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Creation of Communication Groups Using Sound of Smartphones

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Abstract. The development of capable smartphones and other portable devices has ushered new ways of communication and collaboration. For example, smartphones are widely used for sharing files with friends and colleagues at meeting or a conference. In this case, conventionally, short-range radio, such as Bluetooth or Wi-Fi are used. Encrypted data can be send via Bluetooth radio and be received by any devices in a 10m distance. In public places, this increases the likelihood of security breach and communication eavesdrop as the data may be intercepted by any device within range. In this paper, we propose to improve security by controlling the communication range via acoustic waves. Unlike radio waves, acoustic waves' propagation range can be controlled by modifying their amplitude; thus, it is possible to reduce the data sharing range specifically to a range of a specific device. Our preliminary tests by sharing data between two Nexus 5 smartphones indicate that it is possible to unidirectional control the sharing range while sharply reducing any possibility to eavesdrop on the communication. This increased the communication security since only devices within the specified range and direction were aware of the data sharing.

Keywords. acoustic waves, co-location, smartphone, Wi-Fi Direct

1. Introduction

Data sharing and communication has always been at the forefront of the disruptive technology since the heyday of the World Wide Web. Email, instant message, and VoIP services nearly obsoleted the need for typed letters and telegrams and have noticeably reduced the need for in-person communication. The development of peer-to-peer (P2P) communication services further improved file sharing –albeit at risk of copyright infringement. Recent communication methods were introduced due to advances in hardware and software. This further improved collaboration and data sharing. For example, cloud-based sync and sharing services such as Dropbox, Apple's Airdrop and Google Drive took collaboration and data sharing to the next level. The benefits gained from these technologies include cost and time saving, knowledge and expertise dissemination and a plethora of other benefits that would be impossible otherwise.

Traditionally, desktop computers and laptop were the main computing devices for personal and professional usage. However, a recent development of powerful mobile devices, such as tablets and smartphones, have shifted this trend. Mobile devices are commonplace while desktop computers are relegated to computation intensive tasks.

These mobile devices, unlike their desktop computer counterparts, are convenient for taking pictures, listening to music, viewing, and editing documents at anytime and anywhere. However, this flexibility comes at a cost when it comes, for example, to file sharing. Conventionally, emails and other cloudy services are used for this task. For mobile devices, however, when there is an internet traffic congestion, or in the presence of large files, it takes too long to share, and requires a prohibitively expensive mobile data. Another disadvantage of conventional communication methods is the lack of control of the sharing range which is usually established by the radio waves at approximatively 20 and 10 meters away for Wi-Fi and Bluetooth, respectively. This limitation increases security risk of eavesdropping especially in public places as radio waves can cross through walls. This also makes it difficult to define a co-location to be shared in a room since data shared via radio is always broadcasted in the radio wave range.

In our research, we propose to use acoustic waves for easy devices connecting. Our system allows to establish a communication between two nearby devices. One device shares its IP address, and the second device use it to locate and access data on the first device via Wi-Fi Direct [1], which enables Wi-Fi devices to connect directly to share files. This new approach has many advantage. First, unlike exiting radio wave based technologies, it allows to granularly control the communication range by simply increasing or decreasing the sound intensity. This improves security and reduces the possibility of hacker eavesdropping on the communication. Second, it is more versatile and compatible to all existing systems that support sound processing. NFC is also a short-range connection mean. However, its range is too short and most devices do not have NFC sensors. Using acoustic waves, we improve security and is much versatile. Third, because we use Wi-Fi Direct for data sharing, our system provides a much secure fast data sharing while requiring very little handshaking time. Further, acoustic waves do not require internet services and/or extra communication hardware. Sound can propagate as long as air molecules exist. Thus, sound is can be even used in underground indoor environments. Finally, sound can be emitted by speakers on smartphones, and obtained by microphones on smartphones. Thus, our system does not require any extra hardware. These advantages motivated us to use sound to create a shared communication space. This can be particularly useful for anonymous communication and machine to machine (M2M) communicating between Internet of Things (IoT) devices.

In this paper, we discuss the design and implementation of the sessions establishing system by acoustic waves generated by smartphones and the result of the sharing range by an output acoustic waves intensity. We also discuss the resulting added security and reliability of the communication and explore its feasibility and practicality.

2. Related Works

There is a considerable amount of work on indoor localization in the absence of GPS. Techniques of indoor localization is closely related to our work because it can be applied to the segmentation of real-world space. Chung-Hao et al. [2] used Kalman-filter-based drift removal to achieve fast and precise localization using Radio Frequency IDentification (RFID) readers and tags. In addition to the utilization of decay of wireless signals, some work uses the electrical field. Grosse-Puppendahl et al. [3] installed electrical field sensors into the ceiling of room and detected the location of a person by measuring the variation in electrical field. Thus, the person does not need to wear any special device in the room. These indoor localization techniques necessitate deployment of some equipment in the environment, which incurs an additional cost of measurement. Furthermore, the electrical field sensor is not robust for detecting multiple people.

