The Challenges of Ambient Collaboration

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ABSTRACT

Collaborative capabilities are a hallmark of a new generation of networked applications. While traditional collaboration puts the computer in the foreground to help users interface through personal computing portholes, ambient collaboration reverses this paradigm by placing the machine in the background and enabling users to synergistically share a workspace with focus on mutual presence and tasks rather than tools. Although various ambient collaborative systems have been deployed in recent years, the field itself lacks a conceptual framework, in particular in contrast with legacy collaborative technologies. We introduce a simple systematics and roadmap for ambient collaboration to identify opportunities and challenges unique to this class of computing.

Categories and Subject Descriptors

C.0 [**Computer Systems Organization**]: General - *System Architectures*; C.2.4 [**Computer-Communication Networks**]: Distributed Systems - *Distributed Applications*; H.5.3 [**Information Systems**]: Group and Organization Interfaces - *Collaborative Computing;*

General Terms

Design, Reliability, Experimentation, Human Factors.

Keywords

Contextual computing, ambient media, ubiquitous collaboration, tetherless group workspaces.

1. INTRODUCTION

Collaborative technologies increasingly permeate our daily lives. Legacy collaboration has made progress in various areas such as web meetings, video conferencing, or instant messaging, but the effectiveness of such systems is still limited. Existing systems have not met users' needs for greater transparency, presence, and the ability to easily work with likeminded users ubiquitously and unobtrusively.

The novel paradigm of ambient collaboration turns the mechanics of collaboration inside out and marks a shift from "placeware" to "spaceware", that is, from co-working through personal computers as focal point to cognizant computing periphery that surrounds the user with an unobtrusive interaction canvas of intuitive, group-centric interfaces. Ambient computing tacitly merges with the surroundings to provide lightweight interfaces for cooperative task execution. This paradigm widens the computer-mediated workspace metaphor and makes the computer the "machine behind the curtain". It also opens up new avenues in how ambient computing devices can assist collaborative group processes and help to leverage mutual presence in conjunction with shared task focus.

We argue that building such systems based on Weiser's notion of "calm" technology [14] requires radical rethinking of the desktop metaphor and the conceptual elements that successfully birthed the desktop PC. Ambient technologies need to match the vision of the disappearing computer [13] in a digital culture clash with ingrained legacy windows, icons, mouse, and pointer interfaces. To network humans in large-scale ambient environments, "tacit collaboration" will have to be structured around user tasks, activities, and presence, rather than configuration and control-driven menus. Design of such environment must intrinsically embrace planning, logistics, coordination, communication, monitoring, and rendering from a shared and social computing perspective, rather than individual workspaces. In order to bring more clarity to the design space, we provide a nutshell summary of ambient collaboration concepts and offer a taxonomy of its various dimensions in Section 2. Section 3 frames current challenges in designing ambient collaboration environments and Section 4 offers an outlook.

2. ARCHITECTURE AND SYSTEMATICS

Pervasive computing infrastructures that facilitate collaboration build on the same design principles governing "anywhere, anytime" computing. They possess specific characteristics that need to be considered by developers.

- Such systems are intended to serve *communities* of users, whose traits and roles, together with contextual information of mutual requirements and agreements, should be integrated into collective grid databases to reflect the semantics and pragmatics of collaboration processes.

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- Ambient collaboration is put into action by an amalgam of *many concurrent applications*. Process configuration and runtime management must run autonomously and shield the user as much as possible from administrative inputs.
- *Blending asynchronous with synchronous use* must be supported for roaming users and disconnected operation. Replication of shared data and context requires network intelligence to bring content to users in a mix of online and offline collaboration.
- Support for shared demonstrative reference (*deixis)* is needed to support users' cross-referential sharing of objects. Existing methods like telepointers may not suffice due to limited context use.
- Ambient collaboration should be independent from the heterogeneous cooperative runtime environments, applications, languages and sharing paradigms enabling it, serving individual users as well as groups. New mechanisms to *dynamically and seamlessly coordinate* ambient and non-ambient applications and platforms are needed.
- Ambient collaboration centers around the notion of social networking with joint task focus and needs hence to be integrated with novel concepts of *identity management, trust, and community networking*.

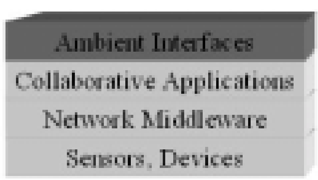

Figure 1: Prototypical ACE Architecture.

A basic layered architecture for ambient collaborative environments (ACEs) is shown in Fig. 1. The ACE design space is a tuple

<U, A, D, T, C>

where **U**sers run **A**pplications on heterogeneous **D**evices to collaborate on **T**asks with various **C**onnectivity parameters.

