# Bluetooth Positioning

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## Abstract

*Research on positioning systems and context-aware applications are being performed in the Alipes project at CDT, Luleå University of Technology, Sweden. An evaluation of Bluetooth as a possible technology for positioning was performed during autumn of 2001 in this project. Proceeding the evaluation a Bluetooth based positioning system was implemented in order to complement the theoretical evaluation with empirical tests.*

*Three different ways of positioning with Bluetooth have been developed for the Alipes project. With a registered positioning service a Bluetooth device has an active role in the positioning task as it sends a position on request. A Bluetooth device can also take a more passive role in a positioning task, which is when the unique address of the device is used by a connected device to look up a position in a database. It is also possible to forward a position gained from a positioning platform like Alipes over Bluetooth.*

*This paper presents a Bluetooth positioning system where the three ways of positioning are implemented. The evaluation and conclusions of Bluetooth as a positioning source and how well Bluetooth performs in such a task are being discussed. To give support to the statements the implementation and tests are also presented.*

## 1 Introduction

Mobile applications are growing in number as more people start to use mobile devices in their everyday life. More people are also using services requiring some kind of wireless communication technology such as GSM, GPRS, UMTS, WLAN and Bluetooth. There are already many services available online for the mobile user but there is still a market for more services.

### 1.1 The Alipes Platform

Providing a positioning system enables many new services to be implemented for a mobile user, for example map retrieval, search for "near by" services such as restaurants and other facilities, what bus to take to get to a certain place, to name a few. This is what the Alipes project focuses on, to provide an efficient positioning platform for mobile devices [1].

There exist many positioning systems but only a few attempts to bring these systems into one platform where they work seamlessly together. The Alipes project is one of those platforms, where several positioning systems work together and provide architecture for location aware applications. There are several advantages to gain from bringing several positioning systems into one platform. One of these advantages is that applications can use several different positioning systems with one simple interface, another is that positions from different positioning systems can be combined to get a more accurate position.

### 1.2 Introduction to Bluetooth

Bluetooth is a low cost, low power, short range radio technology originally developed as a cable replacement to connect devices such as mobile phones, headsets, PDAs and portable computers. By providing a standard way for these accessories to communicate, Bluetooth has created the expression Personal Area Network (PAN) [2]. PAN is a close range network that connects your personal electronic equipment.

There are many protocols in the Bluetooth stack. Some or parts of them are required, while others are optional. The Bluetooth specifications are divided into two major parts [2]. One of the parts is the Bluetooth module; it contains the protocols that are responsible for connecting to and finding other devices. The second is the Bluetooth host, which is responsible for doing what the device was built to do. Some of the host implementation is part of the Bluetooth specification while some is product dependant. These parts do not need to be separate parts in the implementation. However it might be a smart decision to implement them separately because of the different requirements of the two parts.

## 2 Theoretical background

The main intention for this work was to find a communication system that was common on mobile devices and could function as a positioning system. Three different systems was evaluated; Bluetooth, IrDA (infrared) and RFID (Radio Frequency Identification). From these, Bluetooth was found the most suitable communication system based on range, speed and services [3].

Further evaluation of Bluetooth as a positioning system was conducted. We wanted Bluetooth to handle three different scenarios: mobile Bluetooth positioning client, mobile Bluetooth positioning server and static Bluetooth positioning server without any needed software. The benefit of not needing any server software in order to function as a position source is obvious as any Bluetooth device can function as a position source without extra hardware or software. The implementation showed that Bluetooth could function in all these three scenarios. How it was done can be seen in section 2.1.

### 2.1 Bluetooth positioning in Alipes

A mobile positioning system would benefit from having mobile position sources in addition to just static position sources. Thus, a Bluetooth positioning server needs to be mobile as well and the position should change automatically as the Bluetooth device is moved. With the use of the Alipes platform this is possible. A mobile device with both GPS and Bluetooth can get a position from either GPS or Bluetooth; this position can be used to update the position in the Bluetooth positioning server. A Bluetooth positioning client that passes by will get the most recent position from the Bluetooth positioning server. A static Bluetooth device can of course have a static position.

An office computer may use Bluetooth in order to have wireless keyboard and mouse. The office computer is static but does not have any software for positioning installed (since the Bluetooth unit is not meant for positioning). Making use of Bluetooth devices like this in positioning is an important aspect in order to get good position source coverage. In order to make use of these Bluetooth devices a location server was developed. The location server stores the unique address (that every Bluetooth unit has) together with a position. A Bluetooth device that tries to connect to another will automatically get its unique address which it can use to search for a position in the location server.

