) Authorization: Current P2P groupware systems are also addressing issues related to authorization for identity purposes, accessing resources, etc. In our approach we consider that once a peer has been authenticated and has joined the group, they have the same access privileges as all other group members. This is in fact the most likely scenario in collaborative group work.

V. Abstract Model for Event-based Group Activity Awareness in P2P Groupware Systems

In this section we highlight the main features of our abstract model to support the requirements of event-based group activity awareness in P2P groupware systems.

V.k) P2P group-based model: The P2P group-based model considered is that of a superpeer model. In this model, the P2P network is fragmented into several disjoint peergroups (see Fig. 1). The peers of each peergroup are connected to a single superpeer. There is frequent local communication between peers in a peergroup, and less frequent global communication between superpeers.

V.l) Distributed group processes and data persistence model: We will assume a distributed model in which nodes are the peers and superpeers of the network. Group processes are distributed and replicated. Information relating to a group process and to task accomplishment derived from the project workflow are distributed and replicated at each group member within the peergroup (see Fig. 2). The distribution is transparent for peer group members. This model enables efficiency due to local access to data and support of failures (e.g. when peers leave or are disconnected from the network) under dynamicity assumptions. Peers' operations and control information are forwarded to their superpeer which manages the replication and consistency of information within the peergroup (note that replication will occur only within each peergroup as we consider disjoint peergroups).

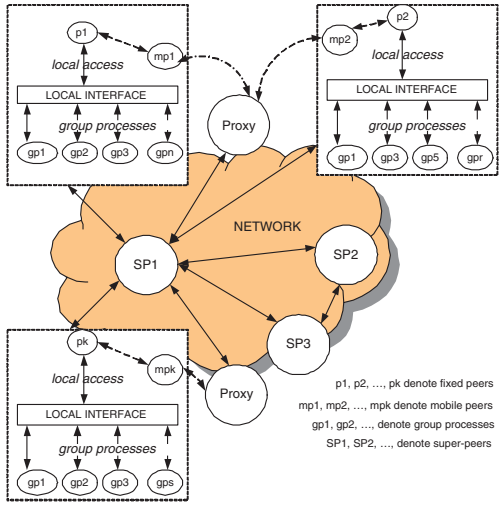

Fig. 2. Distributed replicated model.

V.m) Workflow model for the group project: A group activity can be represented as a workflow corresponding to the project to be accomplished by the group. A finite state machine (FSM) model can be employed, in which states represent members' activities and forward transitions are triggered by events upon user actions in accomplishing these activities. Event sequences are used to model a composition of tasks in the project workflow. We extend the FSM model also with backward transitions so that a group member can redo some tasks e.g. after feedback received on them from other group members.

V.n) ECA rules and query model: ECA rules have proven very useful in workflow management. To achieve the awareness information of group activities, we use ECA rules in our model to: (1) achieve replication and consistency of distributed group processes; (2) automate the receipt of awareness information by peers according to their desired specifications; and (3) query the information on group processes (both passively and actively) so as to provide the types of awareness (see Section IV).

For this, superpeers and peers are assumed to have ECA rule processing capabilities as well as query, storage and update capabilities over their local data. ECA rules created at any peer can be replicated, triggered, evaluated and executed at any other peer in the same peergroup. Operations initiated at a peer site, that affect peer's local data, are first executed locally and then notified to the superpeer. The superpeer then decides

whether the update operation triggers an ECA rule (or rules) to be executed at the rest of the peers in the peergroup.

V.o) Summary services model: As discussed in requirement section (Section IV), supporting overviews/summaries of awareness of information is vital to group activity and are critical in order to support mobile peers of limited computational resources. To that end, we define a model to build up local summaries at peers' sites, which are then used by the superpeer of the peergroup to compose global summaries from the distributed local summaries of peers. We envisage a summarization process at any peer's DBMS to support the construction of local summaries. A global summary is then defined as an indexing structure over the distributed local summaries at the peers of the peergroup.

VI. Supporting Awareness in Mobile P2P Systems

One of the objectives of the proposed model is to support awareness in groupware systems in mixed P2P networks, which may include mobile peers. In our model, mobile peers can be of two types: either stand-alone peers or attached peers. The first type is a normal peer representing a member of a peergroup and is connected to the peergroup through a proxy. The latter represents a peer attached to a fixed peer and is connected to the group through its corresponding fixed peer (see Fig. 2). As can be seen from the requirements, our model aims to support both normal mobile peers and mobile attached peers through the lightweight mechanisms and summary services.

VII. Conclusions and future work

In this paper we have presented an approach for awareness in fully distributed P2P groupware systems. As a first step we have identified the major requirements for activity-based awareness, which is one of the most important forms of supporting group work. The awareness model considered here focuses on supporting group activities in an academic setting so to accomplish a common group project, although it can also be used in a broader scope of teamwork settings in industry, health systems, etc. Our approach aims at overcoming the limitations of awareness in web-based approaches and supporting group work with awareness in many dimensions, including active and passive modes, different degrees of granularity of awareness information, and provision of advanced query processing over such information. Our aim is to support also summaries of awareness information to enable awareness support for mobile peers. Our abstract model has as its foundation a distributed, replicated model of data and process information within a superpeer-based P2P network. A group activity and its tasks are associated with a finite state machine.

In our future work, we will develop further the abstract model and design the awareness primitive operations and services. Also, we will evaluate how the proposed awareness model can be integrated into existing groupware systems.

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