PD Notify: Investigating Personal Content on Public Displays

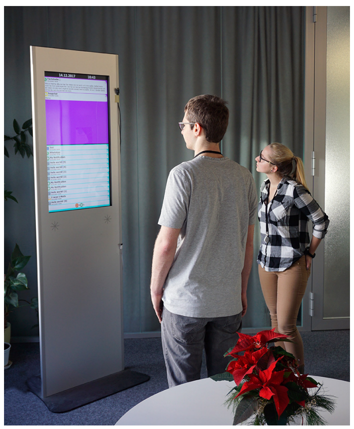

Figure 1: Two users are standing in front of a public display that was used in the study. The display is located in a semi-public kitchen environment. The users wear lanyards with Bluetooth Low Energy (BLE) beacons around their necks. The public display detects the beacons and mirrors the users' smartphone notifications.

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Abstract

Public displays are becoming more and more ubiquitous. Current public displays are mainly used as general information displays or to display advertisements. How personal content should be shown is still an important research topic. In this paper, we present *PD Notify*, a system that mirrors a user's pending smartphone notifications on nearby public displays. Notifications are an essential part of current smartphones and inform users about various events, such as new messages, pending updates, personalized news, and upcoming appointments. *PD Notify* implements privacy settings to control what is shown on the public displays. We conducted an in-situ study in a semi-public work environment for three weeks with seven participants. The results of this first deployment show that displaying personal content on public displays is not only feasible but also valued by users. Participants quickly settled for privacy settings that work for all kinds of content. While they liked the system, they did not want to spend time configuring it.

Author Keywords

Public displays; notifications; pervasive; privacy.

ACM Classification Keywords

H.5.m [Information interfaces and presentation (e.g., HCI)]: Miscellaneous

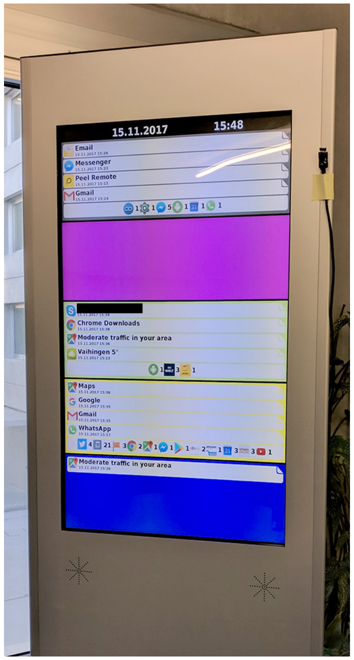

Figure 2: State of the public display with five nearby users. Two users allowed reduced content (green, blue), another two users allowed only app names (gray, yellow), and one user did not have pending notifications (pink).

Introduction and Background

Public displays are becoming increasingly common in many public environments. Currently, most public displays are used to display general information or advertisements, as displaying personal content poses many privacy implications. In prior work, Vogel and Balakrishnan developed design principles and an interaction framework for displaying personal content on public displays [7]. Their framework increases the level of personal content as the user is getting closer to the display. The authors argue that only "harmless" personal content should be shown. Shoemaker and Inkpen investigated interaction techniques to allow private information on shared displays [6]. Langheinrich explored design principles for privacy in ubiquitous computing systems, including the issues of "choice and consent", "proximity", and "pseudonymity" [3]. Alt et al. developed *Digifieds*, a digital public notice area [1].

The lack of public displays showing personal content indicates that further research is needed in this area. We argue that, to learn about personal content on public displays, it is necessary to conduct studies using diverse sets of personal content. Smartphone users are confronted with proactively provided personal content on a daily basis through notifications. Notifications are an essential feature of current smartphones. Apps provide users with a wide range of content, e.g., instant messages, emails, game invites, personalized news, upcoming appointments, and app updates. In a large-scale assessment of mobile notifications, Sahami Shirazi et al. collected notifications from over 40,000 users [5]. The researchers found that users receive a large, diverse set of notifications from a large number of apps. Users value communication-related notifications and, in general, important notifications are about people and events. Pielot et al. showed that while communication-related notifications help to make users feel more connected to others, receiving too many notifications can get overwhelming [4]. Mobile notifications use different cues to attract the user's attention. Hansson et al. compared public with private and subtle with intrusive notification cues [2]. The nature of notifications is that for the most part users do not know when or what they are being notified about. Combined with the diversity of apps and therefore the types of content, smartphone notifications are an excellent source for personal content.

