Summary of *Ripple II: Faster Communication through Physical Vibration (NSDI '16)*

The paper *Ripple II: Faster Communication through Physical Vibration* was published in 2016, introducing a touched-based vibratory communication model Ripple II. The work builds on the first generation Ripple, but redesigns the radio stack in two ways: (1) creating a OFDM-based physical layer which uses microphone instead of accelerometer as the receiver, and (2) designing a MAC layer that accomplishes collision detection at the transmitter and performs proactive symbol retransmission. Ripple II improves the vibration decoding rate from 200 bits/s to 30 kbps comparing to Ripple. The paper also presents two sample applications based on the module: finger ring authentication enabled by transforming vibratory passwords through finger bone, and tabletop multicast communication between devices placed on the same table.

The system design of Ripple II can be split to three parts: physical layer, MAC layer, and applications built on the top. As for physical layer, Ripple II uses vibratory motor as transmitter and microphone as receiver, which brings the challenge to separate physical vibration from acoustic noises and interferences to achieve higher quality vibratory communication. Ripple II mainly introduces four techniques to isolate physical vibration from ambient sounds. First, covering the sound hole to prevent sound from polluting the vibratory signals. Second, including a second microphone and building a module to extract the vibration signals. Third, designing a symbol selective adaptive noise filtering (SNAF) technique including erroneous symbol detection and symbol correctness. Fourth, applying a vibratory signal amplifier at the receiver. Ripple II also implements OFDM over the vibra-motor and microphone link. Ripple II's MAC layer design mainly includes sensing interference from Back-EMF and proactive symbol recovery protocol (PSR protocol). In the evaluation of the paper, the author compares throughput gain from three different settings under various surrounding sound environment. As a baseline, the testing uses two OFDM microphone receivers running on a hardware platform with sound hole covered. The three settings are: (1) baseline + coding, (2) baseline + coding + SNAF, and (3) baseline + coding + SNAF + PSR protocol. The resulting graphs show the improvements made by SNAF and PSR protocol under different sound categories.

In our class discussion, we focused on the background, the technical details of the module designs, and the potential usage of Ripple II in modern applications, and we also discussed the shortcomings of the paper.

We agreed that touched-based physical vibratory communication is a relatively new communication media. There are not many killer applications in the area, but there are quite a few startups exploring the potential usage of this new technique. We compared it to underwater communication using acoustic signals and concluded that although Ripple II can not be directly applied to underwater scenarios, the technical design could also be useful there as a reference. We discussed that comparing to accelerometer that was used as receiver in the first generation (Ripple), microphones provides greater sensitivity and operates over a wider frequency range, which also brings more need of isolating physical vibration from ambient sound. Covering the sound hole and using a secondary microphone are necessary for the separation. We noticed that the signal and interference model provided in the paper are not well explained, such as it does not mention the Gaussian noise experienced by the two microphones as it only focused on interference rather than noise. The paper briefly described MIMO as a failed attempt, arousing our discussion about the reasons and possibilities of adjusting MIMO to Ripple II by applying a special transmitter. We also focused on the two main designs in Ripple II. One is SNAF and the other is PSR protocol. SNAF uses a erroneous symbol detection technique by measuring the vibratory channel responses from the primary and the secondary microphones to check if they maintains a constant ratio, and then applying the erroneous symbols to adaptive filtering technique (i.e., S1 and Y2 are correlate in such case) to correct the symbols. We found out the PSR protocol part is a shortcoming of this paper for it's missing technical details. Lastly, we analyzed that the finger ring authentication application is a great attempt. It brings potential security benefits and convenience from using a token instead of biometric authentication, and it could also be integrated to the current authentication system to create a three-factor authentication. We would also agree that the P2P money transfer mentioned in the paper is a great area to look into as well.