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| Philips |
| Physical Activity Monitor Specification |
| Implementation of the new Bluetooth Physical Activity Monitor Service and Profile GATT Specification drafts |
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| **Dominic Voets** |
| **[Kies de datum]** |

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**Bachelor’s thesis for Fontys University of applied sciences**

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Approved and signed by the company supervisor: J. Espina Perez

Date:

Signature

# Document history

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# Preface

My name is Dominic Voets and I am a student at the Fontys in Eindhoven where I study ICT & Technology. In front of you is my thesis that I have written during my internship at Philips Research, the research department of Royal Philips.

This thesis covers the “Implementation of the Physical Activity Monitor Specification” assignment that I did for my graduation project. The purpose of this project is to test the correctness and completeness of the new Physical Activity Monitor Specification. In this role, I had the chance to contribute to the standardization of the new Bluetooth standard that Philips is driving in the Sports & fitness domain, the Physical Activity Monitor.

During this assignment, I have been able to enjoy multiple long working days with all the people who work here at Philips. I want to thank all of the people at Philips Research for helping me during this assignment, especially Javier Espina Perez, Erik Moll and Maarten Vervelde. Further, I would like to thank my university supervisor Cees van Tilborg, who helped me with this project, problems I had and his always-extended feedback on documents. Finally yet importantly, I want to thank Philips for allowing me to execute my graduation project at their company and the trips they financed to Amsterdam and Cambridge for the interoperability tests.

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# Summary English

This document describes my graduation project that is conducted at the research department of the Royal Philips at the High Tech Campus in Eindhoven. This graduation assignment is done for Fontys Hogeschool in Eindhoven. Philips is a Dutch technology company that has its focus on healthcare; their mission is to improve people’s lives through meaningful innovations. Far before this project, there was no Bluetooth communication standard for the Physical Activity Monitor as there is for heart rate sensors, blood pressure meters etc. This means that if you wanted to use a Physical Activity Monitor you are bound to use the client that it provided and were unable to switch. Thus, Philips initiated a project that will build/write a new specification to solve this problem. When this specification reached a point, where it is able to start implementing services according to this specification is where this project starts. This project is to implement a Physical Activity Monitor Service (server) and Profile (client) to identify gaps and other issues with the new specification in order to update it. This whole project used the Triangulation research method.

First, research is conducted to determine the platforms this project will use for its implementations. Four embedded platforms are considered as a candidate for this research. As these are provided by Philips on the grounds of availability and experience in the project boundaries. Two of these are quickly dropped due to unavailability. This means that only two boards are left: the Cypress and Nordic. After researching the specifications, support, reusability and ease of use the Cypress board is the one that is chosen for this project. After this we determined which platform the project is going to use for the client. Two choices are considered Android or IOS; Philips also provided these in the project boundaries. This platform will be accompanied by the Harald library, this is a Philips build library specifically to use and implement Bluetooth services. Other libraries were available but after recommendations and looking into the library it is chosen to use Harald. After researching the same criteria as for the service, the Android platform was chosen.

After the research, the implementation phase started. During the implementation phase, it is important to criticize the specification as much as possible and consider the choices that are made. The gaps and other issues that are found are very important to contribute and update the specification. The implementations are tested during two informal interoperability tests. One in Amsterdam and one in Cambridge. At these interoperability tests, the implementations made during this project are tested against the implementation of other independent implementers. The implementation has to go through a test plan, which is made before the tests and is conducted by the implementers. The implementations have to pass certain test cases, which for the most part succeeded. Using a fixed set of predefined test cases makes it is much easier to identify gaps, uncertainties and other issues with the specification. During both the implementation and test phases there were findings that contributed into changing and updating the specification.

The most important change that was made during this project was the “Data Record Definition and Transmission of Data Record Fragments” which is the way the data is transferred from the service to the client. There were several other issues found but these were small changes and could almost be resolved immediately.

In the end, two finished and up to date implementations were made according to the specification. All the specification findings were discussed and updated in later versions of the specification. It would be smart to keep these implementations up to date as soon as the specification changes. That way it is much easier to maintain.