In this paper, we introduce *PD Notify*, a system to explore personal content on public displays. *PD Notify* mirrors the user's pending smartphone notifications on nearby public displays. The system consists of public displays that can detect nearby users and a smartphone application that forwards the users' notifications to the displays. Users are in control how much content should be shown on the displays, on a global and an app-specific level. We report the system architecture and the first deployment in a semi-public work environment. To evaluate the system, we conducted a three-week long in-situ study with seven participants. In the study, we logged the participants' behavior with the system and conducted semi-structured interviews. The results show that displaying personal content on public displays is not only feasible but also valued by users. Participants quickly settled for privacy settings that work for all kinds of content. While they liked the system, they did not want to spend time configuring it.

System

PD Notify mirrors users' pending smartphone notifications on nearby public displays. To access the notifications, we implemented an Android app that listens for added and removed notifications on the user's device. The app forwards the notifications to a central server using a secure connection. The central server can then forward the notifications to connected public displays. The system supports any

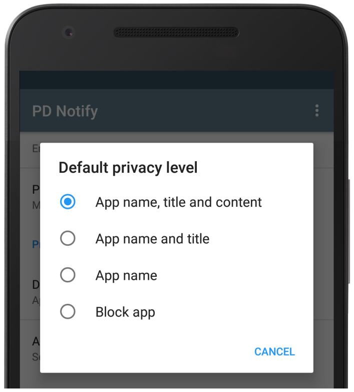

Figure 3: Settings dialog for the default privacy level, applying to all apps unless overwritten.

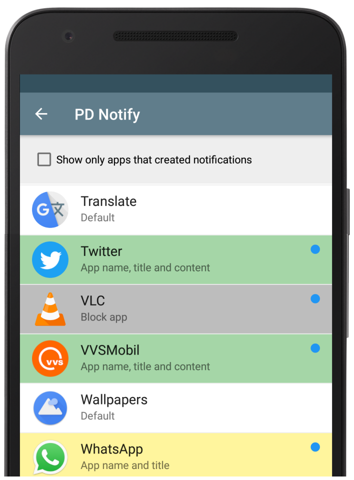

Figure 4: Per-app privacy level overview. Blue dots indicate that the app created at least one notification. Overwritten privacy levels are color-coded to provide information at a glance.

number of public displays. Privacy settings in the app allow users to control how much content should be sent to the central server and therefore should be shown on the public displays. Based on our work on notifications on shared smart TVs [8] we implemented four privacy levels that correspond to “send everything”, “limited content”, “app name only”, and “nothing”. A global privacy level applies to all apps (see Figure 3) and can be overwritten on a per-app basis (see Figure 4). Changing the privacy level instantly updates the content shown on the public displays. Further, a “clear all” button allows users to immediately remove all notifications from all displays at once.

According to prior work, personal content should only be shown on public displays if users are near the display [7]. We explored the idea of using the smartphones’ Bluetooth functionality to detect nearby users. In tests, we found that the Bluetooth signal quality varied considerably between different kinds of smartphones. Instead, we opted for using “Gigaset G-tag” Bluetooth Low Energy (BLE) beacons attached to lanyards (see Figure 7). These beacons broadcast a unique Bluetooth address every two seconds. The public displays continuously scan for the beacons. A user is regarded as near a public display if the number of received BLE broadcasts in a time window and the Received Signal Strength Indicator (RSSI) are above certain thresholds. The thresholds are defined per public display depending on the environment. The BLE scanners inside the public displays continuously send the list of detected users to the central server, which in return forwards the nearby users’ notifications to the display. If multiple users are near a display, the screen space is divided equally. All users are assigned a specific color on the public display that allows them to quickly see which notifications belong to them while providing pseudonymity (see Figures 1 and 2).

Study

We now report the first deployment of the *PD Notify* system. In a three-week long in-situ study, seven participants mirrored their personal smartphone notifications on two public displays in a semi-public work environment.

Design

We conducted the study in a corridor of a university building. We set up two public displays in popular meeting areas. Both displays featured 40” screens with a resolution of 1080×1920. Two “Raspberry Pi 3 Model B” single-board computers powered the displays and continuously scanned for nearby beacons. The corridor plan with the public displays and the participants’ offices is shown in Figure 6.

Procedure

All participants signed a consent form and filled out a survey about demographic data. We then installed the Android app on the users’ personal Android smartphones. We walked them through the app and explained all settings. The app was set to mirror all notification content to the public displays for all participants. Then, we distributed the beacons and assigned a color-code to each participant. We instructed the participants to use the app as they see fit and explicitly stated that disabling the app was allowed. After three weeks, we invited the participants to export the log data, fill out a questionnaire, and conducted semi-structured interviews. All participants participated voluntarily and did not receive a monetary reward.

