Towards Spontaneous Group Binding with Wearable Devices

Abstract
Before a group of co-located users can engage in spontaneous collaborative interactions with their devices, they must first bind their devices into a group. While a wide range of binding methods have been developed for connecting conventional devices such as computers or smartphones, the existing methods are not necessarily applicable to wearable devices, which are far more personal, intimate, and have different form factors and features. This calls for new research from various domains on group binding methods for wearable devices.

Author Keywords
Co-located interaction; wearable devices; device ecosystem binding; group association; pairing.

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

Introduction
Before a group of co-located users can engage in spontaneous collaborative interactions with their devices, they must first connect their devices into a multi-device ecosystem. This is rather a complex technical procedure with several steps. The devices must discover the other available devices in proximity,
and the users need to indicate which of these devices are intended to join in the ecosystem. A wireless network is then established to enable exchange of data and coordination of interactions between the devices. As the users cannot see the wireless connections, the process of connecting devices should provide sufficient cues and security, so that the users can ensure that the right devices are connected. As the intention is to enable ad hoc interactions, it should be possible to connect devices that have no prior knowledge of each other in a fast and easy manner. If the process for connecting devices is too complicated or tedious, the users might lose their interest in multi-device interactions in the first place.

Existing Device-Binding Methods
The general problem of spontaneous device binding (also known as device association, pairing, or coupling) has been studied extensively across multiple research domains. Researchers have proposed a wide range of different binding techniques [1].

The majority of the existing work on device binding has been technology and security driven. But binding methods are not only technical means of connecting devices – they have strong social and emotional aspects. Many factors influence the users’ preferences of binding methods, including the environment, the social setting, and the other people present [3]. Much of earlier work has focused largely on a single user operating the connection process; however, scenarios involving multiple users differ in many respects from single-user scenarios, making the single-user binding methods not necessarily applicable in multi-user scenarios. Furthermore, a larger group of users enables many new approaches and strategies beyond single-user methods.

Natural Methods for Binding Groups
In our work, we have been looking at the binding process in medium-sized groups of four to six users from a user’s perspective. We have aimed to understand how people would naturally connect wireless devices, without explicit instructions and regardless of the technical limitations posed by current hardware. Therefore, we conducted a focus-group study with non-technical participants to find out how people connect devices as a group [2].

To avoid biases caused by existing device interfaces, we used low fidelity props (with different dimensions, mobility and rigidity) as surrogates (see Fig. 1). We adopted the guessability study methodology [10], and asked participants to come up with their own techniques for connecting various groups of devices. The participants used a think-aloud protocol and took turns to suggest and explain actions that they had come up with (see Fig. 2).

Results showed that physicality (e.g., the shape and size of devices) influences how people perceive the interaction for group binding. Devices with a small surface area are difficult to enter commands, so people resorted to fast maneuvering actions, like performing a gesture. On the contrary, people prefer less movement for bulky devices, such as tablet computers. Device affordance also influenced how people conceptualize the interaction, as they relate interaction techniques from other device types. For instance, our participants used the metaphor of pointing mobile phones as a remote control.
Of the user-defined techniques we observed, one that our participants often suggested was the method of bringing devices into a physical contact. Touch-based methods are fast and expressive, and they enable better awareness of the group formation, as members can easily perceive the touching actions. In addition, touch-based interactive technology, such as short-range communication like NFC, already pervasively exists in mobile devices. This makes the interaction particularly attractive for immediate adoption.

**Binding with Device Touch**

Based on these observations, we have designed and evaluated a series of group binding methods based on device touch [7] [4] [5] (see Fig. 3). In a medium-sized group, a wide variety of different touching patterns and orders is possible, dividing the group-binding task in different ways between the participants. Leader-driven approaches [4] concentrate the group creation task on a single participant that has strong control over the group. Such an approach may be appropriate, for example, if the leader is sharing some personal content within the group. It requires only one person to know how to set up a group, but selecting the leader may add democratic complexity. On the other hand, peer-based methods [4], where everybody is involved in creating the group, help to create a greater sense of community. Also, they can scale better to form larger groups.

When given the freedom to select any approach [5], people have spontaneously applied patterns where they opportunistically select nearby devices to touch next and the group membership virally spreads across the group, from one person to another (see Fig. 4). The viral patterns are efficient, require no advance planning, and keep everybody involved in the group creation process. People have also suggested patterns where several devices are touched simultaneously to make the group creation more efficient. Some people consider group binding as a single step procedure, rather than divided into multiple pairings [2].

Device binding in groups is a highly collaborative activity [4] [5] [6]. Users are eager to help each other when some of them encounter problems, and together they can solve and overcome most usability and technical problems encountered. Especially in larger groups, the main challenges are related to group work and social interactions within the group. Techniques that require users to surrender possession of their personal devices to another user are often inappropriate in a group setting, as users prefer to control their own devices due to privacy concerns [9]. Many groups also have internal structures that can be relevant for collaborative applications. These include different roles (such as a chairperson and a secretary in a meeting), subgroups (such as different parties in a negotiation), or the order of the participants (for example, in a turn-based game). We have evaluated different manual and automatic methods for defining the roles and the order of the members during the group formation phase [4] [5] [8].

Overall, we found that when designing binding methods for groups of users, it is important to consider robustness in real-life conditions [5]. While many methods can work well in theory or with mock-ups, in reality, applications involving multiple entities are complex distributed systems. As multiple devices are involved, there is a high risk that any of the devices may fail technically due to detection failure, broken
network connections, or the software may crash in any device. Also, some users may not be aware of the steps they should follow, or unable to do so, for example, arriving late or being occupied by other tasks such as incoming telephone calls. Therefore, the binding methods should be flexible and robust, allowing the users to adapt them to the changing needs of the situation and to recover from failures.

**Group Binding with Wearable Devices**

Currently, we see an increasing diversity of devices with the emergence of new wearable form factors, including wrist-worn and head-worn devices. As more and more people wear such devices, situations where there are multiple persons present with wearable devices will become commonplace. In those situations, wearable devices could support collaborative tasks and shared experiences through multi-user applications.

Existing binding methods that have been designed for conventional devices such as computers, smartphones, and tablets, are not necessarily applicable to wearable devices, which are far more personal and intimate. For example, while touching can be a natural way of selecting another user’s phone or tablet, it might be inappropriate when the device is head-mounted. The existing methods also do not take advantage of unique features of wearable devices that could enable more natural and innovative ways to form groups. One way to conceptualize this is to consider wearable devices as already attached to their owners, so binding of multi-user wearable devices can form through people’s social interactions. A handshake, for example, could indicate a level of acquaintance, so devices can form a connection for people to share business contacts. A hug, on the other hand, is more intimate, so more personal information could be sent.

Another factor that we need to consider is users’ immediate access to their devices. Different types of wearable devices are accessed differently. A head-worn device is already exposed to the world, while interacting with a smartwatch requires lifting the arm, which could be difficult if the user is holding items. Furthermore, on-body devices (e.g. heart rate monitors) could be hidden beneath clothes, accessing the devices in public may deem inappropriate.

Wearable devices undoubtedly open up new opportunities. However, we should not neglect that mobile devices will still be in play. We could transfer our knowledge learned from studying binding of mobile devices and create collaborative applications that involve both wearable and mobile devices, like how to adapt existing techniques to accommodate the wearable form factors. At the same time we should also consider new applications that only involved wearable devices, like the interactions described above. This calls for new research from various domains on group binding methods for connecting wearable devices.

**References**


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