# Summary Dutch

-

# Abbreviations and Terminology

Table 1 Abbreviations and Terminology

|  |  |
| --- | --- |
|  | Description |
| ATT\_MTU size | The maximum amount of data possible to be send in one message this is determined in the connection phase between the Server and Client. Minimum ATT\_MTU size is 23 Bytes |
| BLE | Bluetooth Low Energy |
| Bluetooth SIG | Bluetooth Special Interest Group |
| GATT | Generic Attributes, This defines data structures which are used for BLE communication |
| GATT Characteristic | Defined attribute types that contain a single logical value |
| GATT Database | Storage point of the GATT Characteristics |
| IOP | Interoperability Test |
| OS | Operating System |
|  |  |
| PAM | Physical Activity Monitor |
| PAMP | Physical Activity Monitor Profile ( Client ) |
| PAMS | Physical Activity Monitor Service ( Server ) |
| PID | Project Initiation Document |

# Introduction

Would it not be great to use any Bluetooth device with any phone and any application without worrying about the fact that they might not work together? The answer is Interoperability.

This thesis is going to tell you how this project strives to make the part of the Physical Activity Monitor possible and interoperable. This project helps to make it possible to do this with a Physical Activity Monitor. A Physical Activity Monitor monitors all the activity of the user. This consists of things like walking activity, sleeping activity, heart rates and the intensity of these. This way the user can easily get information about his/her activity.

In this thesis, information will be given about the company, process of the project and its findings. Information about the implementation of the Physical Activity Monitor Service and Profile. Also, it will cover the interoperability tests and the findings during these tests. Specifically the specification findings. Parts that have been changed due to the interoperability tests and parts that were changed during the implementation phase.

This project was executed at the Royal Philips at the High Tech Campus in Eindhoven. At the research department of Philips. Where they are striving to standardize a communication protocol for the Physical Activity Monitor. Currently there is no such standard. This means that when you want to use a Physical Activity Monitor you are required to use the client that they provide. You are not able to switch around without needing to switch everything around. During this project two implementations will be made, a Physical Activity Monitor Service and a Physical Activity Monitor Profile. The service will be implemented on an embedded systems development board. This will imitate an actual Physical Activity Monitor. The profile will be implemented as a phone application. Both of these implementations will be made according to the most updated version of the specification. During the making of these implementations it is important to criticize the specification and search for incompleteness, gaps and flaws. The implementations also participated in interoperability tests where they were tested against implementations of independent developers.

These problems can then be resolved in a later version of the specification. When the specification is finished and approved by Bluetooth Special Interest Group it means that the communication for the Physical Activity Monitor is standardized and ready to be adopted to a 1.0 version of the specification and to be used by other companies and implementers. This project is done according to the Triangulation research method (Dunn, 2002).

In chapter 2 information can be found about the company where this project is executed, chapter 3 is about the assignment, its reasoning, goal and other details. Chapter 4 covers everything about the different researches that are executed. Chapter 5 and 6 is about the implementation of the Service and Profile, this chapter also includes all the specification specific findings that are found during the project and tests. Chapter 7 is the conclusion and some recommendations.

# The company

The company where the internship is executed is Royal Philips. More specifically Royal Philips Research at the high tech campus in Eindhoven. Philips is a Dutch technology company which headquarters currently is in Amsterdam. Philips has its focus in the area of healthcare. Gerard Philips and this father Frederik founded the company in Eindhoven in 1891.

Philips Research is a global organization with departments all over the world and the headquarters are located in Eindhoven at the High tech campus. Philips research’s mission is to “improve people’s lives through meaningful innovation”. Their vision is to strive to make the world healthier and more sustainable through innovation. Their goal is to improve the lives of 3 billion people a year by 2025. They want to improve the quality of people’s lives through technology-enabled meaningful innovations – as co-creator and strategic partner for the Philips businesses and complementary open innovation ecosystem participants.

Today, Philips is a diversified health and well-being company. The diversity is reflected in the organization, and allows them to address the challenges and needs of people in a unique way. They touch so many aspects of people’s lives that the true impact of the innovation is in the combination of the solutions

## 2.1 Organization Chart

Below you can find the organization chart of Royal Philips, the chart shows which people are involved in the project and where they are located in the Philips organization. The intern and the company supervisor work in the software concepts department.

TBD THE ACTUAL CHART.

## 2.2 Contact information

Global headquarters

Philips Research

High Tech Campus 34

5656 AE Eindhoven

The Netherlands

+31 40 27 91111

# The assignment

## 3.1 Reason

This internship is about the development of a new of a new Bluetooth Low Energy (BLE) Service & Profile specification, the Physical Activity Monitor (PAM). Javier Espina Perez will mainly write this specification. To complete the specification multiple proof of concepts, implementations of services and profiles, have to be made. These prototypes need to undergo interoperability tests (IOP) to check completeness and correctness of the specification. This specification will standardize the communication between any PAM device and her clients. This means that any monitor/service can communicate with any client.

