Internet of the Equine - Outreach Activity

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1 Introduction

The objective of this outreach activity is to demonstrate various ways in which data can be transferred over Bluetooth. This will allow students to gain insight into the BT devices that they use in their everyday lives, hopefully inspiring some to develop their own BT projects.

2 Learning Objectives

1. Explain the basic structure of BT GATT services.
2. Compare a custom GATT service to the standard Nordic UART service.
3. Observe how BT can be used to transfer data in real-time to a smart phone.
4. Discuss how IMU data can be used in a health monitor.

3 Apparatus
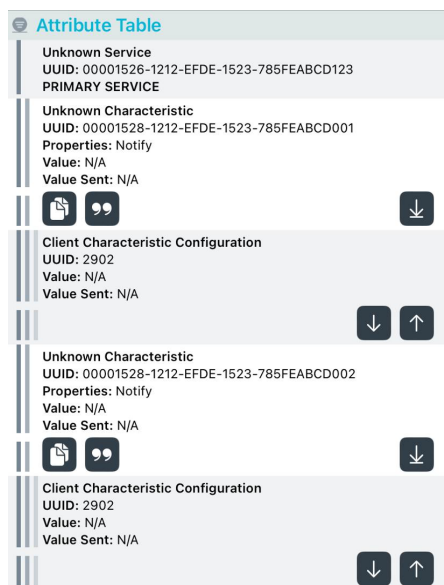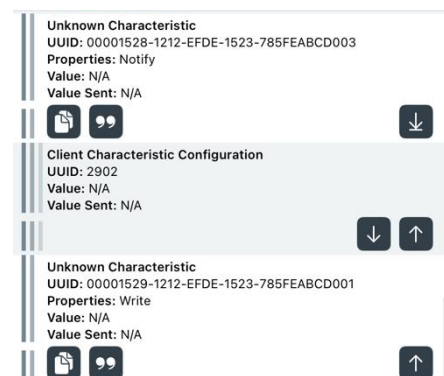

(a)   (b)

Figure 1 - Applications used in activities. (a) nRF Connect and (b) Bluefruit Connect

The students will need mobile phones or tablets with the applications 'nRF Connect' and 'Bluefruit Connect' downloaded.

(a)   (b)

Figure 2 - Custom GATT service provided by simplified code

A simplified version of the code must also be programmed onto each of the IMU units. This reduces the full IMU service so that it only has three 'notify' characteristics (for each orientation axis) and one 'write' characteristic (to start and stop measurements), as shown in Figure 2. The activities were done in four teams of three so that each group would get one IMU unit each.

4 Activities

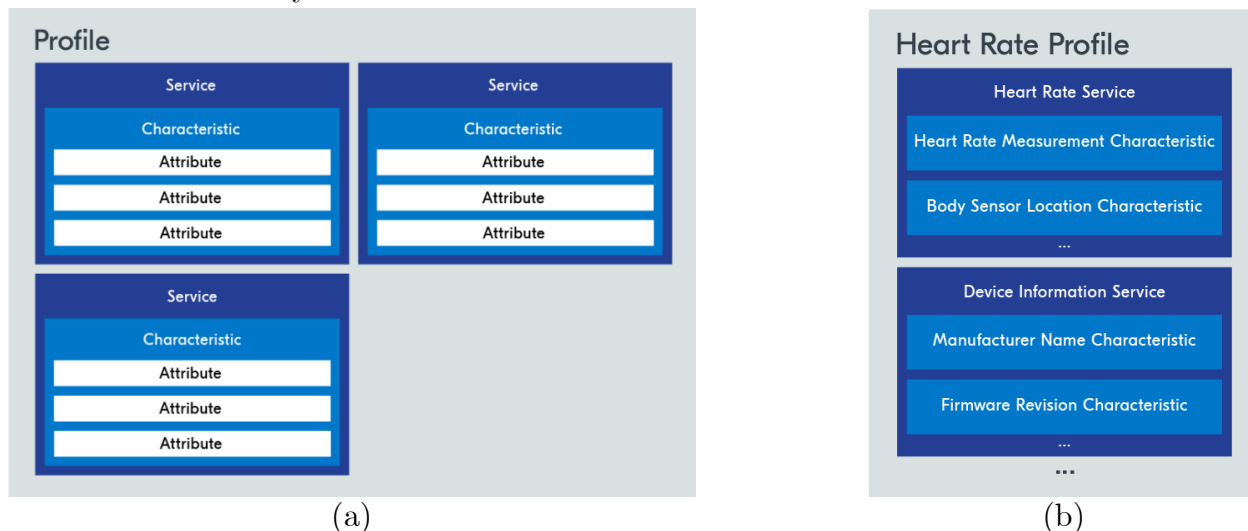## 4.1 The GATT Layer

(a)   (b)

Figure 3 - GATT layer hierarchy for (a) general profile and (b) heart rate profile

First, the GATT (**G**eneric **Att**ribute) layer, which governs BT operations after connection, should be introduced to students. This consists of characteristics, which contain information as well as metadata describing this information. These can be combined to form services, which in turn can be combined to create profiles. The standard Heart Rate Profile (Figure 3(b)), used for various health monitors, can be given as an example. In this way, the difference between services and profiles can be illustrated: services group similar types of data, whereas profiles group different kinds of information that together may be used by similar devices.
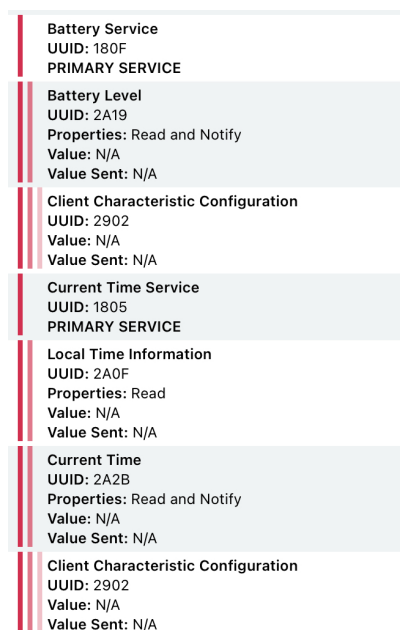

Figure 4 - Example of BT services provided by an iPhone

To demonstrate how this service is used by devices that would be familiar to the students, the students should be instructed to search for one of their group member's smartphones in nRF Connect and investigate the BT services that are exposed. Figure 4 illustrates examples of services that might be seen on an iPhone: battery and current time.

