EasyGroups: Binding Mobile Devices for Collaborative Interactions

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Abstract
We present a touch and proximity based method for binding a group of mobile devices into an ecosystem for collaborative interactions. We aim to provide a seamless user experience by integrating the binding method with the application start-up flow. Our method also determines the order of the devices, allowing implementation of spatial interactions.

Keywords
Collocated Interaction; Mobile Phones; Device Ecosystem Binding; Group Association

ACM Classification Keywords
H.5.m [Information Interfaces and Presentation (e.g., HCI)]: Miscellaneous;

Introduction
Mobile devices were originally conceived and have traditionally been applied for individual use. Recent advances in sensor and short-range communication technologies offer new opportunities for collaborative use of mobile devices. Groups of collocated users can couple their devices together and create ecosystems of interaction [17], allowing the users to engage in shared multi-user activities and experiences with their mobile devices. In our earlier work, we have developed the

Social and Spatial Interactions (SSI) platform [10], which supports such collaborative use of mobile devices. In addition to collaborative interactions, the platform also supports spatial interactions in the shared space, for example, throwing virtual objects like photos between devices. The spatial interactions are made possible by integration of radio tracking technology into the devices. We have demonstrated the benefits of collaborative use of mobile devices in a number of different applications, including mind map creation [11], photo sharing [12], and public expression [7].

Before a group of users can engage in collaborative interactions with their mobile devices, the multi-device ecosystem must first be set up. This involves initiating the necessary system and application software in all devices. The devices must first become aware of the other devices existing in the proximity, and then those devices intended to participate in the ecosystem must be identified. A communication channel then needs to be established between the devices participating in the ecosystem, in order to allow exchange of data and coordination of the interactions. Wireless short-range communication technologies are typically used to exchange data between devices – in the SSI platform, the devices communicate using WLAN technology. The process of setting up the ecosystem is generally known as *device binding* or *ecosystem binding* [17] (also known as *device association, pairing*, or *coupling* [3]). As the intention is to enable spontaneous interactions, it should be possible to bind devices having no prior knowledge of each other in a fast and easy way. If the process of binding devices is too complicated or tedious, the users might lose interest in utilizing multi-device interactions in the first place. As the wireless connections provide no physical indications like cables of which devices are actually connected, the binding process should provide sufficient cues so that the users can ensure that the right devices are connected.

In this paper, we introduce *EasyGroups*, a device binding method for establishing an ecosystem of mobile devices to support collaborative interactions within a group of collocated users. Our method is based on device proximity and touch interactions, which have been found to be intuitive and easy to explain methods for device binding, but which have been little explored in prior research [2]. While our method can be applied to situations without any specific spatial arrangement of users or devices, it is best suited for situations, where the users and devices are arranged in a circular formation, for example, when the users are sitting around a table. To demonstrate our method in practice, we implement it in the context of the *pass-them-around* application for sharing photographs [12]. We consider the complete application start-up process and fully integrate the device binding method with the application start-up flow, aiming to provide a seamless experience to the users. Further, our method also determines the order of the devices around the table, allowing implementation of spatial interactions without the need for the radio tracking technology utilized in the earlier SSI applications.

The rest of this paper is structured as follows. First, we provide a brief overview of related work in the areas of human-computer interaction (HCI) and security. We then give a detailed description of the EasyGroups binding method and demonstrate it in the context of a photo sharing application. Finally, we present conclusions and discuss potential future research directions.

Related Work

The problem of device binding has been extensively studied in the fields of human-computer interaction and security research. A wide range of methods for device binding has been proposed – in security research alone, over 20 different methods have been identified [14]. These methods vary in terms of device hardware requirements, amount of user involvement, and level of provided security.

Within the limited space of this paper, it is only possible to provide a high-level overview with some examples of the proposed binding methods. The most common device binding methods today, such as those typically utilized in Bluetooth and WLAN networks, are based on scanning the environment for available devices and then presenting a list of the found devices to the user for selecting the other device to bind with. Proposed alternative methods include a variety of techniques based on synchronous user actions, for example, pressing buttons simultaneously on both devices [15], bumping the devices together [4], or shaking the devices together [6]. Device binding can also be based on continuous gestures spanning from one device display to another [5]. Methods based on spatial alignment of the devices include pointing, for example, with laser light [13], or placing the devices in close proximity of each other [16]. It is also possible to bind devices with various auxiliary devices, for example, tokens [1]. For a more comprehensive review of device binding methods proposed within HCI research, we refer to a paper by Terrenghi, et al. [17].