The user space **U** entails how users arrange their activities. Autonomy can range from codependency in activities to completely independent work. Mobility can range across several ambient spaces, or fixing users to a single workspace. Deploying ambient computing inherently creates locality and less mobility, with the advantage that users will not have to carry the computer. Presence describes the degree to which users are aware of others given certain personality or activity cues, which may extend beyond the individual to an entire group.

The application dimension **A** describes how the runtime environment adapts to user profiles in a specific shared work context. Interactive spaces can be rendered in two or three dimensions where 2D interfaces integrated with tables or walls are currently predominant. Input and output can be centered around typing and pointing tools, or allow for more natural interaction by integrating voice, gestures or haptics. Control of shared object access is either moderated or free, which impacts security and privacy. Shared ambient spaces require access and concurrency control methods beyond current OS protection mechanisms. Floor control to mediate interaction exchanges and orchestrate shared object usage has great relevance in ambient spaces since representation of shared objects may link to real-world spaces beyond the scope of the aging desktop metaphor.

Devices **D** can be found in "ambient appliances", either at the micro-level, for example as sensors, or at the macro-level as wall-sized displays. The various embedded operating systems driving these devices impact the heterogeneity and interoperability of ACEs. Size and placement of devices will affect whether they are used as a singular tools or as integrative "roomware" [12]. Once ambient systems enter the consumer market, questions of integration will need to be addressed - will they be offered as all-in-one devices or as separate components in modular kits? Similarly, will such devices offer unimodal or multimodal media usage, i.e. the ability to work with a specific data such as images, or a combination of various media. Composure reflects whether a device renders the workspace in abstract, metaphorical terms, in contrast with more realistic spatial representations.

The task dimension **T** addresses, whether the workspace created for a task is open and accessible by anyone, or closed and by invitation only, which is essentially an authentication matter. Tasks can lead from one to another in workflow style, or can be separate. Tasks may need to be carried out sequentially or in parallel threads, and may be governed by specific control policies and group rules.

The connectivity dimension **C** represents how distributed sites network with each other. Continuity describes whether transmission is continuous or bursty. Dissemination can be either one-to-one, one-to-many or many-to-many. For multiparty transmissions, underlying communication services such as IP or overlay multicast may be critical. Depending on the purpose and application, transmissions may be one-way or bidirectional. Scale addresses how many devices, users, and sites need to be linked together. Locality describes the distribution of ambient components and activities across the space, from furniture, cubicles, or rooms to entire buildings. Finally, temporality marks whether coordination among users is at the same time, or at different times.

Naturally, the type of applications, tasks and interactions will change based on the specific mix of these various factors. Table 1 summarizes the parameter spectrum for characterizing ambient collaborative spaces in relation to the above discussion. The instantiation of these factors creates a particular situational work context that an ambient system should be aware of and support. Given the multitude of characteristics, engineering of such system faces various challenges, which are discussed next.

Table 1: Design Parameter Space for ACEs.

U	AUTONOMY: dependent – independent MOBILITY: fixed – roaming PRESENCE: individual – groups
A	ADAPTIVITY: none – fully DIMENSIONALITY: 2D – 3D I/O: conceptual – natural CONTROL: moderated – free-flow
D	EMBEDDING: micro – macro HETEROGENEITY: one – many platforms INTERFACE: tool – space centric INTEGRATION separate – all-in-one MODALITY: uni – multi COMPOSURE: synthetic – realistic
T	ACCESSIBILITY: closed – open CONTINUITY: separate – seamless THREADING: sequential – concurrent EXECUTION: uncontrolled – controlled
C	CONTINUITY: intermittent – continuous DISSEMINATION unicast – multicast DIRECTIONALITY: simplex – duplex SCALE: small – large LOCALITY: room – distributed TEMPORALITY: asynchronous – synchronous

3. CHALLENGES

Pervasive collaboration accordingly encounters many challenges in the gathering, interpretation, storage, and dissemination of large amounts of data from embedded sensors. Data must be perpetually collected, filtered for relevance, integrated into the current context, and securely and scalably disseminated to cooperative work spaces, while ensuring user privacy. Interaction design, sensing and context, infrastructure and heterogeneity, discovery, dynamism and robustness, and security are thematic issues. Ambient collaboration faces similar challenges to building virtual environments [2, 9], however, proper integration of local and remote user workspaces is essential. The notion of context [4] is crucial for intimate teamwork. Using the same ambient interfaces and integrative collaborative applications, users should be enabled to learn, create, exchange, retrieve and archive information, and hence effectively co-operate on shared tasks.

3.1 Dependability, Data Migration and Robustness

If ambient computing enables users to leave the personal computer at home, system availability, disruption tolerance, and data accessibility from anywhere at anytime become a critical operational premise. With the environment becoming the computer, data must be securely accessible 24/7. Given the common vulnerability of current computing systems, nomadic collaboration with ambient systems hence requires a greater level of dependable computing [11] than known to date. Storage, replication, content migration and caching are particularly important when users are to let go of the notion of keeping content close to their body and to travel freely with the expectation that their data spaces are available for individual or shared access in ubiquitous computing [1]. Ambient usage implies that such content migration and the network support to establish shared workspaces in ambient spaces will be largely transparent to the user.