Finger printing is a technique to use pre-determined wireless signal strength. He et al. [4] achieved higher precision than conventional methods by combining the information about both terminals and access points.

Although these localization techniques have been improved to increase accuracy, they cannot distinguish two adjacent rooms if their border is separated by walls that penetrate wireless signals. Our work seeks a method of distinguishing different rooms.

BeepBeep [5] is a system for localization using sound emitted from smartphones. Unlike BeepBeep, we use sound for creating a communication group. Also, because we used high frequency acoustic waves, sound emitted from device does not disturb users' talking.

ChirpCast [6] is a system for distributing access keys using ultrasonic transmissions. While ChirpCast is distributing access keys for all devices in a room, our system focuses on devices in a closer range. By narrowing the connecting range, it is possible to eliminate unknown devises.

Dhwani [7] is a system for short-range communicating short using NFC. However, some devices do not have NFC readers. Also, NFC can be used within too narrow range: 20-30 cm. On the other hand, our system uses off-the-shelf microphones and speakers on the smartphones, and sound can go a few meters away by controlling the output intensity.

Since our work is using high frequency acoustic waves, it is possible to detect the co-location without passing through the wall, by controlling the sound wave output intensity, it is also possible to control the range in which the session is established. Also, since acoustic waves are outputted from the speaker built in the smartphone, and sound waves are acquired using the microphone built in the smartphone, the labor and cost of installing special sensors can be reduced. Since it is unnecessary to install a special sensor in the room, there is no restriction on the use environment, and it can be used in any space.

3. Design and Implementation

The objective of creating a common space within a certain range is collaborative work among co-located group members such as file sharing. Since we assume collaborative work with smartphones, we use Wi-Fi Direct as a communication means. Unlike traditional Wi-Fi Direct use, we choose an acoustic wave at frequency fs in a non-audible range to human for establishing a communication session. This system consists of two components: an acoustic wave sender and receiver. The sent data load consists of the IP address of the sender, synchronization signal, and parity bits for error correction.

An essential part in the system is the control of the common space by adjusting the magnitude of the emitted acoustic waves from the sender; when the magnitude of the signal is larger, the range of the common space becomes larger. A space around the sender is divided into shared and non-shared range. Within the shared range, smartphones are shared with the procedure defined in the system (Figure 1).

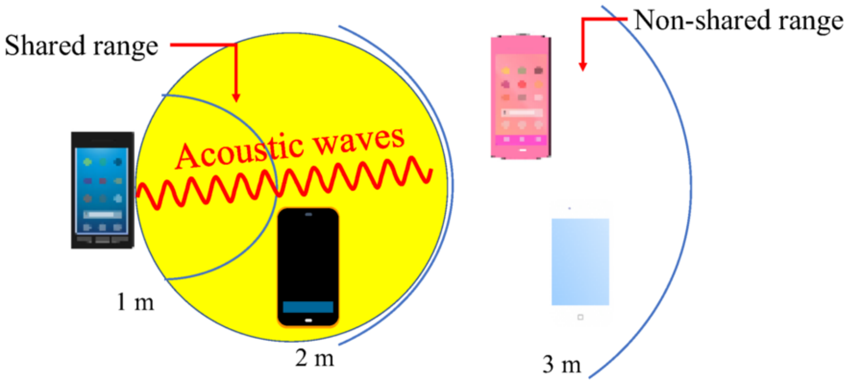

Figure 1. Dividing the space with acoustic waves.

3.1. Acoustic Wave Sender

To establish a session of Wi-Fi Direct, the sender device needs to send its IP address to a receiver device. Here, the IP address is modulated into an acoustic signal at frequency Fs, encoded using On-Off Keying (OOK), and then transmitted at an interval Td. A 1 bit is encoded by emitting a continuous sound for Td milliseconds while a 0 bit is encoded by discontinuing the sound for Td milliseconds as shown in Figure 2.

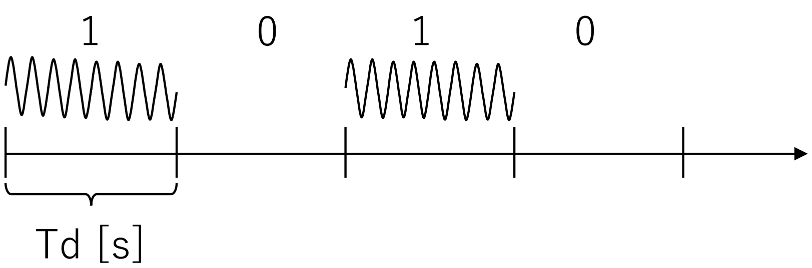

Figure 2. IP bit encoding using an On-Off keying.