## 3.2 Initial Situation

The initial situation consists of existing PAM’s, which are not interoperable. This means that there are many manufacturers, which develop and sell a PAM and if a user wants to use this PAM, he is required to use the included software to interpret their PAM information. This means that all users are restricted to these clients. If a user does not like the included client, he is not able to change to different client, which work in a different way since they cannot communicate with the PAM. This should not be the case. After the standardization of the PAM specification, this problem would be resolved. Meaning that any PAM can communicate with any application giving the user much more freedom in choice.

## 3.3 Goal

The objective of the project is to develop the first implementations of the upcoming Bluetooth PAM specification on an embedded system development kit (server) and Android/iOS (client). The PAMS is implemented on the server and the PAMP on the client. For each of these a proof of concept is built according to the specification. These proofs of concept will undergo IOP’s to determine the completeness and correctness of the specification to the extent that it is finished. These IOP’s will help complete the specification since any flaws or other issues will be determined during the tests. These finding will contribute to changes in a later version of the specification draft.

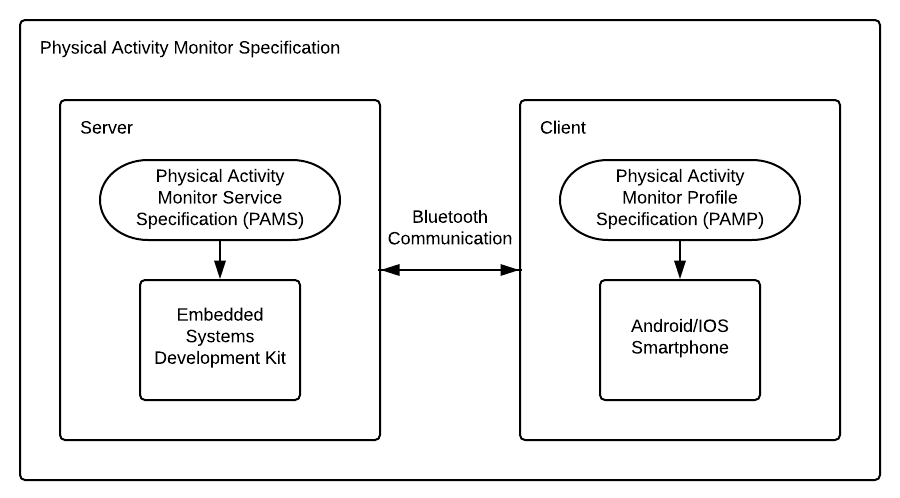


Figure Architectural Overview PAM

During the IOP’s, multiple servers and clients are tested against each other. Independent developers implement these clients and servers. The only thing these implementers will receive is the latest version of the specification and then implement their PAMS, PAMP or both without any consultation or communication between the implementers. If the specification is clear and correct these implementations should be interoperable without any modifications. The findings while testing the Physical Activity Monitor Profile (PAMP) and Physical Activity Monitor Service (PAMS) are more important than the proofs of concept itself this does not mean that the proofs of concept are allowed to be implemented sloppy. Whenever there is a fault while testing it has to be easy to find out where the problem is coming from, the proof of concept or the specification. To narrow the chance of having faults in the implementation other parties will also implement services and clients (there will be a total of 2-3 clients and 3-4 servers). Having more implementations can help determine if the problem is in the proof of concept or the specification.

The proof of concept that is implemented during this assignment will include all the parts of the specification which have to be proven and tested and will be tested with other services and clients which have to work as intended without any modification. When this is the case, we will have evidence that the specification is complete and correct, i.e. enabling independent developers to achieve implementations of the specification that are interoperable.

## 3.4 Approach of the Assignment / Strategy

During this internship, a PAMS and PAMP is implemented according to the specification. This will be done while following the Triangulation Research Method (Dunn, 2002). During these implementations the specification and correctness of it has to be taken into account. As soon as there are problems with the specification, this must be fed back to the specification developer. After the implementation has finished, it will be tested against implementations of other independent implementations. During these IOP’s the implementations will be tested. These tests will indicate if the specification is clear for everyone to understand. If this is the case, every implementation will work together without any problems. In most cases this is not the case, thus the implementers and developer of the specification can pinpoint the flaws of the specification. These flaws can vary from unclear description of a certain characteristic or procedure or gaps in functionality of the specification. Prior to this IOP, a test plan is made and the implementations will be tested according to this plan. All implementations will have to undergo and pass all the test cases described in the test plan. More information about these IOP’s will be discussed further in chapter 5 and detailed information can be found in the appendix somthingsomthing

The shortest way to describe the assignment is:

* Develop a PAMS and PAMP and determine the quality of the specification and actively participate in IOP’s

At first, the focus shall lay on the PAMS since there is a short time between the start of the implementation and the first IOP in Amsterdam. At the first IOP there will only be one other implementation, which is a PAMP so there is no need to implement our own PAMP now. This means that in the first 2 months only the PAMS will be developed.