The security-oriented research on device binding has primarily been addressing the problem of device authentication. As the communication takes place over invisible wireless channels, the user cannot be sure that he or she is really connecting to the other device intended to, opening the possibility for so-called Man-in-the-Middle attacks. To counter this threat, a wide variety of methods have been proposed that authenticate the wireless connection over *auxiliary communication channels* (also known as *out-of-band channels*), which can be perceived and managed by human users. For an overview of proposed secure binding methods, we refer to a recent paper by Uzun, et al. [18].

The development of new binding methods has been largely technology-driven with little user involvement. As an example of a more user-centered approach, Chong and Gellersen [2] present a study on users' spontaneous actions for device binding. In the study, the users' were asked to invent methods for binding together low-fidelity acrylic prototypes of different devices. Device proximity and touch based methods were found to be among the most commonly proposed methods, and the physical contact of devices was also considered as the easiest method to describe and teach to another person. Still, there has been little work exploring such techniques in the literature.

Binding methods are not just means for connecting devices – they have strong social and emotional aspects. In their study, Ion, et al. [8] found that in real-life situations, the users did not always use the easiest or fastest binding method available, nor the one they liked the best. Many factors influenced their choice of the binding method, including the place, the social setting, the other people present, and the sensitivity of data. Users were willing to take security risks to comply with social norms.

Figure 1. After starting the app, the user is instructed to add other devices by touching them one by one in order around the table.

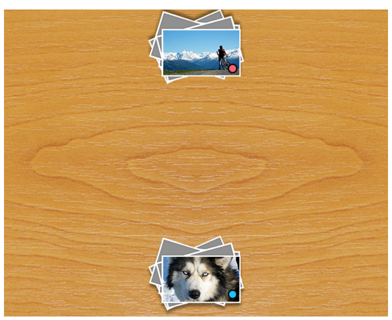

Figure 2. Table overview showing two devices as part of the group.

The vast majority of prior research has focused on scenarios of a single user binding two devices with each other (for example, binding a headset with a mobile device). Only recently have researchers started to consider more complex scenarios involving multiple users and devices. Such multi-user scenarios differ in many respects from the single-user scenarios, making the single-user device binding methods not necessarily applicable to multi-user scenarios. In multi-user scenarios, communication between group members provides an additional source for potential errors. On the other hand, the users are typically willing to help each other and make decisions by mutual agreement, which reduces the amount of errors [9]. Methods that involve physical exchange of devices have been found to be unacceptable unless the users know each other very well, as the users are unwilling to hand in their devices to strangers [18].

Chong and Gellersen [3] present a framework that summarizes and classifies the different factors that influence the usability of spontaneous device binding.

Design of EasyGroups

Based on our experiences with the three earlier SSI applications and the relevant literature, we set out to design *EasyGroups*, a device binding method that would allow collocated people to easily form a group and start an application in one seamless experience. The method was specifically targeted at situations, where the users are arranged in a circular formation, for example, sitting around a table, in which case it can also define the order of the devices around the table. The basic method, however, can also be applied in situations without any specific spatial arrangement.

Interaction Techniques

EasyGroups allows groups of people (between 2 and n) to engage in collocated *ad hoc* interactions using their mobile devices. Visual, auditory, and tactile feedback is provided in each step of the setup process.

To begin group formation, one person should start the *EasyGroups* application on their device (the *host device*). That user is then instructed to touch other devices one by one around the table to add them to the group (Figure 1). By asking the user to connect the next device to their right, we are able to define the order of the devices on the table. Visual feedback is shown in portrait mode to suggest users to hold the device vertically for a more comfortable grip.

Using radio-based proximity detection technology, the host device discovers the new device and tries to connect with it. When the connection has been established, the text shown on Figure 1 changes to "Hold it! Adding device to the group." The host device then sends connectivity information over Bluetooth to the new device, so it can 1) start the *EasyGroups* application, 2) connect to the WLAN network, and 3) join the group. When the new device has joined the group, an overview of the table is presented showing the number of devices that have joined the group (Figure 2). An animation shows how the devices are arranged on the table. As an additional cue, the color of each physical device (e.g., black, white, cyan, or magenta) is indicated on the screen (Figure 4). In parallel, feedback is shown on the host device so the user can move on to connect the next device. On average, it takes 10-15 seconds to add a new device to the group. Therefore, a group of four people can be created in 30-45 seconds.