By using this encoding mechanism, the IP is represented by a sequence of sounds (1 bit) and no-sounds (0 bit) to represent its 32-bit value. Additionally, to enhance the error recovery capability, we inserted five parity bits and thus the total number of transmitted bits is 39. In addition to the information bits, a preamble synchronization signal (SS) announces to the receiver the start of the transmission.

3.2. Acoustic Wave Receiver

The user places the client device in the reception standby state, and it receives the acoustic wave signal from the host device. Figure 3 shows the flow chart of signal reception and error correction.

Since the synchronization signal, which is 4 bits, exists at the head of the acoustic wave signal transmitted from the host device, after detecting the synchronization signal, the client device starts to recognize the acoustic wave signal and restores the 39-digit numeric string from the acoustic wave signal. In addition to the IP address, the 39-digit numeric string includes parity bits and synchronization signal. P_6 judges whether the total error detection number is one or less digit, or two or more digits. Since it is impossible to restore the IP address in the case of two or more digits of error detections, it does not attempt to establish a session and returns to the reception standby state and waits for the retransmission of the acoustic wave signal. When there is one or less error detection, since error correction is possible at the client device, it confirms P_0 to P_5. When an error is detected, error correction is performed. When no error is detected at P_0 to P_5, it is determined that the sound wave signal has been properly received, and the client device restores from the binary digit string to the IP address of the host device. After restoring the IP address, the client device attempts to establish a Wi-Fi Direct session with the host device.

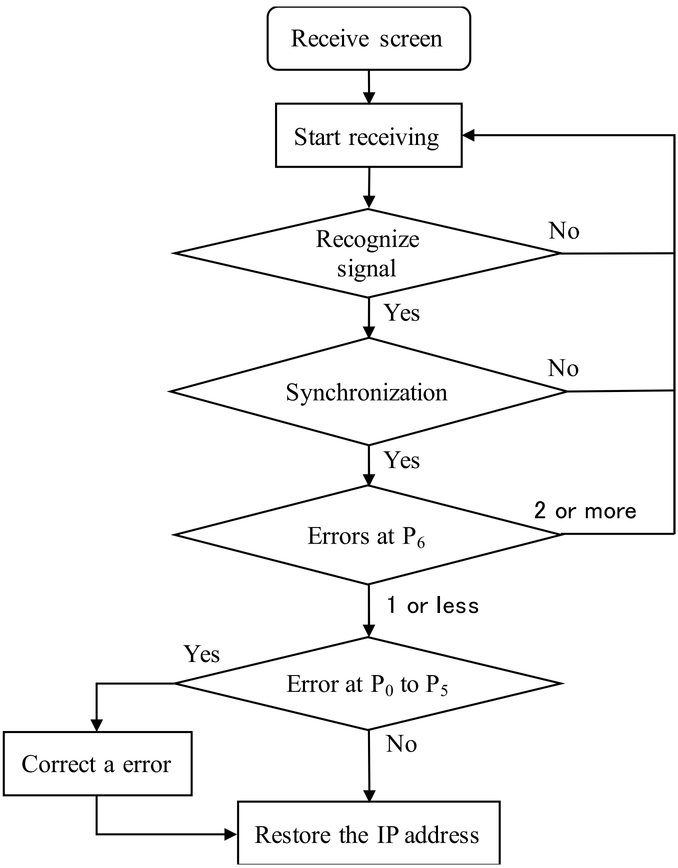

Figure 3. Flow chart of signal reception and correction.

4. Experiments and Results

To test our design, we used two Nexus 5 smartphones. One served as an acoustic wave sender. It encodes and broadcasts its IP address. The encoding is done by modulating the wave signal at fs = 19 kHz, Td = 200 ms, and SS = 0xA. Another smartphone, the acoustic wave receiver, listens to the incoming wave signal and decodes the sender's IP to establish the communication. In these experiments, we measured the recognizable distance when changing the acoustic wave transmission output intensity. As the use environment of this system is assumed to be at noisy offices or cafes due to environmental sounds, we experimented with noise environment of 60 to 70 dB [8], which is the same noise level as noise which can occur in our daily life. In this experiment, we used a 70 Db white noise to test our range-controlled communication. In the noisy environment, we measured the recognition accuracy between the two devices, initially located at 50cm apart. Then, we increased the distance between the two devices in a 25cm increments up to 2.5m as shown in Figure 4. This accuracy was measure for three acoustic from the sender devices: -15 dB, -18 dB, and -21 dB. For each acoustic intensity, we measured the recognition accuracy of the communication between the two devices and we found that it was possible to control the range of communication between the two devices (Figure 4). In these experiments, only the recognition accuracy for the first sound wave receptions is reported and the results of the second acoustic wave receptions to the recognition accuracy is not reported.

