Demo Abstract

ALPS - The Acoustic Location Processing System

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Abstract

We demonstrate *ALPS* [1], a platform that augments BLE proximity beacons with ultrasonic transmitters in a manner that allows for precise and robust indoor localization. *ALPS* uses Time-Difference-Of-Arrival (TDOA) and Time-Of-Flight (TOF) ranging to accurately localize mobile devices such as off-the-shelf smartphones and tablets in 2D space. Users inside the demo area will be able to determine their location and can directly plot it relatively to a map of the area using our app on a smartphone. Once a receiving device has determined its initial position, it can synchronize its audio clock with the transmission infrastructure to perform TOF-based localization, which provides similar position accuracy to TDOA-based localization with fewer beacons. Multilateration and trilateration processing for each device's location is offloaded onto a cloud-based solver that can provide localization as a service to *ALPS* and similar TOF/TDOA-based systems.

1 System Description

ALPS is a hybrid BLE-ultrasound system that is able to provide significantly improved ranging capabilities as compared to BLE-only beacons. The system consists of time synchronized beacons that transmit ultrasonic chirps similar to those described in [2] and [3]. These chirps are inaudible to humans, but are still detectable by modern smartphones. The phone can then use TDOA to determine ranges and to synchronize with the infrastructure (as described in [3]) so that it can directly measure TOF. *ALPS* uses BLE on each node to synchronize receivers to the transmitting infrastructure.The inclusion of BLE both simplifies the design and allows for the entire ultrasonic bandwidth to be used exclusively for ranging.

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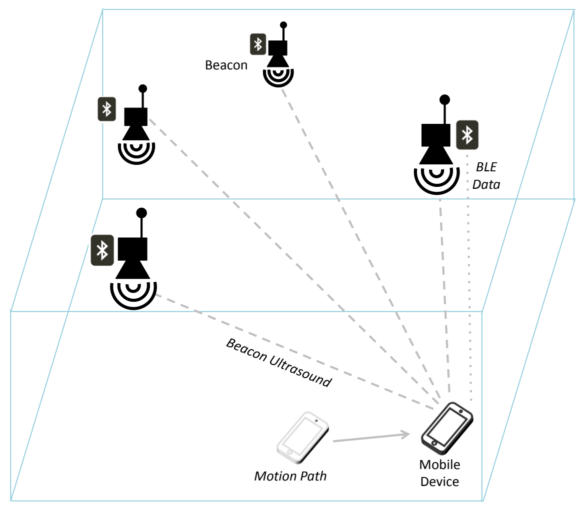

Figure 1. System overview

1.1 Architecture

A typical system setup consists of three or more *ALPS* transmitters deployed at known locations in the target area as seen in Figure 1. Placement of the transmitters is flexible, however the system performs best when the Line-Of-Sight (LOS) coverage of the transmitters is maximized. In most deployments, this would mean mounting them to the ceiling. The transmitters are time synchronized using 802.15.4 radios that listen to periodic transmissions from a master node. The timing master node can be one of the installed beacons. Once a mobile device estimates its range from four or more beacons, its position can be estimated using multilateration. *ALPS* employs a novel time synchronization technique where signals from multiple transmitters can be used to synchronize the audio sampling subsystem of each mobile device with global time. Once synchronized, the devices can perform TOF ranging. This significantly decreases the number of beacons required to cover an indoor space and improves performance in the face of obstructions.

The mobile device performs the capture and demodulation of the ultrasound signals to obtain their relative Time-Of-Arrivals (TOA) and then transmits this data via websocket to a cloud-based solver program. The solver determines the device's position via trilateration or multilateration and sends it back to the device. This architecture offloads the most processing intensive work onto a more powerful ma-

Figure 2. ALPS Beacon

chine with access to maps that can provide a faster update rate and reduced energy consumption on the resource constrained mobile device. The cloud-based solver can process the TOA data from other TOF/TDOA-based localization systems, therefore providing localization as a service.

1.2 Hardware

We demonstrate an embedded, low-power hardware platform for our transmission infrastructure. The complete hybrid ultrasound and BLE beacon is shown in Figure 2 and consists of the following main components: (1) An ultrasound transceiver board with an 802.15.4 radio (2) a BLE daughter board (3) a piezo bullet tweeter with attached omnidirectional horn and (4) a battery pack for optional battery powered operation.

1.3 Ranging

We use Time-Division-Multiple-Access (TDMA) to multiplex the transmission of our ultrasound transmitters over time and transmit ultrasonic chirps for precise ranging. Instead of encoding data using the chirps, *ALPS* relies on BLE advertisement packets in an iBeacon compatible format to signal the current TDMA time slot. This eliminates the need for a complicated and more processing intensive demodulation step on the phone and makes the ultrasound signals shorter and more likely to be detected correctly.

2 Time Synchronization

Mobile devices can be synchronized to the transmission infrastructure for performing TOF ranging instead of TDOA-based ranging. This is done by first determining the device's position using TDOA ranging and multilateration and then calculating the distance to at least one transmitter. Since the ultrasound transmissions are periodic, the beginning of the TDMA cycle can be determined based on the distance to the transmitter, the TOA of its transmission in the device's recording buffer and the time slot of the transmission. Since the device's ADC has a free running clock, we can synchronize it to the transmission cycle of the beacons by determining the sample in the recording buffer that corresponds to the beginning of the TDMA cycle. This then allows for TOF ranging to be used instead of TDOA.

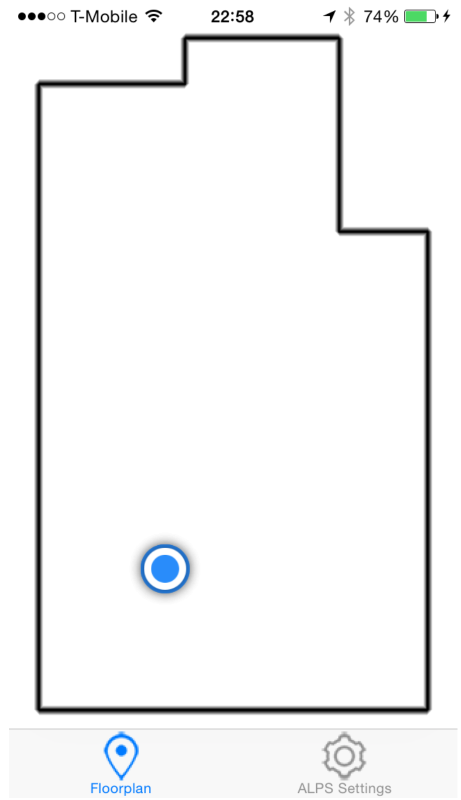

Figure 3. Screenshot of iOS localization app

3 Demonstration

We demonstrate our system by providing each user with a mobile device running an app that displays a map of the demo area and the current position of the mobile device as seen in Figure 3. The position is updated continuously as users move throughout the space. The app also displays the most recent TOA data that was obtained and whether the mobile device is synchronized to the transmission infrastructure. This will allow users to monitor which beacons were used in the last position update and experiment with how localization accuracy is impacted when beacons are selectively blocked or when the device loses synchronization.

4 References

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