Location Services and Direction Finding with Bluetooth

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Bluetooth location services

**proximity solutions**
- item finding solutions (e.g. personal property tags)
- point of interest information solutions (e.g. proximity marketing)

**positioning systems**
- real time locating systems (RTLS) (e.g. asset tracking)
- indoor positioning systems (IPS) (e.g. wayfinding)
Bluetooth location services

- Item finding solutions (e.g. personal property tags)
- Point of interest information solutions (e.g. proximity marketing)
- Real time locating systems (RTLS) (e.g. asset tracking)
- Indoor positioning systems (IPS) (e.g. wayfinding)

Bluetooth beacons
(iBeacon, Eddystone)

Proximity Profile
Find Me Profile

Indoor Positioning Profile
Positioning Without Direction

Person is in range of the beacon

Signal strength tells us *roughly* how far away they are

We have no idea what direction one is from the other
Positioning with Direction Finding

Knowing direction, dramatically improves location accuracy

Bluetooth Direction Finding – new in 5.1
Item finding requires an experimental approach when we don’t know the direction of the lost item!

Item Finding Without Direction
Item Finding With Direction

The user experience is considerably better when we can indicate the direction to walk in!
New - Directional Discovery
About Bluetooth Direction Finding
Angle of Arrival

Transmitter
- sends special packets using a single antenna

Receiver
- has multiple antenna arranged in an array
- antennas see received signal phase difference because of different distances to the transmitter
- takes IQ samples from received signal while switching between active antenna
- relative signal direction calculated using sampled data

For RTLS, item finding, and PoI
Angle of Departure

Transmitter
- sends special packets while switching between active antenna arranged in an array

Receiver
- receives signals using single antenna
- has knowledge of antenna layout within transmitter
- takes IQ samples from received signals
- relative signal direction calculated using sampled data

For indoor positioning systems (IPS)
A variety of antenna array designs are possible and they affect the maths and parameters into the maths.
High Accuracy Location Potential

For Highest Accuracy Calculate 2 angles
- Azimuth and Elevation are commonly measured
- Intersection provides accurate location determination
- Requires suitable antenna array
High Accuracy Location Potential

For Highest Accuracy Calculate 2 angles
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Location accuracy to within 10cm becomes possible
RF Fundamentals - Wavelength

Bluetooth: \(~12.5\text{cm}\)
RF Fundamentals - Phase

\[ \frac{\pi}{2} \quad \pi \quad \frac{3\pi}{2} \quad 2\pi \]
Phase and Distance from a Transmitter

2 antennae at the same distance from the transmitter

Same signal

Same frequency and so same wave length

Phase is the same at both antennae at a given point in time
Phase and Distance from a Transmitter

But with 2 antennae at different distances from the transmitter

And the difference between the two antenna distances is not a multiple of the wave length

Phase is **NOT** the same at both antennae at a given point in time
Phase and Distance from a Transmitter
Direction Finding from phase difference and antenna details

\[ \theta = \arccos\left( \frac{\psi \lambda}{2\pi d} \right) \]

- \( \psi \) is the phase difference
- \( \lambda \) is the wavelength
- \( d \) is the distance between adjacent antennae
RF Fundamentals - IQ Sampling

IQ data is sampled at strict time intervals. With AoA, we sample from one antenna at a time, moving from antenna to antenna in a given sequence.

A different phase angle means this antenna is at a different distance from the receiver compared to another antennae.

The IQ samples can be used to calculate the phase difference in the radio signal received using different elements of the antenna array, which in turn can be used to estimate the angle of arrival (AoA).

We have to know details of the antenna array and get our sample timing right.

Seeing this in motion is much easier to appreciate.
Frequency Deviation

Analogue symbols represent digital 0s and 1s

Within a radio channel two frequencies are used, one to represent 0 and one for 1

Therefore two wavelengths are used within a channel

This complicates direction calculations since wavelength is a part of the formula

And phase angle sampling would need different timing for the different frequencies

So… we don’t sample everything and restrict sampling to something….special
Direction Finding Signals

DF signals are standard Bluetooth packets with an extra field called the **Constant Tone Extension (CTE)**

CTE appears after the CRC and is not included in the CRC calculation

CTE consists of a series of 1 symbols and is therefore a constant frequency for a given channel

Its length is requested by the host

CTE is not subjected to the whitening process

It is the CTE which is IQ sampled and from which phase differences are determined
Direction Finding and the Bluetooth stack
Stack Configurations

HOST
- Generic Access Profile (GAP)
- Generic Attribute Profile (GATT)
- Attribute Protocol (ATT)

Host Controller Interface
- Link Layer
- Physical Layer

Bluetooth LE Controller
- Radio

NB: stack diagram has been simplified
Stack Configurations

HOST
- Generic Access Profile (GAP)
- Generic Attribute Profile (GATT)
- Attribute Protocol (ATT)

HOST
- Models
- Access
- Network
- Bearers

NB: stack diagram has been simplified
All the action takes place in the controller.

The HCI allows the host to configure, enable and disable IQ sampling and CTE details.

Both connection-oriented and connectionless communication scenarios are supported.

The *application* has plenty of work to do.

- IQ sampling enablement and configuration
- CTE enablement and configuration

**NB: stack diagram has been simplified**
Host A and B are connected

New HCI commands lets **Host A** set CTE receive parameters and then enable CTE request sending

**LE Set Connection CTE Receive Parameters**

**LE Set Connection CTE Request Enable**

New HCI commands lets **Host B** set CTE transmit parameters and then enable CTE response sending

Host A sends new LL_CTE_REQ
Host B replies with LL_CTE_RSP

Until CTE requests are disabled by Host A
Bluetooth Direction Finding

Where next?
Core Specifications

The Bluetooth® Core Specification defines the technology building blocks that developers use to create the interoperable devices that make up the thriving Bluetooth ecosystem. The Bluetooth specification is overseen by the Bluetooth Special Interest Group (SIG) and is regularly updated and enhanced by Bluetooth SIG Working Groups to meet evolving technology and market needs.

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Bluetooth SIG Resources – Reading Material

Bluetooth Direction Finding: A Technical Overview
This comprehensive overview examines how two new Bluetooth direction finding methods can enable location services solutions that support high-accuracy.
LEARN MORE

Enhancing Bluetooth Location Services with Direction Finding
See how the new direction finding feature will enhance the performance of Bluetooth location services solutions.
LEARN MORE

Bluetooth Angle Estimation for Real-Time Locationing
In this paper, Silicon Labs explains the basics of Bluetooth Angle of Arrival (AoA) and Angle of Departure (AoD) technologies, and give some theory for estimating direction of arrival.
LEARN MORE
questions?

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