iWRAP – HEALTH DEVICE PROFILE

APPLICATION NOTE

Monday, 29 June 2009

Version 1.3

VERSION HISTORY

Version	Comment
1.0	First version
1.1	IEEE 11073 chapter added
1.2	iWRAP section added
1.3	Chapter 5 finalized

TABLE OF CONTENTS

1 Introduction

This application note discusses Bluetooth Health Device Profile (HDP), describes its advantages and how it can be utilized. Also practical examples are given how the HDP is used with the iWRAP firmware.

1.1 Background

Bluetooth is used in a variety of medical applications as a secure and reliable connection method. Typically the implementations have been based on Bluetooth Serial Port Profile (SPP) and manufacturer specific proprietary implementations and protocols. Therefore different implementations have had a poor level of interoperability with each other.

For this reason the Bluetooth SIG formed the Medical Device Working Group (MED WG) and set a goal to develop a profile that would introduce interoperability between different medical sensors (sources) and collecting devices (sinks) from different manufacturers. The work resulted Multi-channel Adaptation Protocol (MCAP) and the Bluetooth Health Device Profile (HDP), which were adopted during 2008.

The application level interoperability is provided by ISO/IEEE 11073-20601 Personal Health Data Exchange Protocol and IEEE 11073-104xx device specializations.

1.2 Use cases

HDP is mainly targeted to supporting variety of in-home or in-hospital applications. The most typical use cases are different portable sensors like ECG transmitters, blood glucose level meters or blood pressure meters that transmit the measurements in the hospital to a monitoring PC. In an in-home application the measurements the from sensors could be transmitted to a gateway device that forwards the information to remote servers for further processing.

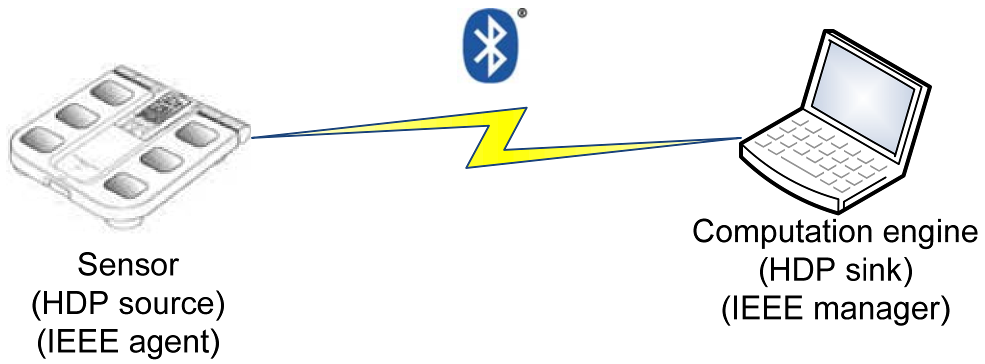

Figure 1: Use case 1

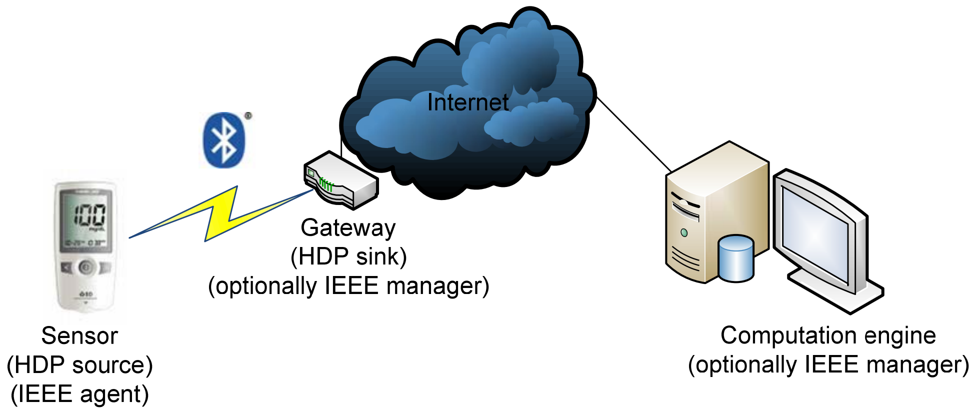

Figure 2: Use case 2

1.3 Advantages of HDP

Medical, Healthcare and Fitness Applicability

HDP is a specialized profile designed to allow for interoperability between medical, healthcare and fitness applications from different vendors. This gives HDP a significant advantage over more generic profiles like Serial Port Profile, or others that only provide a base layer for proprietary protocols and data formats.