After the IOP in Amsterdam development of the PAMP will start. There is chosen to develop the PAMP on the Android platform accompanied by the Philips Harald Library. More information and reasoning can be found in a later chapter and extensive information in appendix somthinsomthing.

Below there is a list of the deliverables during this graduation project.

**Project initiation document (PID)**

This document contains all the information about the initiation of the project the purpose of this document is to define the goal. In addition, it must serve as a basis to manage the project and to guarantee its success. During the making of the PID, several things have become clear:

1. Reason of the assignment
2. Goal of the assignment
3. Initial situation
4. Approach and Strategy
5. Project Management

**Research Document for implementation platform of the PAMS and PAMP.**

After making the PID, it has become clear that we need to research possible implementation platforms for the PAMS and PAMP. In this document is a lot of information about the possible platforms for both the implementations, the criteria the platforms had to suffice to and the platforms that have been chosen.

**PAMS implementation according to the most updated version of the specification.**

The Physical Activity Monitor Service implementation according to the updated service specification. This implementation should be flexible since the current specification is changing a lot during the project.

**PAMP implementation according to the most updated version of the specification.**

The Physical Activity Monitor Profile implementation according to the updated profile specification. This implementation should also be flexible to make changes easy and low time consuming.

**Test result document of the IOP’s which have been attended to (including found gaps and changes made during the IOP).**

Documents of the test results of the IOP done in Amsterdam and Cambridge. From these test results, we can see if the implementations are according to the specification. Here a list of finding during these IOP’s will also be given.

**A system design document with the PAMS design and PAMP design.**

Document, which shows the hardware and software, designs of the PAMP and PAMS. Which will make the transfer and understanding of the implementations easier.

**A final report of the internship (this document)**

This Document, which is a summary of the whole internship that is executed.

**Transfer the finished implementation and documents to Javier Espina Perez.**

To finalize the internship all the implementations must be transferred and delivered in a working state to the company supervisor.

# Research

The main question that must be answered is:

* To what extend is the current version of the Physical Activity Monitor Specification complete and correct?

The PAMS and PAMP must be implemented on a platform that supports BLE. Prior to the start of the implementation of these library research is done to determine a suitable platform for the PAMS and PAMS followed by a lab research. This is formulated in a sub-question:

* Which platform from the preselection is most suitable to implement a PAMS?
* Which platform from the preselection is most suitable to implement a PAMP?

More information about the “most suitable” statement and the criteria of the platforms can be found in chapter 4 or the appendix somthingsomthing .

After research has been done and several meetings are conducted there is chosen to develop an implementation for the PAMS on the Cypress PSoC 4 Bluetooth Low Energy CY8CKIT-042-BLE Board. And the client on an Android phone accompanied by the Harald library. More information and reasoning can be found in chapter 4 and extensive information in appendix somthingsomthing.

The project is ~~designed to be~~ a research project. That means that the main reason this project has to be done is to find gaps and incomplete parts of the current specification. During the implementation of both the PAMS and PAMP it is mandatory that the implementer is always looking and criticizing the specification. This way we can find gaps and other problems with the specification that then can be resolved in a later version. This part of the document is ~~not~~ about ~~the research towards the specification but~~ the research towards the platforms on which the PAMS and PAMP will be implemented. More information about the research of the specification will be discussed later in this document. For detailed information about the PAMS and PAMP Platform research, refer to appendix somthingsomthing.

## 4.1 Embedded platform research

Before the start of the implementation of the PAMS a decision needs to be made on, which platform will be used to implement the PAMS. Philips has indicated that for this case, there are four available options and thus these four options will be looked into in this part of the research.

* Nordic Semiconductor
* Cypress BLE
* ST-Development board
* Philips in-house development board

While investigating these development boards some criteria will be looked at which will determine which board is “most suitable” and will be used for the implementation.

**Availability**

Check whether the board is actually available and ready to use. First, there must be looked into the availability of the embedded boards. Before the start, information was given that some boards may or may not be available to use. The boards must be available and ready to use to participate in the research, which already made two board drop out because it was not available at the point. The boards that were dropped at this stage were the in-house Philips development board which would be available in more than 2 weeks and the ST-Development Board which had to be ordered and could take up to 3 weeks of delivery time.

