ALPS: The Acoustic Location Processing System

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ABSTRACT

We demonstrate ALPS, an ultrasonic Time-of-Flight (TOF) localization system for mobile devices. ALPS capitalizes on the ability of off-the-shelf smart-phones to detect audio above the human hearing range to localize the phone to within sub-meter accuracy. Synchronized beacons deployed in the environment periodically send out time multiplexed ranging signals consisting of ultrasonic chirps. Each mobile device runs an application that synchronizes to the ultrasonic transmissions over a Bluetooth Low Energy (BLE) connection, records a snapshot of audio, determines the TOF of the captured ultrasonic signals and then uses map data to compute the device's location. Visual Inertial Odometry (VIO) data from the phone's camera and Inertial Measurement Unit (IMU) is fused with the absolute ultrasonic location data to provide a high update rate of up to $60Hz$ and improved localization accuracy. The system is capable of performing localization in 2D and 3D space.

1. SYSTEM DESCRIPTION

ALPS is an indoor ultrasonic localization system that can be used to localize modern mobile devices like smartphones and tablets without requiring any additional hardware or modifications 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 [1], where multiple beacons (as seen in Figure 1) can send time multiplexed ranging signals to any number of mobile receivers. The overall architecture seen in Figure 2 shows the main components of the system, including the beacons, the mobile device that is being localized and the plug forwarder/network master time synchronization nodes. The beacons are synchronized by a network of plug forwarder nodes that connect to a central network master node using 802.15.4 and LoRa radios. Mobile devices are tightly synchronized to the infrastructure using BLE, enabling high resolution TOF ranging.

Figure 1: ALPS Beacon

The beacons continuously broadcast their unique ID via BLE to allow for an installation to be divided into multiple Time Division Multiple Access (TDMA) zones in order to keep the transmission cycle duration low. VIO data from the mobile device's camera and IMU sensors is fused with the absolute location data provided by the ultrasound beacons to provide a high location update rate and improved accuracy, especially when obstacles are present that may block the ultrasound transmissions. While the ultrasound beacons only provide 2D location data, the VIO system is able to estimate the z location of the mobile device by measuring its distance from the floor.

Each ALPS beacon, as seen in Figure 1, features four

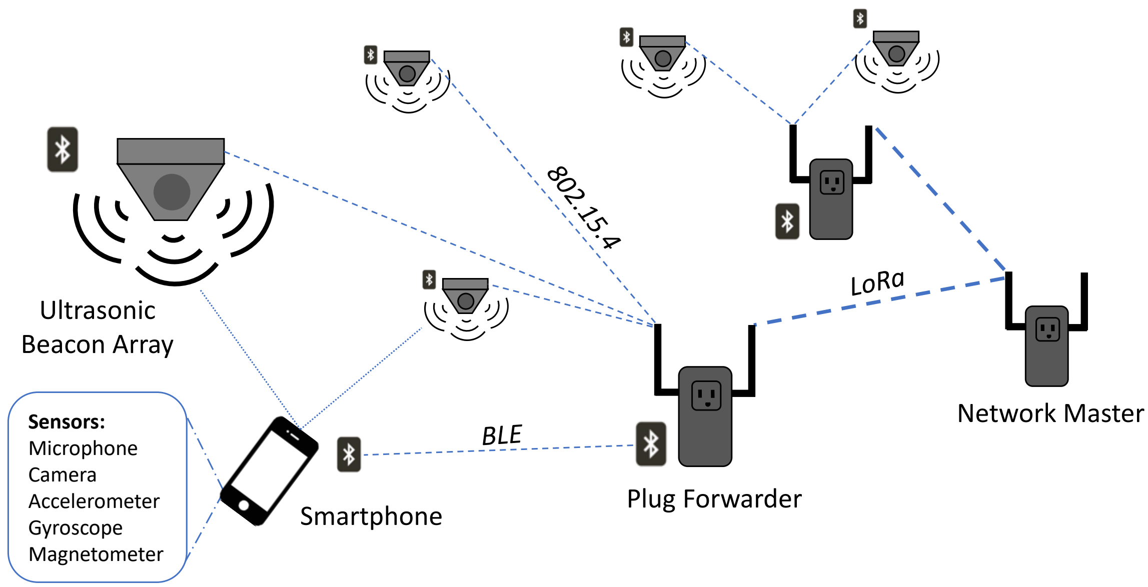

Figure 2: System Architecture

speakers to provide omnidirectional ultrasound coverage and can be solar powered from nearby light fixtures for continuous operation without the need to run wires. In our deployment the beacons will be mounted from the ceiling using magnetic mounts or on tripod stands that will placed throughout the competition space. A receiver can be any mobile device sensitive to up to 24kHz of audio 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, O. Shih, B. Sinopoli, and A. Rowe. Alps: A bluetooth and ultrasound platform for mapping and localization. In *Proceedings of the 13th ACM Conference on Embedded Networked Sensor Systems*, SenSys '15, pages 73–84, New York, NY, USA, 2015. ACM.