Wireless Service Discovery

HDP provides a standard wireless discovery method where a device's device-type and supported application data-type is determined. This discovery occurs by using the Generic Access Profile (GAP) discovery procedures and the Service Discovery Protocol (SDP).

Reliable Connection-oriented behavior

HDP uses the connection oriented capability of the Bluetooth lower layers to ensure more reliable behavior when a *Source* moves out of range or disconnects (either inadvertently or intentionally). This allows both *Source* and *Sink* to recognize that the link has been broken, and to take appropriate actions.

Additionally, the Reliable Data Channel deals with the detection and retransmission of packets corrupted by interference on the radio link. The Frame Check Sequence (FCS), which is optional for L2CAP, is particularly important when operating with high interference levels such as being near Wi-Fi or other ISM band devices.

Reliable Control Channel

The HDP Control Channel uses Enhanced Retransmission Mode for improved reliability desired for signaling commands.

Support for Flexible Data Channel configurations

HDP Data Channels allow for independent configuration as this provides flexibility to the applications. Data Channels configured as 'reliable' use Enhanced Retransmission Mode, while data channels configured as 'streaming' use Streaming Mode. The use of FCS is optional for Data Channels and mandatory for the Control Channel.

Application-level Interoperability

HDP, along with the ISO/IEEE 11073-20601 Optimized Exchange Protocol, provides a structured approach for the establishment of Control and Data Channels to allow for information exchange between the communicating health devices. As device specializations are added in ISO/IEEE 11073-104XX and adopted by the MED WG, the Bluetooth Assigned Numbers document allow for the addition of the adopted specializations without having to update the HDP specifications..

Efficient Reconnection mechanism

HDP allows devices to retain the state of the system and eliminates redundant configuration steps upon reconnection. This procedure allows devices to disconnect while there is no receiving or transmitting of data, and then reconnect as data becomes available. This method reduces average power consumption.

High resolution clock synchronization

HDP also defines an optional Clock Synchronization Protocol (CSP) that allows for precise timing synchronization (note: theoretically in the microsecond range) between health devices. This feature is for health devices, such as high-speed sensors, that require close synchronization.

Optimized for devices with low resources

HDP has a small set of simple control commands and makes it relatively inexpensive to implement. It is also possible for devices to support an even smaller subset of the available commands depending on the role of the device and individual application requirements. This is helpful for product requirements defining limited code and memory space.

Source: [1]

2 IEEE 11073-20601 Specification

The IEEE 11073-20601 Optimized Exchange Protocol provides a framework of object-oriented information modeling, information access and measurement data transfer suitable to a wide variety of personal health devices. Examples of such health devices are as follows: weight scales, thermometers, pulse oximeters, blood pressure monitors, and glucose meters. On addition the protocol is designed to support a range of home health sensors. The goal of IEEE 11072-20601 is to enable interoperability between sensors and data management devices to process, display or transfer the specific measurements. IEEE 11073-20601 protocol is designed for use with transports such as Bluetooth and USB.