Participants

We recruited participants from the corridor who owned Android smartphones. We excluded one participant due to technical reasons, resulting in seven participants (1 female). They were between 26 and 35 years old ($M = 29.14, SD = 3.24$). All participants were Ph.D. students with a technical background.

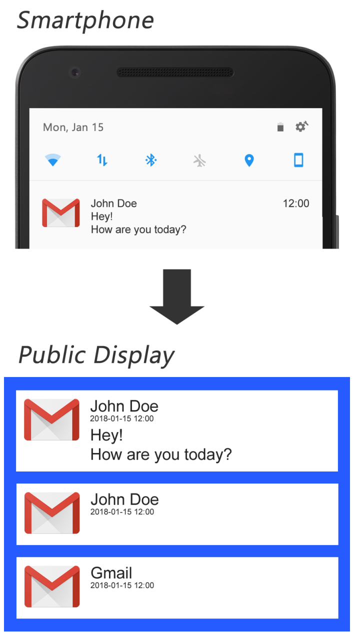

Figure 5: An exemplary smartphone notification mirrored to a public display. Depending on the privacy level selected by the user, the level of detail on the public display is reduced. The fourth privacy level is not to mirror notifications from the app at all. The background color (blue) is used as a color-code to provide pseudonymity.

Results

We now report the user's interaction and experience with the system, and summarize the semi-structured interviews.

Notifications and Privacy Settings

During the study participants received between 135 and 608 notifications per day ($M = 375, SD = 204$). These numbers include updates to existing notifications, like periodically refreshing weather forecasts. Participants had between 15 and 51 apps notifying them ($M = 33, SD = 12$). Categorizing these apps showed that most notifications were from the category *Instant Messaging* (46.96%), followed by *Email & Phone* (21.49%), *Tools* (7.46%), *General Information* (8.84%), *Android System* (8.08%), *Entertainment* (2.78%), *Finance & Shopping* (2.37%), *Social Media & Dating* (1.71%), and *Health & Fitness* (0.30%). On average, per day participants spent 35 minutes in front of the public display located in the kitchen area and 30 minutes in the sofa corner.

All but one participant initially tested various default privacy levels and settled for one setting that they were comfortable with for all kinds of content within the first day of the study. In the end, no participant chose to display all content, two participants allowed reduced content, and four participants permitted only the app names. One participant initially allowed all content to be shown but changed the setting to block all content after five days. The participant told us that he assumed that no one could speak his language but then noticed that people were, in fact, reading his notifications. This caused him to block all notifications on the public displays. App-specific privacy settings were only used by 3 participants, in all cases to block specific apps completely. One participant blocked 14 of 31 apps (various categories), one blocked 4 of 51 apps (all *Social Media & Dating*), and one 2 of 25 (*General Information* and *Entertainment*).

Questionnaire

We asked participants to rate statements on a 7-point Likert scale from 1 (strongly disagree) to 7 (strongly agree). Participants agreed that the system worked as expected ($M = 5.57, SD = 1.40$) and that the visualization of the notifications was appealing ($M = 5.00, SD = 1.73$). They had privacy concerns ($M = 5.43, SD = 1.81$) but found the provided privacy levels to be sufficient ($M = 5.57, SD = 2.15$). However, they disagreed that the color-coding provided privacy ($M = 3.86, SD = 2.61$). Overall, the usefulness of the system was rated as neutral to positive ($M = 4.43, SD = 2.37$).

In free text fields, we asked the participants why they chose their corresponding default privacy level. Participants all agreed that they do not want to share the information in the notifications with others. One participant mentioned that he chose the level because his colleagues chose the level as well. All participants agreed that displaying all content is only appropriate for private displays, e.g., at home. One participant mentioned that showing full content would only work if it can be ensured that no sensitive personal data is being displayed. Displaying reduced content or only app names worked best for all but one participant. They agreed that these options provide them just enough information hints to know whether the notification is important.