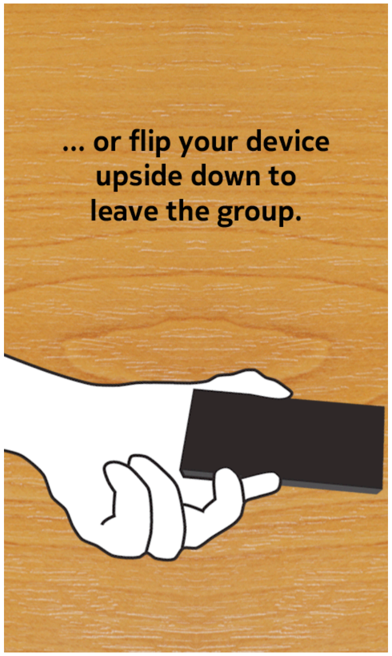

Figure 3. Feedback when a device (other than the host) is picked showing how to leave the group.

Figure 4. Color of the physical device is indicated on screen (magenta).

Once the group has been completed, the user that formed the group must put the host device down on the table. The current text and hand illustration (Figure 1) on the host device then slide sideways from the screen, the table background is rotated 90 degrees and zoomed out, and the content currently shown on the devices slide from the edges to their final positions (Figure 2).

As stated earlier, the order of people around a table is also defined during the group formation. As a result, people can engage in spatial interactions (for example, throwing virtual objects between devices such as photos). *EasyGroups* incorporates functionality from the *pass-them-around* prototype [12] so people can share photos with others at the table.

When a person other than the owner of the host device picks up their device from the table, they will be able to either add a new group member or leave the group. Feedback cycles between Figures 1 and 3 to show the different options available at that time. After picking their device up from the table, the user must flip it upside down to leave the group. As the screen is no longer visible to its owner, auditory and haptic feedback is given.

If a new person wishes to join an existing group (or to rejoin it after a brief absence), any group member must first pick their device up from the table. After touching the incoming group member's device, the new device is added next in line after the person who just added them. This method to add new devices was designed both to allow for maximum flexibility so that others than the host can also add group members, and to define the order of the new device in a single action.

To close the group, the owner of the host device must first pick up their device and then exit the group by flipping their device upside down. As a result, *EasyGroups* is closed on all devices.

Implementation
We implemented a prototype of *EasyGroups* on Nokia N9 mobile devices running the MeeGo operating system. To demonstrate group formation in a more realistic context, we included photo sharing functionality similar to the *pass-them-around* prototype [12]. The EasyGroups prototype was implemented in C++ on top of the Qt 4.7 software framework. QML and Qt Quick 1.1 were utilized for user interface graphics, and the N9's internal accelerometer was used for gesture detection.

Group formation consists of two parts: device discovery and connectivity info transfer. Device discovery is done with radio-based proximity detection technology. The necessary connectivity and initialization information is then transferred to the discovered device over Bluetooth. For the initialization information, a daemon that listens to a predetermined Bluetooth socket was developed and installed on the devices. After the daemon receives the connectivity information, it starts the actual *EasyGroups* application, which connects to the WLAN network and joins in the network session.

Conclusion and Future Work

We have presented *EasyGroups*, an intuitive touch-based method for binding a group of mobile devices for collaborative interactions. In addition to device binding, the method also defines the device order, which can be used to enable spatial interactions. In future work, we plan to make end-user evaluations of *EasyGroups* with

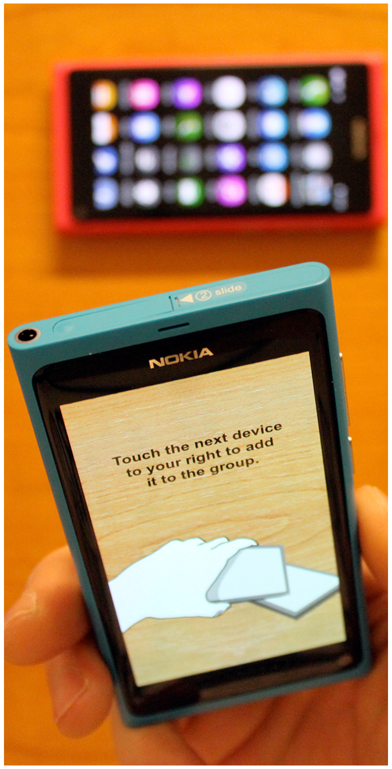

Figure 5. The *EasyGroups* prototype. The owner of the host device (cyan) is about to add the first device (magenta) to the group.

different group sizes in various application scenarios and contexts of use, including evaluation of how well it supports spatial interactions. We also plan to further develop the method to allow a more secure binding process, and to study the alternative radio technologies for proximity detection, including NFC, Bluetooth, Bluetooth Low-Energy, and WiFi Direct.

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