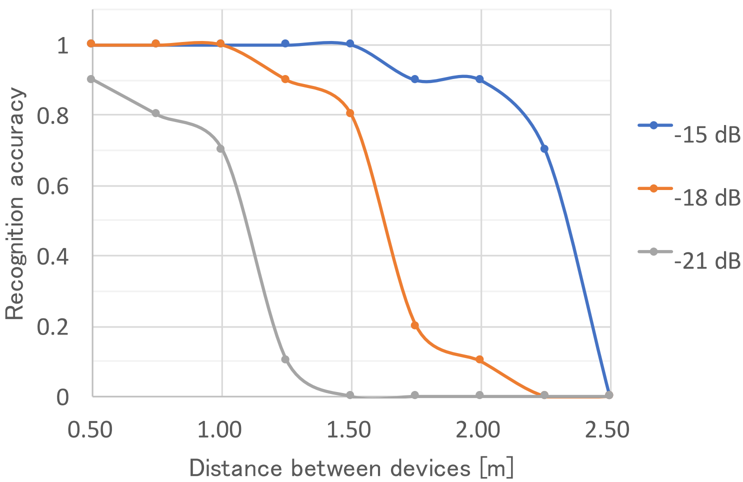

Figure 4. The results of experiments.

In our experiments, we tested at high acoustic frequency (19 kHz). Thus, the two devices could establish a communication only when they are aligned and the microphone of the host device is facing to the speaker of the client device. Indeed, high frequency acoustic waves do not propagate in all directions. Thus, this limitation further increases the communication security by reducing any possibility to intercept the communication unless the interceptor is in the sender's direction.

5. Conclusion and Future Work

In this paper, we have described a system to create a common space for collaborative work with smartphones using acoustic signals. Our preliminary study has shown that the size of the common space can be controlled with the magnitude of the signal emitted at a sender. As shown in Figure 4, this system can adjust an output acoustic wave intensity to control the sharing range, which is shorter than a radio wave propagates. Sound can propagate as long as air molecules exist. Our proposed system defines arbitrary distance from a host device as the co-location and distinguish a device in the co-location from devices in the same room. This improve security and versatility compared to existing radio based approaches. Because this system is using a high frequency sound, directionality of the communication is much strong. Thus, it is not possible for any communication eavesdropping device to intercept the communication between the two devices. Our approach proves that acoustic wave transfers the signal to connect devices. However, at this point, in order to create a simple proof of concept prototype, we did not encrypt the signal of IP address. We will apply encrypting and Cyclic Redundancy Check to improve security and accuracy more in our future work.

In our future study, we will develop an Application Programming Interface (API) to allow an easy use of the system.

References

[1] Daniel Camps-Mur, Andres Garcia-Saavedra, and Pablo Serrano, "Device-to-device communications with Wi-Fi Direct: overview and experimentation", IEEE Wireless Communications **20** (2013), 96-104.

[2] Chung-Hao Huang, Lun-Hui Lee, Chian C. Ho, Lang-Long Wu, and Zu-Hao Lai, "Real-Time RFID Indoor Positioning System Based on Kalman-Filter Drift Removal and Heron-Bilateration Location Estimation", *IEEE Transactions on Instrumentation and Measurement* **64** (2015), 728 - 739.

[3] Tobias Grosse-Puppendahl, Xavier Dellangnol, Christian Hatzfeld, Biying Fu, Mario Kupnik, Arjan Kuijper, Matthias R. Hastall, James Scott, and Marco Gruteser, "Platypus — Indoor Localization and Identification through Sensing Electric Potential Changes in Human Bodies", MobiSys '16, p. 17-30, 2016.

[4] Suining He and S.-H. Gary Chan, "Tilejunction: Mitigating Signal Noise for Fingerprint-Based Indoor Localization", *IEEE Transactions on Mobile Computing* **15** (2016), 1554 - 1568.

[5] Chunyi Peng, Guobin Shen, Yongguang Zhang, Yanlin Li, and Kun Tan, "BeepBeep: a high accuracy acoustic ranging system using COTS mobile devices", ACM SenSys'07, 2007.

[6] Francis Iannacci and Yanping Huang, "ChirpCast: Data Transmission via Audio", ArXiv, 2010.

[7] Rajalakshmi Nandakumar, Krishna Kant Chintalapudi, Venkata N. Padmanabhan, and Ramarathnam Venkatesan, "Dhwani: Secure Peer-to-Peer Acoustic NFC", SIGCOMM'13, p.63-74, 2013.

[8] John R. Hassall, "Environmental Noise Report", 2014.