Semi-Structured Interviews

All but one participant kept their chosen privacy level after the initial setup, as they found that it worked for all kinds of content. P1 and P2 mentioned that they would feel comfortable to show more content in open spaces with more people. P2 stated that over time he learned which color belongs to which user. Although the privacy levels were sufficient, he would be more comfortable with displaying more content if word filters were available. P7 stated that she was

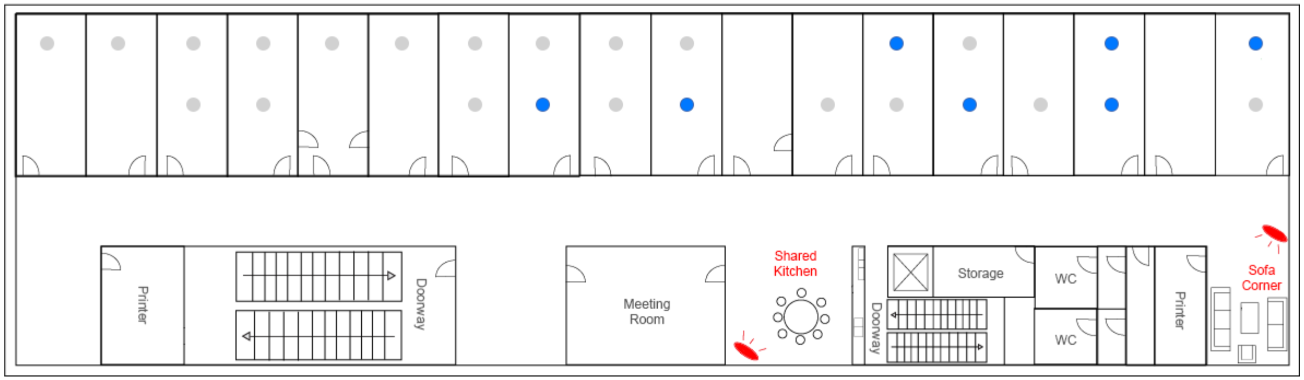

Figure 6: Floor plan of the corridor the study was conducted in. The corridor itself is semi-public with students and visitors regularly walking around. A shared kitchen and a sofa corner are popular meeting places in which we set up a public display each (shown in red). Blue dots indicate the offices of the study participants. Gray dots indicate people who did not participate in the study.

Figure 7: A Bluetooth Low Energy (BLE) beacon as used in the study. All participants carried the same type of beacon, allowing for a reliable detection of nearby users. Ballpoint pen for scale.

concerned because the system makes things written by other people public, which resulted in her initially clearing her notifications more often.

P3 thought more about his notifications when walking towards a public display to avoid embarrassing notifications. Participants liked not having to take their phones out of the pocket. A side effect of the system was that participants left their phones more often in their offices (P2, P3, P7). According to P7, the system made people more accepting of the fact that "you are not responsive all the time".

Participants sometimes forgot to carry their beacon or smartphone (P2, P3, P4, P7). In case of the smartphone, participants told us about their positive and negative experiences. The system allowed them to see their notifications when they forgot their smartphones in their offices. However, without their smartphones, participants were unable to dismiss unwanted notifications. P7 disliked having to carry the beacon. When asked if the detection should work with the smartphone only, she replied that ideally she should not have to carry anything.

P3 told us that the notifications were a topic to talk about in the meeting areas. However, P7 found that it led to awkwardness because people asked why she has a certain app or did not finish a task yet (to-do app visible). P5 explained that he once terminated a conversation in the kitchen because he saw a notification on the display.

Nearly all participants were interested to use the system as a pervasive information display at home (P2, P3, P4, P6, P7). P2 suggested being able to share media on the public display when nearby. It could be used as a "public whiteboard" to share messages with colleagues (P2, P5, P7). P1 and P2 wished to interact with the public display directly, e.g., using touch to dismiss notifications. Participants suggested displaying some information persistently, e.g., weather forecasts, public transport information, smartphone battery levels, and upcoming events.

Summary and Conclusion

In this paper, we presented *PD Notify*, a system to investigate personal content on public displays. The system mirrors the user's pending smartphone notifications on nearby public displays, enabling us to test a variety of different content from instant messages to calendar appointments. Users can change the level of detail that is shown on the displays using global and app-specific privacy settings. We conducted an in-situ study in a semi-public work environment, where we deployed two public displays in popular meeting areas. Seven co-workers used the system for three weeks, and we conducted subsequent semi-structured interviews with the participants.

The results of this first deployment show that displaying personal content on public displays is not only feasible but also valued by users. Participants limited the display of personal content regardless of the content category. They initially tested various privacy settings but quickly settled on one setting that they were comfortable with for all kinds of content, with app-specific settings being an exception. An important finding is that no participant allowed all content to be shown on the public displays. Most participants favored displaying reduced content or only the names of apps. While participants liked the system, they did not want to spend time configuring it. This raises important implications and interesting discussion points regarding personal content on public displays, e.g., the need for reasonable default settings. In the future, we plan to improve the system based on the feedback we received from the participants and deploy it in more environments to gain insights from a more diverse set of participants.

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