Demo: Tap2Pair: Associating Wireless Devices with Tapping

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ABSTRACT

The IoT era demands ad-hoc wireless devices association for a convenient and spontaneous cross-device interaction experience. Currently, users associate two devices by selecting the advertising device (e.g. a mouse) from a list displayed by the scanning device (e.g. a laptop). However, the association can be misplaced since it is often more convenient to initiate association from the advertising device (e.g. when switching a mouse between two computers). Tap2Pair allows users to simply tap on an advertising device to associate with the target scanning device. It does not require any modification of existing wireless devices and is compatible with most wireless protocols. Hands tap near the advertising device's antenna can change the strength of the signal received by scanning devices. Scanning devices can then calculate signal features and initiate association if certain criteria are met. We demonstrate two association strategies for different scenarios: 1. Hold and tap an advertising device near the target scanning device; 2. Tap at the corresponding frequency of the target scanning device.

CCS CONCEPTS

• **Human-centered computing** → **Interaction paradigms**; *HCI design and evaluation methods.*

KEYWORDS

wireless device association;tapping;pairing;RSSI

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1 INTRODUCTION

In the Internet of Things (IoT) era, there are more and more wireless devices in our daily lives. Such ubiquitously deployed computing devices can enable more natural and convenient cross-device interactions experience. Before the interaction, however, users need to establish a connection between devices. Spontaneous device association then become vital to the experience of such interactions.

Currently, users can initiate an association from the scanning device by selecting the target advertising device from a list displayed on the screen (Figure. 1a) [2]. For example, when connecting a Bluetooth earphone to a smartphone, users must start the Bluetooth scan, search for the earphone display name, then select the target item. Such GUI-based association mechanism is widely used by mainstream operating systems for Bluetooth and WIFI connections [1, 5].

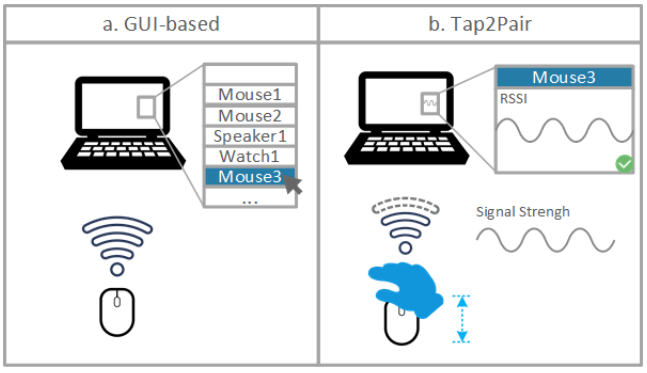

Figure 1: a. The GUI-based association mechanism. Users initiate association by selecting from a list. b. Tap2Pair association mechanism. Users initiate association by tapping the adverting device with hands.

However, the GUI-based mechanism requires advanced I/O resources like screen and input device, thus can only work on a limited number of devices. Furthermore, such a mechanism is often misplaced. For example, it is more convenient to initiate association from the mouse (advertising device) when switching between two laptops (scanning devices). Users also prefer to initiate an association from the usually smaller and lighter advertising device [2, 6]. Previous researches add extra hardware like NFC [9] and IR transceiver [4] to initiate an association from the advertising device. However, these methods require additional hardware and firmware support, which are not suitable for small, cost-sensitive, or power-constrained wireless devices.

Tap2Pair enables users to initiate association from advertising devices spontaneously. Users can simply tap on an advertising device to initiate an association. Hands near the wireless device's antenna will block the signal and cause antenna impedance mismatch, which decreases the transmitted signal strength [7]. Thus, tapping near the device's antenna will lead to periodic changes of the Received Signal Strength Indicator (RSSI), which can be recorded by surrounding scanning devices. The scanning devices can then analyze the RSSI sequences and send the connection request to the advertising device, whose RSSI sequence meets certain criteria. Tap2Pair works with commercial-off-the-shelf (COTS) wireless devices without any hardware or firmware modification. It works with any wireless protocol that provides RSSI reading (e.g. Bluetooth, WIFI), and is compatible with current GUI-based association mechanism.

2 RELATED WORK

With the rapid development of IoT devices, there are more researches on spontaneous and convenient association mechanisms. For example, multi-devices controlling wireless mouses are developed with an additional button for switching two different PCs [8]. Near Field Communication (NFC) enabled smartphones to connect with different smart devices by proximity [3, 9]. The users also can use an IR transmitter and receiver for pinpointed IoT devices association [4]. However, these works need additional hardware or modification of the firmware.

Tap-to-Pair [10] proposed a novel mechanism that allows users to initiate association spontaneously by tapping in sync with a blinking pattern (e.g. a blinking LED) displayed on the scanning device. Even though such mechanism enables remote device association with many scanning devices, the required blinking patterns can introduce visual distractions. The association strategies proposed in this paper, however, do not require extra hardware or introduce visual distractions.