A positioning client needs to automatically select from what source it should fetch a position. The current implementation will search for all surrounding Bluetooth devices and establish a radio link with each of these devices. The next step is to establish a connection between the link managers in order to get a reliable connection, and finally a connection to the service discovery protocol [3] can be made. A device can now search for the positioning service with use of the unique identifier corresponding to it.

A device with the positioning server software installed will answer the service search request with necessary information to continue with the connection. With the gained information a connection can be made which will allow transfer of a position from the server to the connected device.

A device with no positioning server software installed will answer negatively upon a position service search request. The searching device will then try to connect to the location server database and look for a position using the unique address as search key. If the location server is not running locally the Bluetooth device will need an Internet connection in order to connect to the server.

More information about the different positioning methods can be found in "Positioning with Bluetooth, IrDA and RFID".

### 2.2 Theoretical performance

Low power consumption is preferred when developing systems for mobile devices. Bluetooth is designed to have low power consumption and has several power saving functions built into the protocol. Apart from the power saving functions there are also three power classes for Bluetooth. The most common one is also the one that requires the least power. The lowest power class provides a communication range of about 10 meters.

The range of the Bluetooth device affects the accuracy of a position acquired via the Bluetooth system. There is an indicator that indicates the received signal strength but this indicator is too inaccurate to be used as a measurement of the distance between two communicating Bluetooth devices. Thus, the worst-case scenario gives an accuracy of about 10 meters that corresponds to the maximum communication range between two Bluetooth devices.

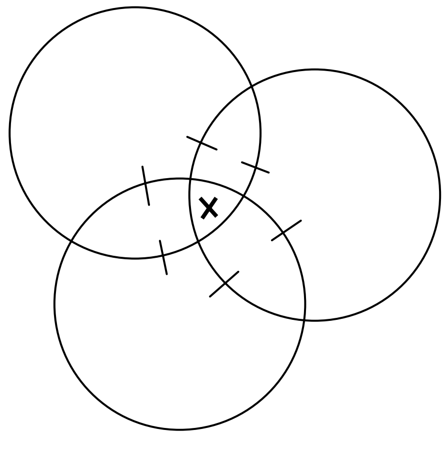


*Figure 1: Graphical view of Triangulation procedure.*

Triangulation [4] is performed in order to improve the accuracy. As mentioned earlier the worst case corresponds to the max range of the device, however when several different positions are detected, triangulation, will improve the accuracy of the position. The accuracy for a device can be drawn as a circle around its position. To calculate the triangulation the points where the distance is at its max on intersecting circles are recorded. The resulting position is in the middle of these points which can be seen in figure 1.

The Alipes platform is designed for context aware applications and some of these applications would benefit from a network connection. Bluetooth can form ad hoc networks with up to seven other devices with Bluetooth. One of these devices may have connection to the Internet and connected devices can then benefit from this connection. A connection to the Internet can also, as described earlier, be used to connect to a database with positions for different Bluetooth devices.

### 2.3 Reliability and security

Bluetooth works in the license free ISM (Industrial, Scientific and Medical) band, which is very crowded and thus has a lot of interference. Bluetooth solves this problem by hopping in frequency 1600 times per second while sending one packet of data every frequency hop. If a frequency suffers from a lot of disturbance only one packet will be lost. Bluetooth has cyclic redundancy check, forward error correction and the ability to request a lost package to be resent, which will also ensure the reliability of the communication between Bluetooth devices.

As for security Bluetooth make use of the encryption algorithm called SAFER+. It is a 128 bit based encryption algorithm that was designed as a candidate for the U.S. Advanced Encryption Standard (AES). Apart from advanced encryption the frequency hopping of Bluetooth makes it hard to eavesdrop on a communication between Bluetooth units.

## 3 Implementation

The Alipes platform is developed in Java and therefore we chose to do as much as possible in Java. By this we gained easier integration with Alipes and also portable code to other operating systems and platforms. However, since no public implementation of Bluetooth exist in Java at current date; we developed a library in C++ that the Java part could call through the Java native interface. This library is a link between the Java side and a Bluetooth stack developed by Ericsson.

The hardware we used were two Bluetooth starter kits from Ericsson connected to the computers through a serial cable. We also had two Bluetooth pc-cards and a Bluetooth USB device from 3Com, two Compaq Ipaqs with Bluetooth that we used for testing.

### 3.1 Design

The goal of our design was to make it flexible, meaning it would be easy to port the code to another operating system. To accomplish this we implemented the separate protocols in separate classes. We also implemented the different data element types in separate classes to make porting easier.

In order to make further extensions of our positioning application easier, we made an extensive implementation of the Bluetooth interface in Java. Thus, the so called Native code in C++ covers many of the commands featured in the Bluetooth stack by Ericsson.