4.2   Custom GATT Service

Next, the various attribute permissions (read, write, notify and indicate) should be explained to students. There was not time for this in the outreach event, but a brief discussion could be held concerning the relative merits of read, notify and indicate for sending data from the server to the client. For example, what implications does requiring acknowledgement of packet receipt have on the data throughput?

The demo for this section requires students to use nRF Connect again, but instead to subscribe to their team's IMU unit. After subscribing to all of the 'notify' characteristics, the students should initiate measurement by sending 'True' to the 'write' characteristic. As the IMU unit is moved around, the received values should change, showing the changing orientation of the device.

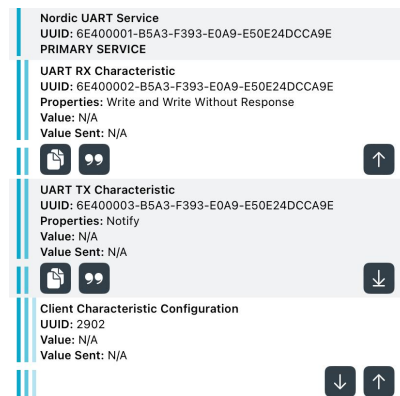## 4.3   Nordic UART Service

Figure 5 - Appearance of Nordic UART service on nRF Connect

Once the custom GATT service has been explored, the students should find the Nordic UART Service, a standard service that emulates Serial over a BT connection. Next, the students should subscribe to the UART RX characteristic. Instead of data from each axis being sent through a separate characteristic, all orientation data should be transferred via the UART TX characteristic.

After both approaches have been demonstrated, the students can discuss the pros and cons of each, with respect to data rate, user interface and flexibility. There was not sufficient time for this in the outreach event, so instead a general discussion on what must be considered when designing a data interface was held. Students provided a variety of good answers including range, security and compatibility.

4.4   Data Plotting

Finally, the orientation will be visualised using Bluefruit Connect. The students should follow the following steps:

1. Disconnect from the device in 'nRF Connect'.
2. Open 'Bluefruit Connect' and connect to the device.
3. Open 'nRF Connect' again and reconnect to the device.
4. In nRF Connect: write 'True' to the write characteristic.
5. In Bluefruit Connect: click 'Plotter'.
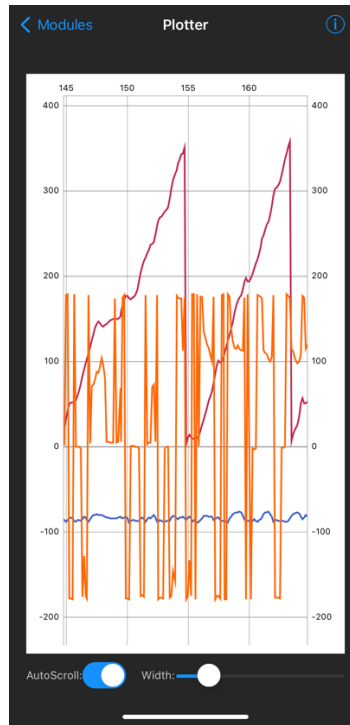6. Strap device to leg and try walking around in a circle.

Figure 6 - Example of data plotting in Bluefruit Connect

Through this activity, the students should be able to see some repeating patterns in the orientation data, as illustrated by Figure 6. Peaks in the red plot correspond to full laps being completed, whereas peaks in the orange plot correspond to individual steps.

4.5 Discussion of Applications
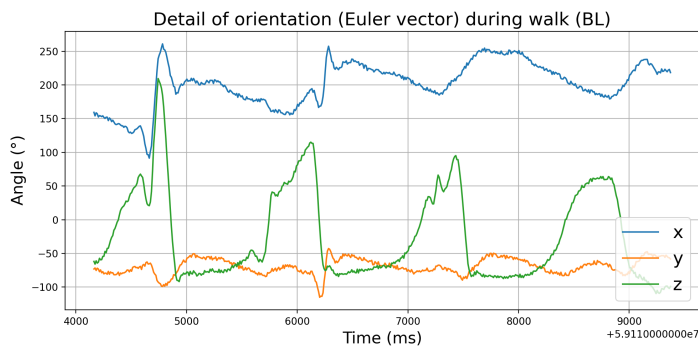
(a)

(b)

Figure 7 - Orientation data from horse

At this point, the corresponding results obtained from the equine testing can be presented to the students. Similar to human gait, there are sharp peaks present in the data corresponding to strides. A discussion of potential uses for this data could be conducted. During the outreach event, students suggested a range of applications, including diagnosis of musculoskeletal disorders, gait characterisation for the purpose of simulation and tracking of missing horses.

5 Reflection

The activity took longer than expected, because only one IMU unit functioned correctly, hence a significant amount of time had to be spent troubleshooting. Due to this, future iterations of this activity may benefit from the instructor handling all BT operations, with the plotting occurring as a demo rather than a hands-on experience. Although this would come at the cost of interactivity, it would likely lead to more learning and enjoyment for the students.