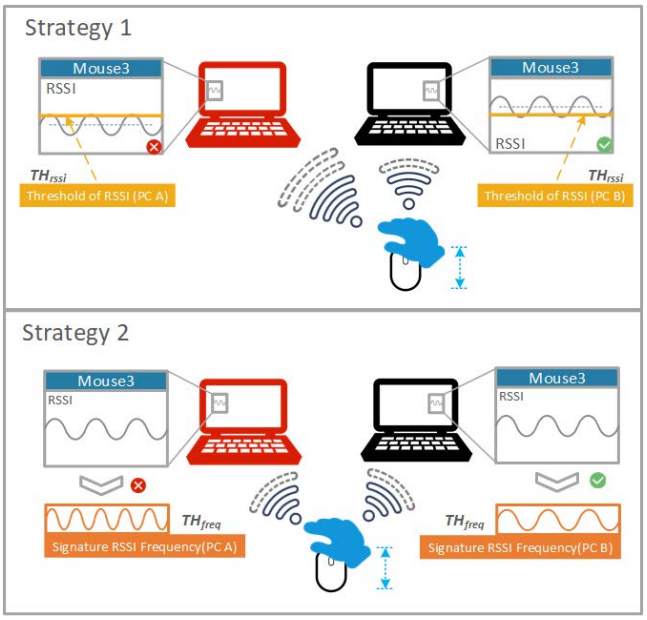

Figure 2: Tap2Pair strategies. Strategy 1 (top) detects the mean absolute RSSI and tapping frequency for the association; Strategy 2 (bottom) detects the corresponding frequency of RSSI for the association.

3 ASSOCIATION STRATEGIES

In this paper, we propose two association strategies for two common association scenarios (Figure. 2).

`Strategy 1` (Figure. 2(top)) : Users can hold an advertising device close to the target device, then tap on the advertising device periodically. The target scanning device is selected when it has detected periodic taps on the advertising device, and the mean absolute RSSI value is higher than a threshold TH_{rssi} at the same time. The mean absolute RSSI value is high enough to consider the adverting device is nearby. Periodic taps are detected when the frequency component of the advertising device's RSSI sequence is higher than a threshold TH_{freq}. When the criteria are met, the scanning device will send a connection request to the corresponding advertising device. Strategy 1 applies to scenarios when one device is small and light enough to be brought near the target device.

`Strategy 2` (Figure. 2(bottom)) : In this strategy, each scanning device has its own signature frequency. Users just tap on the advertising device at the corresponding frequency for associating target scanning device without requirements of relative positions of the two devices. The scanning device is selected when the maximal frequency component of the RSSI sequence falls within the designated frequency range (e.g. slow, medium, fast). Our Strategy 2 applies to scenarios when there are only 2-3 potential target scanning devices

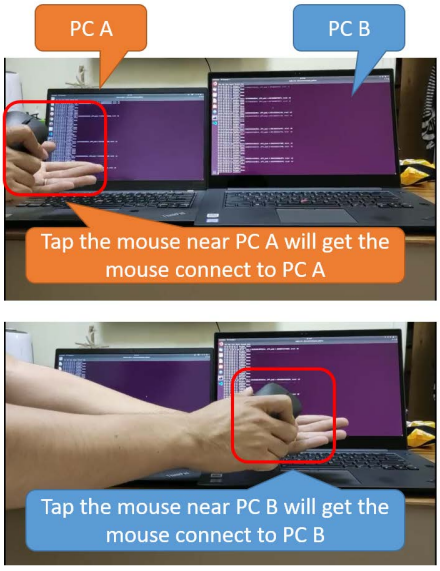

Figure 3: Strategy 1: The user holds the mouse near the target PC and taps the mouse on the antenna to get the PC connected.

around. For example, a mouse on the office desk may only need to connect with a laptop or a PC.

4 DEMO SYSTEM

We demonstrate the two association strategies using one Microsoft Designer Bluetooth mouse and two laptops running Ubuntu 18.04. We run Bluetooth RSSI monitoring programs on these laptops, which monitors the RSSI of the advertising devices and matches their signal with the laptop's signature. Users can pair the mouse with the laptops using either Strategy 1 or Strategy 2.

Strategy 1

Users turn on the advertising mode of the mouse, hold it close to the target laptop, then keep tapping on the mouse until the two devices are connected. The monitoring program of two laptops detect if the mean absolute RSSI of the Bluetooth mouse is above TH_{rssi} and the maximal frequency component is higher than TH_{freq} as shown in Figure. 3.

Strategy 2

Users turn on the advertising mode of the mouse, then tap on the mouse at a lower frequency (0.2-1Hz, empirically decided) to connect with one laptop or tap at a higher frequency (1-3Hz, empirically decided) to connect with the other one. The monitoring program detects whether the RSSI's maximal frequency component is within the designated range as shown in Figure. 4.

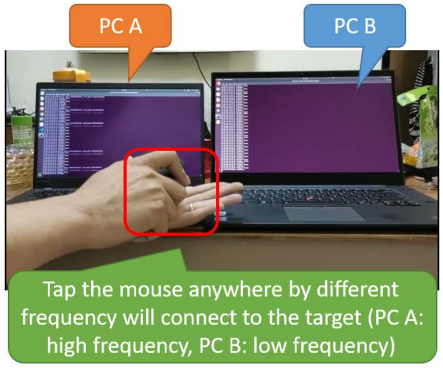

Figure 4: Strategy 2: The user taps on the mouse with different frequencies to get the target PC connected, PC A is set to have high frequency and PC B is set to have low frequency as its signature.

5 LIMITATIONS AND FUTURE WORK

The proposed two strategies are suitable for two common wireless device association scenarios. However, when there are more scanning devices, Strategy 1 may get confusion of nearby devices, since it becomes difficult to detect proximity based on absolute RSSI value. For Strategy 2, the signature frequency range is fixed for each scanning device. In the future, we plan to improve proximity detection accuracy by leveraging RSSI values of all surrounding scanning devices. Strategy 2 can also support more target scanning devices by differentiating more tapping patterns (e.g. frequency-changing tapping sequence).

6 CONCLUSION

Tap2Pair can achieve spontaneous association from the adverting wireless devices with simply taping on it. It does not require any hardware or firmware modification of existing devices. And it's compatible with most current wireless protocols and existing GUI-based association mechanisms. We demonstrated two strategies to show the feasibility of this technique.

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