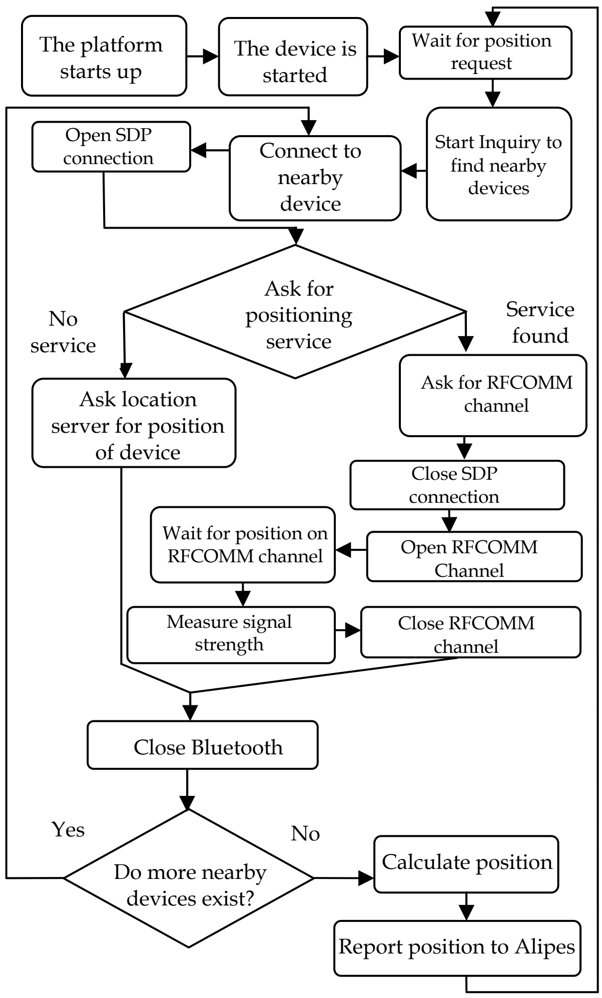


*Figure 2: Flow diagram of the implementation*

The complete task of our implementation for retrieving a position can be seen in figure 2 as a flow diagram. SDP, which stands for service discovery protocol, is one of the standard protocols in Bluetooth. RFCOMM is the protocol used to emulate standard serial communication over Bluetooth and is used by many services as the base for data communications over Bluetooth.

### 3.2 Testing

Five devices excluding the client device were placed at different locations in a corridor, see figure 3. Signal strength to determine distance was not used in this test since earlier tests had shown it to be an unreliable source. Thus, the accuracy was hard-coded to 10 meters.

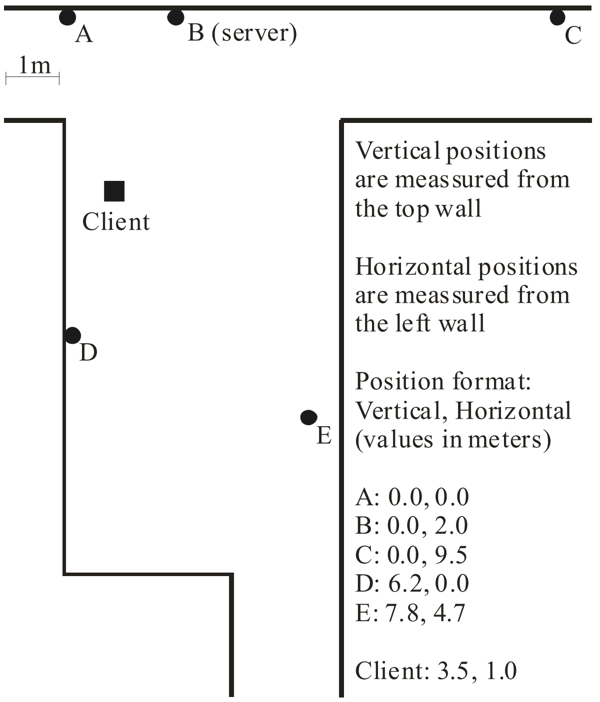


*Figure 3: The field-test setup*

The test was performed by letting the client search for a position in its surrounding. For every connection made, the time was recorded. The resulting position of the triangulation and the total time for the search was reported in the end.