The ISO/IEEE 11073 specifications contains the 20601 Core protocol specification describing the tools to represent and convey data and a set of Device Data Specializations, which contains details how 20601 is applied to a specific health device. At the time of writing this document the following Device Data Specializations existed:

- IEEE 11073-10404 – Pulse Oximeter
- IEEE 11073-10407 – Blood Pressure Monitor
- IEEE 11073-10408 - Thermometer
- IEEE 11073-10415 – Weighing Scale
- IEEE 11073-10417 – Glucose Meter

Source: [1]

Data exchange specification	Document number	Document name
0x01	ISO/IEEE 11073-20601	Health informatics - Personal health device communication - Application profile - Optimized exchange protocol

Table 1: Data exchange specifications

Note: All other values reserved

Data type	MDEP Data type	IEEE 11073	IEEE 11073 Document name
Pulse oximeter	0x1004 (4100 decimal)	11073-10404	Health informatics - Personal health device communication - Device specialization - Pulse oximeter
Blood pressure monitor	0x1007 (4103 decimal)	11073-10407	Health informatics - Personal health device communication - Device specialization - Blood pressure monitor
Body thermometer	0x1008 (4104 decimal)	11073-10408	Health informatics - Personal health device communication - Device specialization - Thermometer
Body weight scale	0x100F (4111 decimal)	11073-10415	Health informatics - Personal health device communication - Device specialization - Weighing scale

Glucose meter	0x1011 (4113 decimal)	11073-10417	Health informatics - Personal health device communication - Device Specialization - Glucose meter

Table 2: HDP device data specializations

Note: All other values reserved.

Reference: [2]

3 Transfer of Measurement Data over HDP

Before describing the steps involved in conveying measurement data, the terminology used requires some definition. HDP defines a Source to be a transmitter of medical application data, and 20601 uses the term Agent for the node that transmits personal health data. Similarly, HDP's notion of a Sink is essentially that of the 20601 Manager. When discussing about HDP terms source and sink are used and when discussing about 20601 Agent and Manager are used.

Some more detailed introduction to HDP is also needed. HDP provides two types of connections:

- Control channels - This is used to negotiate data channel parameters, and setting up the data channel(s).
- Data channels – Data channels are used for the actual data 11073-xxxxx) transmission. Two types of data channels exists:
    1. Reliable data channels
    2. Streaming data channels

Either a Source or a Sink may initiate a connection by first establishing a control channel. After the control channel is established, it is used to negotiate and establish one or more data channels. As said earlier two types of data channels can be set up: reliable and streaming data channels. Reliable data channels are appropriate for transmitting measurement or alert information where the confidence in the exchange is at its highest and streaming data channels are useful when the timeliness is a higher priority than the reliable delivery of every frame so for example when sending wave form data where small data losses can occasionally occur.

Once the MCAP Data Link (MDL) has been established, a connection indication is sent to the 11073-20601 application layer. This initiates a series of transactions defined by connection state machines within the Agent and Manager. The first step involves the Agent sending an Association Request message, which includes a high-level description of itself to the Manager.

If the Manager does not wish to communicate with the Agent, it will reply with an Association Response message with a rejection status code. On the other hand, if the Manager deems it appropriate to continue the Association, it will respond in one of two ways.

1. If the Manager has previously communicated with this device, or it has been programmed to understand the collection of objects, attributes and data transmission details (e.g. "standard configuration"), then the Manager will respond by accepting the association, at which point the Agent and Manager are considered to be in the Operating state.
2. If the Manager is not familiar with enough details of the Agent's implementation, then the Manager will accept the association, but will ask that the Agent describe its implementation by means of a Configuration process.

Note: The association traffic is on the first Reliable Data Channel (per MCL) and each MCL must have its own "first Reliable Data Channel" for its association traffic. Recommended but not required, the confirmed event traffic should be on the first Reliable Data Channel as well. For multiple device specializations when supported by a device, it is also recommended to associate to them at the same time as opposed to sequentially as if they are physically separate devices.

The Operating state is where measurement data transfer may occur. This transfer occurs through a number of methods, each of which may be suitable for a different style of communication.

Either the Manager or Agent may initiate data transfer. If the Manager initiates data transfer, then it may do so by:

1. Asking the Agent for a single measurement, if available, or
2. Telling the Agent that it may transfer data for a fixed period of time, or
3. Controlling the Agent's transmission of data using explicit Start and Stop commands.

When either the Agent or the Manager terminates an association, it may do so by issuing an Association Release Request. The device on the other end of the link responds with an Association Release Response. At this point, the 20601 layer informs HDP to disconnect the communications link. Another means of terminating an association, not shown here, is by means of an Association Abort. There is no required response from such a transmission.

