# ALPS: An Ultrasonic Localization System

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## ABSTRACT

We demonstrate ALPS, an ultrasonic zone-based and time-of-flight localization system for mobile devices. ALPS capitalizes on the ability of smart-phones to detect audio above the human hearing range and does not require any additional hardware. Synchronized transmitters deployed in the environment periodically send time multiplexed ranging signals consisting of ultrasonic chirps. Each mobile device runs an application that records a snapshot of audio, determines the Time Of Arrival (TOA) of the captured ultrasonic signals and then uses out-of-band map data to compute a location. Bluetooth Low Energy (BLE) hardware integrated into the transmitters allows for the identification of the captured ultrasonic signals in order to map them to individual transmitters and provides additional RSSI based location information. The confinement of ultrasound within walls is ideal for zone-based localization and the relatively slow propagation of sound allows for accurate Time Difference Of Arrival (TDOA) and TOA ranging in larger open spaces.

## 1. SYSTEM DESCRIPTION

ALPS is an indoor ultrasonic ranging technique that can be used to localize modern mobile devices like smartphones and tablets without requiring any additional hardware on the receiver side. The method uses a communication scheme in the audio bandwidth just above the human hearing frequency range where mobile devices are still sensitive. ALPS uses a variant of the ultrasonic modulation technique described in [2] where multiple transmitters can send time multiplexed ranging signals to any number of mobile receivers. The overall architecture shown in Figure 1 shows the main components which include the transmitters, the mobile device that is being localized, along with the localization and mapping backend. The transmitters are time synchronized using an 802.15.4 radio to enable high resolution TDOA ranging given the geographical origins of the signals. The transmitters continuously broadcast their transmission schedule via BLE to alllow every receiver to map its captured ultrasound signals to the transmitters that sent them. Once a receiver has successfully computed its location using TDOA ranging, it may synchronize itself to the transmitting infrastructure as described in [1]. This allows TOA ranging to be performed, reducing the amount of ultrasound signals that need to be captured successfully. Additional information from inertial measurement sensors on the phone and BLE RSSI data from the transmitters is used to filter location estimates.

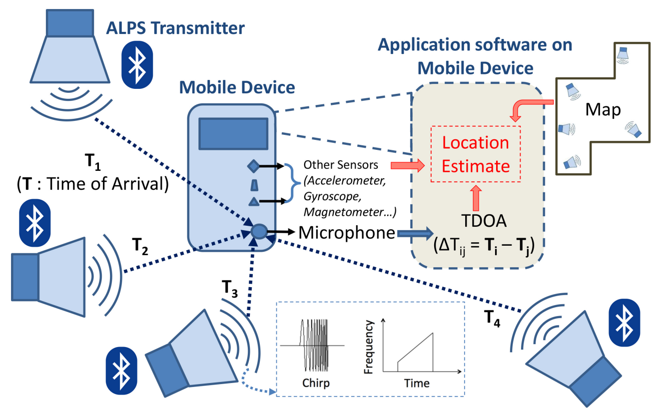


Figure 1: System Architecture

Figure 2 shows an ALPS transmitter. In our deployment, the transmitters are mounted on tripod stands that will be placed thoughout large rooms or in any single zone-based areas. The ultrasound transmitter features an omnidirectional horn, which disperses the ultrasound in a spherical pattern. The receivers can be any mobile device sensitive to up to 24kHz of audio

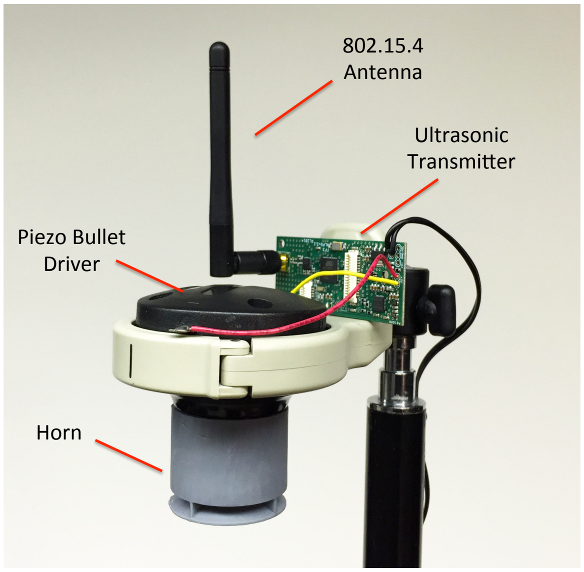


**Figure 2: ALPS Transmitter**

bandwidth that runs our localization software. The user downloads an application which includes a map constructed during installation. As the user walks around the room, the application tracks the user and provides the current location. The application will be demonstrated on an iOS device.

## 2. REFERENCES

[1] P. Lazik, N. Rajagopal, B. Sinopoli, and A. Rowe. Ultrasonic time synchronization and ranging on smartphones. In *IEEE Real-Time Applications Symposium (RTAS 2015)*. IEEE, 2015.

[2] P. Lazik and A. Rowe. Indoor pseudo-ranging of mobile devices using ultrasonic chirps. In *Proceedings of the 10th ACM Conference on Embedded Network Sensor Systems*, pages 99–112. ACM, 2012.