3.2 Infrastructure and Interoperability

Unless proprietary operation is intended, compatibility among ambient collaborative systems will be essential, in particular due to a lack of standards and implementations on various proprietary platforms. Multimedia usage in ambient collaboratories and media spaces [3, 7] requires very high bandwidth to interconnect multiple sites.

3.3 Scale and Scope

ACEs must scale well at great scope. Scalability concerns the coverage, spatial layout and number of embedded systems as well as network performance, as a function of user group dynamics and interactivity patterns. Scoping concerns the formation of groups at a distance and how far traffic can reach to bring local and remote teams together.

3.4 Interfaces and Workspace Metaphors

Cramton [5] identifies five problem areas in establishing mutual knowledge in distributed collaboration: failure to communicate contextual information, unevenly distributed information, difficulties in communicating the salience of information, speed differences in access to information, and problems in interpreting silence. These factors can also be seen as constituents in the failure of current collaborative systems [8]. The proper interweaving of physical and remote spaces in ambient collaboration demands simplicity and intuitive use beyond mouse, pen, and keyboard. Winograd [13] refers to this more sophisticated integration of local and remote objects in spatial metaphors as the "overface". Ambient collaboration may extend across several remote places, which demands new methods in aggregating and synchronizing such spaces and their information streams. With the idea of ambient deployment in mind, users should not be expected to configure the various peripheral appliances in their workspace, in particular when such environments and the interactions through them change frequently.

3.5 Presence and User Dynamics

Presence protocols at the network level and immersive technologies [9] at the application level are both required to support mutual awareness among users. The exact rendition of presence will depend on the application. A system that is for example intended to support wide-area distance learning by connecting local and remote classrooms through ambient computing should support presence so that students can follow all activities of the teacher, while the teacher is alerted of individual students' needs. Ambient collaborative software should also support groups of users interacting through ambient environments where membership and personal presence fluctuate frequently. Current social computing platforms [6] may accordingly evolve and fuse with ambient systems in a translucent merger of synchronous and asynchronous shared spaces.

3.6 Context, Information Fusion and Filtering

Context [4, 10] becomes a matter not only of how the machine attunes to local users, but how local and remote context are interwoven to create meaningful workspace synergy.

3.7 Security, Trust and Privacy

Ubiquitous access and creation of shared workspaces impose generally stronger requirements on secure protocols for data access and migration. Security in ambient systems is a local and network concern. Shared spaces must be configured bullet-proof so that users in interactive scenarios are not forced to handle individual access issues. Authentication among users, teams of users, and devices are critical, as well as encryption of information flows. Trust in ambient systems is inherently linked to dependability.

3.8 Network Support

Ambient collaboration through the Internet may require additional protocols to support dynamic group formation, scalable transmission of interactive traffic, distributed control to access and manipulate shared workspaces, and to create reliable, time-sensitive communication. Existing transport protocols for this matter may not be a sufficient solution, and lessons learned from networked multimedia systems need to be taken into consideration. Just as session description, announcement, and invitation protocols have been introduced to leverage voice and video conferencing through the internet, novel middleware protocols are needed to orchestrate ambient collaborative work. A related challenge is the provision of Quality-of-Service through the best-effort Internet infrastructure. Ambient collaboration can only stay true to its mission, if system and network issues will not hamper users and their joint work.

4. OUTLOOK

Collaboration is increasingly a driving factor for computing in its perpetual diversification and merging with our daily lives. While traditional collaborative systems clumsily aggregate virtual teams and their tasks with computers in the foreground, ambient collaboration embeds collaborative mechanisms in our surrounding environment and offers greater group cohesion through room or wall-based work areas, thus drastically widening interaction and multitasking scope with the computer in the background. Ambient collaboration is a marriage of the idea of the "disappearing computer" [13] with collaborative technologies.

Development of ambient collaborative systems faces many challenges, such as workspace-device integration, identity and trust management, context provision, presence, network support, and novel paradigms for large-scale interfaces. Naturally, the mechanics of collaboration changes with the tools and interfaces enabling it. Issues such as usability and group effectiveness must hence be addressed additionally. Tying users to particular locations with ambient computing equipment makes working with such systems less attractive. Combining ambient with nomadic collaboration is hence a promising direction for future research.

This paper contributes a first, unified characterization and architectural roadmap for this emerging field. It sheds light on the innovation potential and challenges in ambient collaboration, which will be a critical building block to support high-quality group interaction in future distributed work environments and ultra-high performance networks.

5. REFERENCES

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