PriCal: Dynamic Privacy Adaptation of Collaborative Calendar Displays

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Abstract
Office wall calendars often contain only entries considered public, which reduces their utility for scheduling meetings or gaining an overview of one's schedule. PriCal is a collaborative calendar display that dynamically adapts to present persons and their privacy preferences. We outline our current prototype, consisting of a calendar agent for display adaptation, a mobile app for managing individual calendars and privacy settings, and a system for detecting present persons and identifying registered users.

Author Keywords
Calendar; context; CSCW; groupware; privacy; public displays.

ACM Classification Keywords
H.5.2 [Information interfaces and presentation]: User interfaces; H.5.3 [Information interfaces and presentation]: Group and organization interfaces.

General Terms
Design, Human Factors, Security.

Motivation
Wall displays in offices can facilitate cooperation between coworkers or increase awareness of business processes, e.g., by displaying calendar information to assist groups in

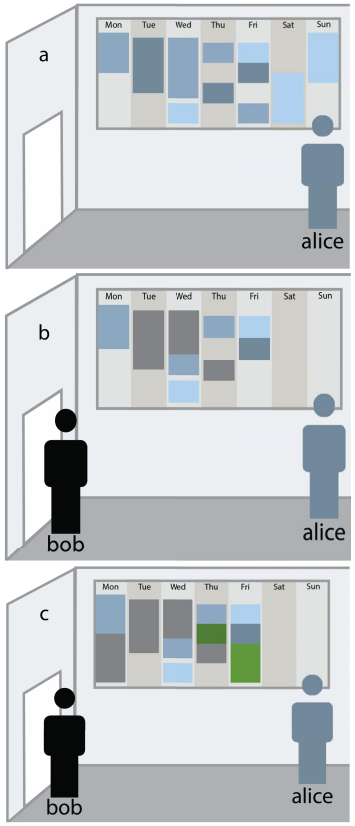

Figure 1: Privacy-adaptive calendar display: (a) The display shows Alice s complete schedule; (b) when Bob enters, certain entries are only shown as busy, others are hidden completely, based on Alice s preferences; (c) Bob s entries are displayed similarly.

scheduling meetings, as well as providing individuals with an overview of their schedule. In contrast to paper-based wall calendars, which are often only used complementary to other calendars [12], calendar displays can be synchronized with a user s digital calendars across computers, mobile devices, and cloud services. However, displaying calendars on a wall display also creates privacy issues, because personal schedules contain a mix of entries, ranging from team meetings and general business appointments to con dential meetings, as well as personal entries [1, 12]. Much of that information would be considered too sensitive to be displayed publicly or even in a semi-public o ce environment, where calendar entries could be seen by potential visitors. Thus, most wall calendar likely only contain information considered to be public, if omission is the only option for privacy management [6]. If that is the case, the utility of a calendar display decreases. The calendar would only provide an incomplete view of the user s actual schedule, and when scheduling a meeting, each involved person would also need to crosscheck personal calendars (paper-based or digital) for additional scheduling con icts.

We propose PriCal, an adaptive calendar display that addresses these issues by dynamically updating displayed information based on privacy preferences of individual users. Our system detects persons in the display s vicinity and uses this context information to adapt what calendar information is shown and how. Consider the example shown in Figure 1. When Alice is alone in her o ce, the calendar display shows her complete schedule, including personal entries. If Bob enters, some entries are only shown as busy, while other are hidden completely, depending on the Alice s privacy preferences for Bob. In addition, Bob s appointments can also appear on the display, ltered according to his preferences for Alice.

Related Work

Palen [6] studied privacy issues of calendar groupware. She nds that users are concerned about revealing their schedule and work time allocation, but also want to protect the privacy of others and con dential business information. Our proposed system is a single-display groupware, as it supports collaboration between users on one display [11]. Privacy of information sharing on such displays has received some attention [4]. Shoemaker & Inkpen [10] propose to create private I/O channels with user-worn shutter glasses to display public and private information simultaneously. Proactive displays adapt their displayed content based on present persons [2]. Proxemic interaction uses multiple dimensions (*distance*, *orientation*, *identity*, *movement*, *location*) to guide device adaptation and interaction in relation to the proximity of persons and devices [5]. Marquardt & Greenberg [5] suggest its potential for dynamic privacy management. Vogel & Balakrishnan [13] propose a calendar application for public displays that only shows a user s calendar entries, if that user is close enough to the display to shield it with her body. In our approach, we leverage distance, identity, and location to obtain an adaptive calendar solution more suitable for collaboration of multiple users.

PriCal: Privacy-adaptive Calendar Display

Dynamic privacy adaptation [8] leverages context awareness to support users in dynamically regulating their privacy in ubicomp environments [7], by either autonomously recon guring disclosure settings according to user preferences or providing situation-speci c recommendations. For collaborative calendar displays, present persons are the dominant factor guiding privacy adaptation. Based on the changing set of present persons, our system dynamically shows, hides, or obfuscates calendar entries on the display, according to the individual

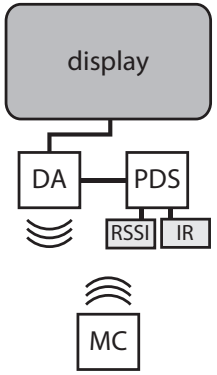

Figure 2: Architecture of the privacy-adaptive calendar display.