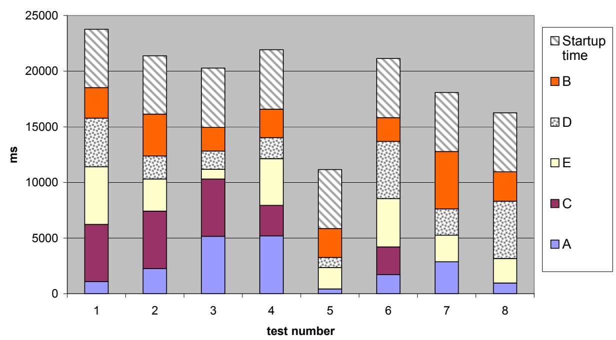


*Figure 4: Results from test-runs*

Figure 4 show the result of our test. We made 8 tests by hand and recorded the time for every connection per test. The startup time in figure 4 is the difference between the sum of the times for every connection and the measured time for the whole test. We can see that this time is almost the same for every test at an average of 5297. Most of this time is for searching of nearby devices, and it was set to search for 5 s. The connection to one device will never exceed 5200 ms as the connection will time out and the client will try to connect to the next device instead. The amount of failed connection for a device can be seen in table 1.

The average position error is 1.7m ± 1.7m. For a more accurate reading we need more test results. The lack of a satisfying test environment for a longer period and the fact that we have some possible major performance gains in development, made us wait with a more complete test. We decided that the results we have will give us sufficient accuracy at this time.

## 4 Performance evaluation

The startup time is static and does not change dependent on how many devices we are connecting to. The rest of the time is dependent on the amount of connected devices and the time that every connection take, see figure 4.

| Device | A | B | C | D | E |
|---|---|---|---|---|---|
| Number of Failed connections | 2 | 1 | 6 | 1 | 1 |

*Table 1: number of failed connections for every device*

As seen in figure 3, device C is approximately 10 meter from the client. The Bluetooth devices used in this test are of power-class 3 which have a typical max range of 10 meters. Our test confirms this as we see in table 1 that device C have very few successful connections. Our hard-coded value for the distance (10 meters) was therefore a good choice. As Bluetooth is a radio based communication there are several things that can disturb the connection between devices. We could see that Bluetooth can be improved in dealing with this as we never did manage to connect to all devices over one test run.

Triangulation will in most cases give a better result than 10 meters. Even though all our tests give us a smaller error than 10 meters the theoretical worst case is still 10 meters.

## 5 Conclusion and discussion

The test of our implementation showed that Bluetooth can function as a position transmitter and/or receiver. If we calculate that a person has an average walking speed of 1.2 m/s and the circle around the Bluetooth position source where the signal strength is high enough has a diameter of 20 m, the time for crossing in a straight line through this circle passing the center would be 16.7 s. If we compare this to the tests, the time spent on positioning exceeds this time in most cases and will require the user to move slower to be able to receive a position. But retrieval of a location is not only relevant when you are moving. For example a user can be located in his office with his digital calendar, which only has Bluetooth for communication. This calendar will receive the position and then adjust the alarm for an upcoming meeting just across the hall to 5 min as no travel time is needed. The current implementation connects to one device at a time. Most of the connection time is spent waiting on the other device and if a parallel connection to all devices could be made this would decrease the total time to the startup time plus the time for the longest connection. For example, test 1 in figure 4 would only take around 10405 ms and in that case we would have enough time for positioning when walking as well. This time could probably be decreased even more as no work has yet been spent on optimizing the code

Bluetooth is a rather inexpensive and small size solution and will probably be integrated in a range of different devices. With a positioning system based on Bluetooth we are able to make these devices location aware. This will open up to new applications and services that can be developed on these devices.

Bluetooth has the ability to share its position. A device could therefore in theory receive a position from a trusted device 100 meters away or more. The position would of course be forwarded several times in this scenario and therefore be very inaccurate.

With the use of our location server, even the devices that do not use Alipes can be used as position sources.

### 5.1 Further Work

The "Bluetooth starter kit" from Ericsson used in this project does not support more then one Bluetooth connection at the same time. Our code is prepared for simultaneous connecting but is at time of writing not using this feature. Once we have access to hardware with the newer Bluetooth standard we will be able to implement the simultaneous connecting feature, without much extra work.

Another for interesting improvement would be to let the device maintain connection to the server as long as it is able to. If a device wants to check for a position over and over it would be spared the effort of reconnecting to the known server. This would most likely save both time and power for the device. This however does not only come with advantages but also flaws. There is a limit of seven connections that a server may uphold and if devices were to stay connected it would run out of free connections. This would both hinder new devices from getting a position but it would also hinder the server from doing anything else that it is using the Bluetooth for. A few restrictions could be added in order to limit the downsides of letting devices stay connected to a server. One of these restrictions could be to limit the number of connections allowed for the positioning service. The Server could then use "first in, first out" (FIFO) to supply connections to new devices that wishes to connect.

The Java APIs for Bluetooth [6] is about to be released. Changing our implementation to use these APIs instead of the native interface should not be too much work. However, at current date only the Java API documentation have been released. Our hope is that with the Java APIs it will be even easier to port our code to different Bluetooth hardware.

## References


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