**Specifications**

The specifications of the board. Things like Flash Memory, RAM Memory, Processor and Bluetooth Core Specification support. This part of the research is vital to later stages of the project. This criterion part is to prevent problems with capability in later stages of the project. Since the data, the PAMS needs to process and transfer is quite big the board must be able to store and transfer enough of data. For this criteria the Nordic board outclassed the Cypress by far.

**Easy to use / User friendly (e.g. development environment included)**

Things like included IDE, library support, implementation of new GATT databases and personal preference of the “way it works”. These criterions were chosen because they have a big influence in the project and its speed. For this criterion the Cypress board outclassed the Nordic one by far. Once the Lab-research started, it quickly became clear that the IDE for the Cypress board was much easier to use. In addition, the building of a custom GATT-Database was straightforward with a GUI that only had to be filled in. For Nordic the building of a GATT-Database had to be made in code, which made it harder, more time consuming and more vulnerable to errors and bugs.

**Support/reusability within Philips**

Are these boards used in other departments of Philips? Do they have knowledge of BLE and would they be willing to help? This would benefit the project a lot if support is nearby. Since it would be easyer to get help if there are any problems or difficulties during the implementation phase. For this criteria both of the boards are used within Philips. That means both scores are decent. But for the Cypress board there is another employee in the same office which is also working with the Cypress board (His Cypress board is using a different BLE chip but the IDE and Core specification are the same) which makes support very close and very quick which leads to a high score for the Cypress board.

Below there is a summary of the research result and it clearly shows that Cypress scored a higher overal value. This means that the cypress board is used for this project.

Table 2 PAMS Platform Research Results Overview

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Importance | Nordic | Cypress | Nordic Score | Cypress Score |
| Specifications (0-10) | 7 | 9 | 7 | 63 | 49 |
| Easy to use (0-10) | 5 | 5 | 9 | 25 | 45 |
| Support/Reusability  (0-10) | 5 | 4 | 8 | 20 | 40 |
| Total Score |  |  |  | 108 | 134 |

## 4.2 Smartphone Operating System Research

Before the start of the implementation of the PAMP a decision needs to be made on, which operating system (OS) will be used to implement the PAMP. Philips has indicated that for this case, there are two available options and thus these two options will be looked into in this part of the research.

* Apple IOS
* Android OS

While investigating these OS some criteria will be looked at which will determine which OS is “most suitable” and will be used for the implementation. For the implementation of the PAMP it is much less important which OS will be used. Both of the OS are capable of supporting BLE and both have enough specifications to make this a non-factor in this research. During this research there was another intern who was working with the Android Harald Library which is a library made by Philips to support BLE and its services. Making it very easy to implement new Profiles. After talking to this intern and he showed how the Harald lib worked it became clear very quick that this library was super easy to use and extend. This library is available on both Apple IOS and Android OS. Before the research starts it is already known that in each case the Harald Library will be used for the PAMP.

**Availability**

Check whether the necessities of each OS are available and ready to use. For IOS this means that a couple of thing have to be available such as:

* MacBook / iMac / Mac Mini (for the IDE of IOS, Xcode)
* iPhone 5s (5s currently is the lowest supported device by Apple)
* Developer Account (Mandatory to build apps)

For android, it is also needed to have the necessities available such as:

* Computer that can run Android Studio (Windows)
* Android Phone (Preferably with a recent version of android 7.0 or higher)

Here it would be a lot easier to use Android since it is possible to implement this on the same computer where the PAMS is being implemented which means that there is no need to get another computer.

**Support/reusability within Philips**

For this project the support part is the biggest criteria since there is next to none experience with app development both for IOS and Android. Support is defenetly going to be needed when implementing the PAMP on one of these OS. Also the company supervisor has stated that he highly prefers the Android platform to implement the PAMP since he will not need to bring an extra macbook and iPhone to the IOP but can use his own working laptop and working phone.Therefore, for this criterion the Android outclassed the IOS.

**Easy To Use**

Things like IDE, library support, preference of the “way it works”. These criterions were chosen because they have a big influence in the project and its speed. Since it is already decided that the Harald library is going to be used it is important to know what the differences are of the library on both of the OS. For the IOS version of the Harald library, it means that it is mostly written in Objective-C, which is the old and unsupported programming language of Apple IOS. The Harald Library on the Android side is written in Java, which is a well-supported programming language. After the laboratory research, it was similar to add new services to each library. Objective-C uses “Small talk” in their programming language, which was very difficult to understand and write.

Below there is a summary of the research result and it clearly shows that Harald Library for Android scored a much higher overal value. This means that the Harald Library for Android is used for this project.