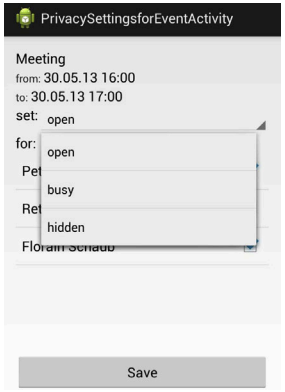

Figure 3: Privacy settings dialog on the mobile client.

preferences of users. Figure 2 shows the main components of our system. A *display agent (DA)* manages displayed calendar content. Its *presence detection system (PDS)* senses the environment for present persons and maintains a list of identi ed and unknown persons nearby, which is also provided to nearby *mobile clients (MC)*. The MC manages a user s calendars and privacy preferences.

Mobile Client

A user s calendar entries are organized in multiple *personal* (e.g., business, personal) and *shared calendars* (e.g., project- or group-related) [12, 6]. The MC is implemented as an Android app, which uses the platform s *Calendar Provider* to access the user s multiple Google calendars. A user can specify privacy preferences per calendar or for speci c entries. Preferences pertain to speci c persons, groups, or unknown persons; they indicate if an entry should be displayed *open*, as *busy*, or *hidden* (see Fig. 3). The user s privacy preferences are evaluated against the set of present persons, when a nearby DA provides an update via wi . The MC generates an accordingly adapted view of the user s schedule, which is pushed to the DA (see Fig. 6).

Display Agent

The DA runs on a Raspberry Pi connected to a wall-mounted display. It is based on the WE-BAT template for public display applications [3], which facilitates integration of user data on displays. The DA receives adapted calendar data for display from multiple MCs. If multiple users provide di erent privacy preferences for an entry (`EVENT_ID`), the DA resolves the con ict by selecting the narrower setting, e.g., hide instead of busy). The merged calendar (see Fig. 5) is displayed with FullCalendar [9].

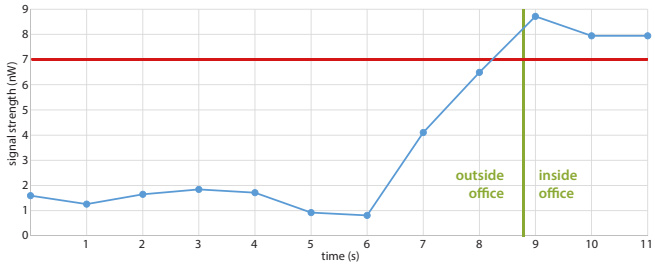

Figure 4: RSSI values of mobile device entering o ce with display from hallway (linear scale, 3-value moving average).

Presence Detection System

Persons in proximity of a display have been detected with magnetic cards, Bluetooth, RFID, or wi [2], as well as body trackers and cameras [13]. Our goal was a low-cost system that enables users to also remain anonymous, if desired. Thus, the PDS measures wi received signal strength (RSSI) of nearby devices with a separate wi module in monitor mode. Registered users are identi ed based on the MAC address of their smartphone. Our measurements indicate su cient RSSI di erences to distinguish between devices inside and outside of individual o ces with su cient accuracy. RSSI values are smoothed with a moving average over the last 3 values (see Fig. 4). The PDS only measures RSSI on speci c messages broadcast periodically by the MC app, which can be deactivated to let users control when they are identi able by the system which is di cult to achieve with camera-based systems.

We further installed an IR sensor in the o ce door frame to detect unknown persons and anonymous users. A sensor-based event is triggered when persons enter or leave the o ce where the display is located, thus, the PDS is aware of any present persons. The set of nearby persons is used by the DA for display adaptation, and also

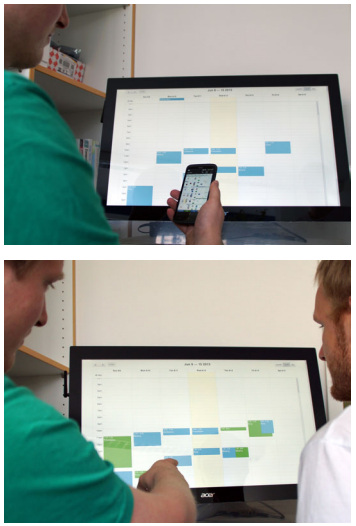

Figure 5: Calendar display with one and two present persons.

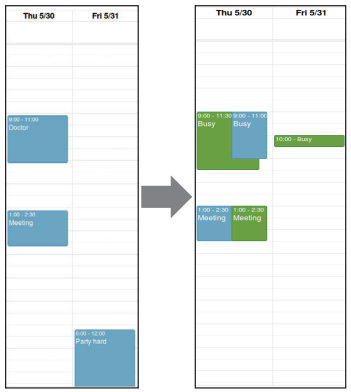

Figure 6: Detailed view showing the adaptation of the first user's calendar entries (*blue*).

provided to nearby devices that connect to the DA. This combined detection system further facilitates gradual adaptation. Sensitive calendar entries can be hidden when the light barrier activated to prevent exposure. Once the entering person has been identified, information may reappear on the display, if less restrictive preferences apply.

Conclusions and Outlook

PriCal allows to display calendar schedules on wall displays without risking exposure of private information. Displayed information is dynamically adapted to present persons based on individual privacy preferences of users. Localized presence detection, management of calendar data by the user's personal device, and the option to remain anonymous enable such adaptation without sacrificing user privacy in the process. Our presence detection system provides a low-cost solution for small to medium-sized offices, each containing one display. The approach could also be adapted for larger or open office spaces by reducing antenna gain to limit detection range and adding depth sensors to persons in front of the display.

PriCal has been implemented as a fully functioning prototype. In preparation of a deployment study of PriCal in a multi-office environment, we are currently refining and field testing the RSSI measurement approach to ensure reliable person detection with a low detection error rate. Furthermore, we are extending the mobile client to learn a user's fine-grained privacy preferences from selective disclosure of entries to free users from specifying detailed and complex preferences, a priori. We also plan to improve the calendar display, e.g., by highlighting shared entries.

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