The 20601 protocol intends for asymmetric device architectures. Agents, by design, intend to measure health data. Their function is not to be a data processor, network device or timekeeper. Computation complexity transfers to the Manager whenever possible. This allows Agents to be small, inexpensive and simple.

Agents typically do not intend to communicate with each other, but rather each Agent communicates with a single Manager. The Manager communicates with multiple Agents and coordinates activities as in cases where the Manager coordinates precise measurement of physiological phenomena detected by distinct Agents.

The 20601 protocol provides a number of facilities to transfer a combination of discrete numeric data, sampled waveform data as well as the ability for the Agent to store data that had been collected over a long period of time and forward that information when requested by the Manager.

A Scanner data construct is able to collect discrete Numeric and waveform data objects and combine them into a single packet for transmission. This allows efficient transmission of Streaming data, since the overhead of support information accompanying multiple data objects reduces by only sending the support information of a single packet.

In several use cases, such as sleep studies, it may be more practical to defer transmitting measurements for several hours, or until several sessions' worth of data have been collected. In order to accommodate the needs of such use cases, 20601 defines models to store, describe the structure of, and transfer data.

HDP and 20601 can support Agents providing multiple types of measurements (i.e. pulse oximeters and blood pressure monitors), because constructs within the data exchange layer allow the description of multiple Device Specializations. Since HDP provides for the establishment of multiple data channels, it is possible to transfer each function's measurements across a dedicated data channel. It would also be possible to partition the channels so that the Agent could transfer the discrete numeric data from all functional units across a reliable data channel, and transfer all waveform data across the streaming data channels.

Source: [1]

4 HDP in iWRAP

The HDP implementation in the iWRAP firmware is illustrated in the Figure 3. iWRAP as seen in the picture implements the HDP source and HDP sink modes. However at the time of writing this document the IEEE Agent and Manager implementations are left to the host's responsibility.

The HDP profile is controlled by the host via one or several of iWRAP interfaces. At the moment the main data and command interface is UART, but some commands and events can also be invoked via GPIO pins.

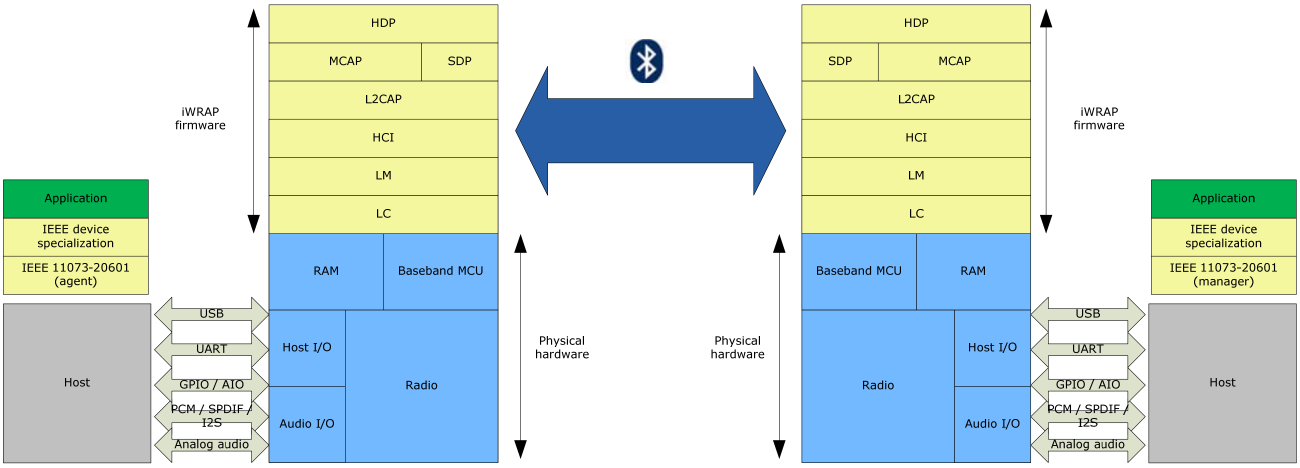

Figure 3: iWRAP HDP architecture

4.1 Multi profile operation

iWRAP supports multi profile operation with HDP. This means on addition to HDP also other types of Bluetooth connections can be established as well. This can include for example Bluetooth Serial Port Profile (SPP), Hands-Free Profile (HFP) or Dial-Up Networking (DUN). At the moment iWRAP supports the following Bluetooth profiles:

- Serial Port Profile (SPP) / DevA and DevB
- Hands-Free Profile (HFP) v.1.5 / HFP and HFP-AG modes
- Headset Profile (HSP) v.1.2 / HSP and HSP-AG modes
- Dial-up Networking Profile (DUN) / Terminal emulation
- OBEX Object Push Profile (OPP) / OPP Server and Client
- OBEX File Transfer Profile (FTP) / FTP Client
- Phone Book Access Profile (PBAP) / PCE mode
- Human Interface Device (HID) / HID device
- Advanced Audio Distribution Profile (A2DP) / Sink and Source modes
- A/V Remote Control Profile (AVRCP) / AVRCP Controller and Target
- Device Identification Profile (DI)
- Health Device Profile (HDP) v1.0 / Source and Sink modes

5 Using HDP with iWRAP

This chapter instructs the HDP usage and configuration with the iWRAP firmware.

5.1 Configuration

5.1.1 HDP Sink

HDP sink is enabled with command “**SET PROFILE HDP SINK {*mdep_data_type*} {*service_name*}**”

mdep_data_type	This parameter configures the MDEP data type i.e. the device type that one wants to implement. See table 2 for possible values.
service_name	This parameter configures user friendly description of the device. Neither special characters nor white spaces are allowed.

HDP profile requires that the IEEE data is encapsulated into a single Bluetooth packet. Therefore with iWRAP the MUX mode must be used. The MUX mode is enabled with command: “**SET CONTROL MUX 1**”

Finally a reset is needed to for the HDP profile to become active.

Below is an example how to enable HDP sink mode (Blood Pressure monitor) and iWRAP MUX mode.

SET PROFILE HDP SINK 1007 BluegigaManager	
SET CONTROL MUX 1	
¿READY.	(READY encapsulated into a MUX frame)
RESET	(Must be sent using the MUX protocol)

5.1.2 HDP Source

HDP source is enabled with command "**SET PROFILE HDP SOURCE {*mdep_data_type*} {*service_name* }**"

mdep_data_type	This parameter configures the MDEP data type i.e. the device type that one wants to implement. See table 2 for possible values.
service_name	This parameter configures user friendly description of the device. Neither special characters nor white spaces are allowed.

HDP profile requires that the IEEE data is encapsulated into a single Bluetooth packet. Therefore with iWRAP the MUX mode must be used. The MUX mode is enabled with command: "**SET CONTROL MUX 1**"

Finally a reset is needed to for the HDP profile to become active.

Below is an example how to enable HDP source mode (Blood Pressure monitor) and iWRAP MUX mode.

```
SET PROFILE HDP SOURCE 1007 BluegigaBPM
SET CONTROL MUX 1
¿READY.     (READY encapsulated into a MUX frame)
RESET       (Must be sent using the MUX protocol)
```

5.2 Service discovery

Bluetooth Health Device Profile enable wireless service discovery, so you can find out the capabilities the remote device supports. Wireless service discovery uses the Bluetooth Service Discovery Profile (SDP).

With iWRAP the service discovery is performed with command: "**SDP {*bd_addr*} {*uuid*} ALL**".

bd_addr	Bluetooth device address of the remote device.
uuid	Universally unique identifier. Refers to the Bluetooth profile one wants to discover. For generic Health Device Profile the UUID is 1400. For HDP source UUID is 1401 and for HDP sink it's 1402.

Below is an example how to perform a service discovery from HDP source to HDP sink using the generic HDP UUID.