Table 3 PAMP Operating System Research Overview

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Importance | Harald IOS | Harald Android | Harald IOS Score | Harald Android Score |
| Availability (0-10) | 7 | 6 | 9 | 42 | 63 |
| Support/Reusability  (0-10) | 6 | 5 | 9 | 30 | 54 |
| Easy to use (0-10) | 8 | 3 | 8 | 24 | 64 |
| Total Score |  |  |  | 96 | 181 |

# Physical Activity Monitor Service

As stated before we started with implementing the PAMS in the first 2 months and decided to come back to the PAMP later. During this implementation, it is our goal to:

1. Implement a working PAMS according to the specification
2. Find flaws and gaps in the current version of the specification

The Bluetooth specification development process explained summarized for **new** specifications:

1. NWP (New Work Proposal): idea for a new profile or specification approved
2. FRD (Functional Requirements Document): functional requirements, problem statement and scope of work approved
3. D05 (Draft 0.5): design work starts, behaviors and coverage of requirements in the FRD are defined.
4. D07 (Draft 0.7): lock down of all mandatory/optional features per the functional requirements while following IEEE established language conventions.
5. D09 (Draft 0.9): the specification is 100% complete and goes through the final plan and adoption schedule.
6. PS (Prototyping spec): This stage begins the Specification Validation (IOP)
7. Formal IOP Testing
8. Final Adoption: Version 1.0 of the new spec.

As you can see, informal IOP testing is not a mandatory part of the process. However, it is very common (and good) practice to start early with implementations and testing.

The first PAMS Specification version, which was received, was D05\_R00.

This version was used to build the first implementation of the PAMS and this was also used in the IOP in Amsterdam.

## 5.1 Informal IOP Amsterdam

The IOP in Amsterdam took place on Dec 5-6, 2017 at the Royal Philips, Amstelplein 2, 1096BC Amsterdam (a.k.a. Breitnertower). During this IOP version D05\_R00 was tested against a Client made by Leif-Alexandre Aschehoug from Nordic Semiconductor ASA.

This document will only describe the problems that were found during the IOP. For information about the IOP, testcases that were run and results of the test cases, please refer to appendix somthingsomthing.

### 5.1.1 Specification specific issues

1. A problem with the Data Record Definition and Transmission of Data Record Fragments.

This means that the explanation in the specification was not clear on the fragmentation of the data.

*Note: The size of a Data Record may exceed the maximum that may be send in a single Handle Value Notification or Indication defined in the Attribute Protocol Specification. The service therefore defines a mechanism for fragmentation of the Data Records into smaller characteristic values so that these may then be notified or indicated sequentially, using a stream of notifications or indications of the data characteristics.*

Currently there was missing test that should state that not every data fragment should repeat the mandatory fields of the characteristic and the way of fragmenting the data was not going right because of the possibility of missing notifications.

The solution that was brought up was: Use one byte as Header, which will be repeated in every data fragment message. This header will define if the message is the first message and the amount of messages remaining.

1. The current session descriptor exceeds the ATT\_MTU-3 Size with 1 byte which is not allowed

The minimum ATT\_MTU size is 23 and the first three octets are reserved for Bluetooth core specification information, which means that there are 20 octets left for data usage. In the current session, no fragmentation thus the length of this characteristic should be shortened by 1 byte. This was done by changing the timestamp in the characteristic.

### 5.1.2 Implementation specific issues

During the IOP in Amsterdam some implementation specific issues were found

1. Endianness of the data

In the implementation, the endianness of the data characteristics and its fields were in BIG ENDIAN when they should be in LITTLE ENDIAN. This means that all the data in the server implementation was mirrored.

In the end, this was an easy fix by mirroring the data and took relatively short time.

1. Removal of non-present fields

Because of the short time this was not done in the implementation, but the data which is actually transferred to the client should be depending on the “Present data flags field” this means that if a field is not present it should not be send to the client.

This was fixed by adding a check for the Present data flags field before adding the specific field to the data that has to be send to the client.

## 5.2 Informal IOP Cambridge

The IOP in Cambridge took place on Mar 11-13, 2018 at the Qualcomm Technology International, Cowley Rd, CB4 0WZ Cambridge. During this IOP version D05\_R06 was tested against a Client made by Leif-Alexandre Aschehoug from Nordic Semiconductor ASA.

This document will only describe the problems that were found during the IOP. For information about the IOP, test cases that were run and results of the test cases, please refer to appendix somthingsomthing.

