

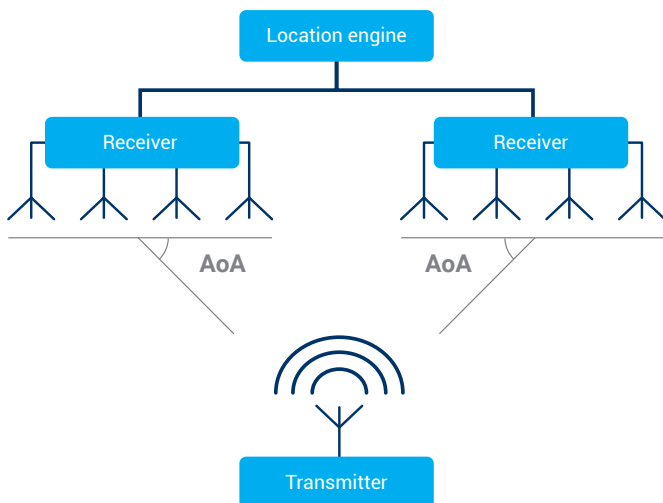


Bluetooth Low Energy AoA/AoD algorithms for low-power MCUs

General description

Wireless communication technologies have undergone a remarkable evolution, revolutionizing various domains, including industrial, consumer, and Internet of Things (IoT) applications. A notable emerging feature of these wireless systems is their ability to accurately determine the Angle of Arrival (AoA) and Angle of Departure (AoD) based on Radio Frequency (RF) signals. AoA/AoD estimation is pivotal in applications such as indoor positioning, asset tracking, autonomous navigation, and context-aware services.

Principle



For AoA, the system utilizes a Bluetooth Low Energy (Bluetooth LE) tag that emits a periodic Constant Tone Extension (CTE), appended to Bluetooth LE packets. This signal is broadcast at a constant frequency, shifted by 250 kHz from the channel's central frequency. The Bluetooth LE anchor subsequently samples the quadrature (IQ) signal at each of its antennas in a consecutive manner. These IQ samples are processed by the microcontroller (MCU), which runs the AoA algorithm to estimate the BLE tag's 3D incident angle concerning the anchor, including both azimuth and elevation angles. For AoD, the antenna array is on the transmitter side, and the tag performs the processing.

Features

- State-of-the-art algorithms for Bluetooth LE Angle of Arrival with RF multipath segregation
- Reduced embedded memory footprint to 17 KB with a latency of 30 ms
- Implemented algorithm in embedded C with RTOS μ 111 or Zephyr, compatible with low-power microcontrollers (Cortex-M4 and similar)
- Tested on nRF52/53 and STM32WB5
- Accuracy in anechoic chamber with error of 1° (typical), 3° (max), with a typical 4x4 antenna matrix and processing the CTE of a single Bluetooth LE packet
- Support for handling IQ sequence rates exceeding the microcontroller's processing rate
- Further processing of the results based on each Bluetooth LE packet provides outlier rejection and angle smoothing

Application

- Indoor positioning
- Asset tracking
- Autonomous navigation
- Context-aware service

	AoA	AoD
Transmitter	Bluetooth LE tag Single antenna	Bluetooth LE gateway Antenna array (switch)
Receiver	Bluetooth LE gateway Antenna array (switch)	Bluetooth LE tag Single antenna
	AoA/AoD algorithm	
2D/3D angle	Computed in gateway	Computed in tag