SDP 00:07:80:81:66:8c 1400 ALL

SDP 00:07:80:81:66:8c < I 0 I 10000 > < I 1 < U 1402 > > < I PROTOCOLDESCRIPTORLIST < < U L2CAP I **1001** > < U 001e I 100 > > > < I 9 < < U 1400 I 100 > > > < I d < < < U L2CAP I **1003** > < U 001f > > > > < I 200 < < I **01** I **1007** I 01 > > > < I 301 I 01 > < I 302 I 00 > < I 6 < I 656e I 6a I 100 > > < I SERVICENAME S "**BluegigaManager**" >

SDP

1001	= L2CAP psm for HDP control channel
1003	= L2CAP psm for HDP data channel
01	**=** MDEP ID
1007	= MDEP data type
BluegigaManager	= Service name

Below is an example how to open a control channel from HDP sink to HDP source using the generic HDP UUID.

SDP 00:07:80:89:a4:85 1400

SDP 00:07:80:89:a4:85 < I SERVICENAME S "BluegigaBPM" > < I PROTOCOLDESCRIPTORLIST < < U L2CAP I 1001 > < U 001e I 100 > > >

SDP

5.3 Connection establishment

5.3.1 MCAP Communications Link (MCL) creation

With HDP, first a control channel needs to be established. The control channel is used for various signalling between the HDP sink and HDP source. Such signalling can for example be data channel creation or termination.

The HDP control channel is opened, typical to iWRAP, with a **CALL** command:

"**CALL {*bd_addr*} {psm} HDP FLOW 803**".

bd_addr	Bluetooth device address of the remote device.
psm	L2CAP psm. Gor HDP this is always 1001.
uuid	Universally unique identifier. Refers to the Bluetooth profile one wants to discover. For generic Health Device Profile the UUID is 1400.
FLOW 803	This configuration defines that Enhanced Retransmission Mode is used for the connection.

Below is an example how to set up a HDP connection from HDP source to HDP sink.

```
CALL 00:07:80:81:66:8c 1001 HDP FLOW 803
CALL 0
CONNECT 0 HDP 4097
```

In a similar fashion the connection can be established from HDP sink to HDP source.

```
CALL 00:07:80:89:a4:85 1001 HDP FLOW 803
CALL 0
CONNECT 0 HDP 4097
```

5.3.2 MCAP Data Link (MDL) creation

Once the MCL has been set up one data channes can be created.

In iWRAP a MDL is created with command: "**HDP CREATE {*mdl*} {*mdep*} {*config*} {*psm*}"**

mdl	An MCAP Data Link ID. Can be anything.
mdep	An MCAP Data End Point (MDEP) ID. Use the MDEP ID found out with SDP. For a generic echo channel use 0.
config	Configuration value. 1 = Reliable connection / data channel, 0 = streaming channel (not supported at the moment).
psm	L2CAP psm for the MDL. Use the L2CAP psm for the data channel found out with SDP.

Here's an example how to set up a single MDL with L2CAP psm 1003. iWRAP automatically opens a 2nd L2CAP connection for the MDL as is seen from the **CONNECT** event.

```
HDP create 1 1 1 1003
HDP 0 MDL 0001 config 1
CONNECT 1 HDP 4099
```

List command can be used to verify that both MCL and MDL exist

```
LIST
LIST 2
LIST 0 CONNECTED L2CAP 320 0 0 904 0 0 00:07:80:81:66:8c 4097 INCOMING ACTIVE SLAVE ENCRYPTED 0 ERETX
LIST 1 CONNECTED L2CAP 672 0 0 4 0 0 00:07:80:81:66:8c 4099 OUTGOING ACTIVE SLAVE ENCRYPTED 0 ERETX
```

5.3.3 MCAP Data Link (MDL) termination

MDL can be terminated at any point, with iWRAP command: "**HDP DELETE {*mdl_id*}"**

mdl_id MDL ID of the data channel to terminate.