### 5.2.1 Specification Specific Issues

1. Missing Application Error Code Telling the client that there are “No Sessions Available”.

There was no error code for “No Sessions Available” which led to using a success response because the operation was accepted but there was no result to be send back to the client.

Adding a “No Sessions Available” error code resolved this problem.

1. Missing a way to set the mandatory field “Average Activity Type” in the summary data characteristics
2. “Predominant Activity Type” field, present in “Current Session” and “Session Descriptor” not writable by client and a data characteristic should not be **directly** writable by the client (this will introduce race conditions if a write happens at the same time as a read procedure)

To make sure there are no race conditions in the specification, which would lead to unexpected behavior this field, must be removed from the “Current Session” and “Session Descriptor” characteristics and a new control point procedure, is introduced to write the “Average Activity Type” data fields in the summary characteristics.

1. Missing Success responses for Control point Procedures

There is no way for the client to know if the control point procedure has been successfully executed or failed.

Success code responses are added to the control point to be indicated to the client.

### 5.2.2 Implementation Specific Issues

1. In the control point “Stop Session” procedure, make sure you also stop the running sub-session.

Forgot to call method *“*stop\_sub\_session(PAM\_SESSIONDESCRIPTOR\_VALUE\_T \*p, uint16\* totalcount)*”* which lead to never stopping the sub session.

Added the method call to resolve this problem.

1. Swap session ID 0001 to 0100 for get ended session data

As stated before the cypress uses LITTLE ENDIAN, which means that the lowest significant byte shall be transferred first. In the server implementation, the first byte was read as the most significant bit with resulted in interpreting the write requests from the client in a wrong way. Example:

Client requested “Enquire Sub Sessions” with parameter “Session ID = 1” which results in a write command of “03 01 00” to the control point. The server implementation read this command as “Enquire Sub Sessions” with “Session ID = 255”. The solution was very simple. The reading of the array fields were swapped around and problem was solved.

1. Error message 86 to 87 for stop session

Responding with the wrong error. Changing the error code, this was solved.

## 5.3 Overview of specification issues found during implementation

Table 4 Overview of PAMS specification issues

|  |  |  |
| --- | --- | --- |
| Version | Issues | Solution |
| D05\_R00 | No issues found |  |
| D05\_R01 | 1. Not clear what “Data Characteristic” meant and that it is different from other Characteristics like the Control point 2. Very unclear description of the transmission of data record fragments | 1. Clarified this in the specification. 2. This was also mentioned in the IOP and a whole new chapter was added to clarify this procedure. |
| D05\_R02 | 1. The Transmission of data record fragments was very complicated when it could be much easier. | 1. A new transfer method for data record fragments was made. |
| D05\_R03 | 1. Minor mistake in specification stating that the size of certain data characteristics were larger than they actually were. 2. Control point procedures unclear of what they should do. | 1. Changed size in the description 2. Changed control point procedure with clarifying text. |
| D05\_R04 | No issues found |  |
| D05\_R05 | In section 4.9.3.2.4 it says:  “The Unsupported Data Characteristic error response shall be sent in response to a *Get Ended Session Data* procedure request if the Data Characteristic parameter value received refers to a characteristic that is not supported by the Server (as specified by the Physical Activity Monitor Features characteristic).”  The feature list does not specify if a full characteristic is supported only if certain fields from this characteristic are supported. | Changed the text to:  “No Data Available  The No Data Available error response shall be sent in response to a Get Ended Session Data procedure request if no data is available that matches the parameter values” |
| D05\_R06 | Issues described in the Cambridge IOP chapter |  |
| D05\_R07 | None found so far |  |

# Physical Activity Monitor Profile

As stated before we started with implementing the PAMP later in the internship process with this implementation, it is our goal to:

1. Implement a working PAMP according to the specification
2. Find flaws and gaps in the current version of the specification

The first PAMP Specification version, which was received, was D05\_R03.

The version that was used to build the first implementation of the PAMP was D05\_R04.

This chapter does not include the IOP Amsterdam because there was no profile implementation to be tested at this IOP. Due to limited time at the start of the implementation phase, it was chosen to focus on a working server for this IOP.

The PAMP Specification contains much more information about other profile requirements and only consists of a small part of the actual PAM specification. This means that there are a lot less changes, difficulties and gaps to be found in the PAMP specification. The PAMP specification contains information about other services, which the PAMP should include, and how they should work together. You can say that it is possible to implement a PAMS with only the PAMS Specification but it is impossible to implement a PAMP with only the PAMP Specification because all the details are in the PAMS. This means that changes in the PAMS specification, which are discussed in the previous chapter, also influence the PAMP implementation.

## 6.1 IOP Cambridge

During the IOP in Cambridge, a working implementation for the PAMP was available. This implementation was not completely finished but it should be able to pass most of the test cases described for this IOP. More info about the IOP Test cases in Cambridge can be found in the appendix .

Unfortunately there was no other company/party which had a working PAMS implementation that we could test against. Therefore, the only tests we could do were with our own PAMS implementation, which lead to passing of the implemented features but did not show any issues with the specification. Because we tested with our own PAMS it very well could mean that, the implementation of the PAMP is also right and working but there is no way to know this for sure. This will be tested in the next IOP where it will be tested against a PAMS. This will be done outside of the internship period.

Most of the changes and issues found in the PAMS Specification during this IOP had a small influence on the PAMP Specification below there is an overview of these specification issues and changes.

Table 5 PAMP Specification issues and changes

|  |  |  |
| --- | --- | --- |
| Version | Issues | Solution |
| D05\_R03 | Not used for any implementation |  |
| D05\_R04 | No PAMP specific issues found only changes in the PAMS that influence the PAMP |  |
| D05\_R05 | No PAMP specific issues found only changes in the PAMS that influence the PAMP |  |
| D05\_R06 | No issues found yet |  |

# Conclusion and Recommendations

During this project a Physical Activity Monitor Service and Profile is implemented. All of the gaps, problems and findings are included and changed in updated versions of the specification. This project vastly contributed to the development of the specification and helped in its progression towards the draft version 7 where it can start locking down all the mandatory and optional features per the functional requirements following the IEEE established language conventions.

The implementation of the Service and Profile are successful and up to date with the latest draft version of the specification. This means that the implementation phase was a success. All the problems that were found in draft version 5, which was used during this project, were discussed and changed to make the specification more mature. The interoperability tests were a big part of these findings. The implementations participated in two interoperability tests where they were tested against different implementations. These tests contributed a lot to determine problems with the specification at that time.

As a whole, the project can be considered as successful since the goal of the project was met. There are quite a few changes that were made to the specification due to this project. These gaps in the specification might have not been found if this project was not executed.

In the end, it would be smart to keep the implementations up to date as the specification keeps updating. This way the implementations will keep providing information about the specification and will help find problems with further version of the specification.

The Cypress development board performed very well for this implementation and is recommended to use for other custom BLE implementations.

# Evaluation

During this project, I got to work with the people of Philips. Since Philips was not my first choice to execute my internship, I was skeptical at first. However, as the project went on these thoughts were erased. The project was much more challenging than I thought at first. There were many parts during the project that had to be taken into account. Such as never ending changes in the specification, which then had to be implemented into the Service and Profile. In the start-up phase of the project process was quite slow since I had troubles with understanding the way the Bluetooth core specification works and how to use it. In addition, the English language was quite a challenge in the beginning. Talking normal English is quite easy but I struggled with the technical terms, which are used much more in this kind of project. I think I learned many things during this project such as talking technical English, which will help me in the future. In addition, working with the Bluetooth Core specification made me understand the way Bluetooth actually works. Working in a big company with many employees was a new experience for me. It was quite useful to have many other people around, this way it is much easier to ask people for help and their insight into problems that were encountered.

During the internship I tried to work on working structured and methodically this was done because normally I am a mess at knowing what to do and when to do it. This was achieved by making a log, which keeps track of the work that has been done on each day. In addition, I tried to save files and project with good names in the right locations so that I know what to find where without losing a lot of time searching for the correct documents.

I also tried working on justification of choices that I made. This was very important for me since normally I am quite uncertain about my choices and I ask many questions. I did this by looking for multiple solutions for problems and then determine which one is the best solution for the problem. By looking at pro’s and con’s. By doing this I will get more self-knowledge and this helps me to make arguments and be more confident in the decisions.

When I started implementing the service, I did not really consider the amount of changes that I would get with each update of the specification. I did not consider this when implementing the first service version. This lead to wasting a lot of time implementing the changes. After I noticed that this was costing me so much time I reconsidered the structure of the implementation and made chances that were aimed at reducing the time it would cost to change the implementation.

During the project, I used C and C++ for the implementation of the service and Java for the implementation of the profile. It was nice to refresh my memory with pointers and the way they work. Pointers were always a very confusing concept for me to understand and I feel like for the first time I really understand how they work now. This was the first time I used Java, it felt like it was very similar to C# which is my favorite programming language which meant I really enjoyed learning Java and building the phone application.

# References

Dunn, R. S. (2002). *An Examination of Online Qualitative Research Methods.* Liberty University.

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