Termination of MDL

```
HDP DELETE 1
HDP 0 DELETE 0001
NO CARRIER 1 ERROR 0
LIST
LIST 1
```

```
LIST 0 CONNECTED L2CAP 320 0 0 1050 0 0 00:07:80:81:66:8c 4097 INCOMING ACTIVE SLAVE ENCRYPTED 0 ERETX
```

5.3.4 MCAP Communications Link (MCL) termination

The MCL can simply be closed with iWRAP command "**CLOSE {*link_id*}**"

link_id	Link ID of MCL connection

MCL connection termination

CLOSE 0

NO CARRIER 0 ERROR 0

5.4 Data transfer

Once both MCL and MDL have been set up data transfer can be made. The MDL is a transparent data link between the HDP source and HDP sink, very similar to Bluetooth Serial Port Profile. However the Bluetooth Health Device Profile mandates that the communications is made using the IEEE 11073-xxxxx protocols.

A few points should be noted:

- Data transmission needs to be done using the iWRAPs MUX mode, because:
  - HDP profile mandates that a single IEEE frame is fitted into a single Bluetooth packet
  - If MUX mode is not used iWRAP can not packetize IEEE frames into a single Bluetooth packet
- At the moment iWRAP does NOT implement any of the IEEE protocols, but they must be implemented by the host system.

6 IEEE agent & manager reference implementation

TBD

7 Terminology

This section describes the terminologies used to describe the profile.

Initiator / Acceptor

The device that initiates the Control Channel connection becomes the “Initiator” of the connection. The device addressed in a Control Channel connection request is the “Acceptor” of the connection.

Control Channel / Data Channel

The first L2CAP channel established between two implementations of MCAP is the “Control Channel”. This channel facilitates the creation of “Data Channels,” through which actual health device data, which the Optimized Exchange Protocol and Device Specializations define, is exchanged.

Streaming and Reliable Data Channels

Two fundamental types of Data Channels exist in HDP: Reliable Data Channels and Streaming Data Channels. Reliable Data Channels are appropriate for transmitting measurement or alert information where the confidence in the exchange is at its highest (e.g. store and forward measurement). Streaming Data Channels are useful when the timeliness of the delivery of each frame is more important than the reliable delivery of every frame (e.g. an ECG waveform, where the low latency is critical). Support for Reliable Data Channels is mandatory for all *Sources* and *Sinks*, while support for Streaming Data Channels is mandatory for all *Sinks* in order to support *Sources* that may request it.

MCAP Data End Point (MDEP)

An MCAP Data End Point (MDEP) represents one logical function, i.e. one "feature", of a device. Each MDEP is described by a set of parameters and includes the following: MDEP ID, MDEP Role (*Source*/*Sink*), MDEP Data Type (Device Specialization), and MDEP Description. Note that a device may have multiple features - for example, it could measure both blood pressure and heart rate, in which case it could host two different MDEPs.

MCAP Data Link (MDL)

An MCAP Data Link (MDL) identifies a pair of MDEPs, one each for *Source* and *Sink*, and its explicit creation occurs by one of the two participating devices as result of a request on the Control Channel.

MCAP Communications Link (MCL)

An MCAP Communications Link (MCL) refers to the collection of L2CAP connections between two instances of MCAP and comprises of a Control Channel and zero or more Data Channels.

MCAP Instance

An MCAP instance can have one or more MCLs. If there are two MCAP instances, then there will be two HDP instances with separate SDP records and at least two instances of the IEEE data layer.

Source: [1]

8 References

[1] The Bluetooth SIG, HEALTH DEVICE PROFILE Implementation Guidance Whitepaper, April 2009

[2] The Bluetooth SIG, Bluetooth Host Operating environment Assigned numbers

9 Contact Information

Sales: sales@bluegiga.com

Technical support: support@bluegiga.com
http://www.bluegiga.com/techforum/

Orders: orders@bluegiga.com

Head Office / Finland:

Phone: +358-9-4355 060
Fax: +358-9-4355 0660

Street Address:

Sinikalliontie 5A
02630 ESPOO
FINLAND

Postal address:

P.O. BOX 120
02631 ESPOO
FINLAND

Sales Office / USA:

Phone: (781) 556-1039
Bluegiga Technologies, Inc.
99 Derby Street, Suite 200 Hingham, MA 02043