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CYCLING SPEED AND CADENCE PROFILE

Abstract:

This profile enables a Collector device to connect and interact with a Cycling Speed and Cadence Sensor for use in sports and fitness applications.

Revision History

Revision	Date	Comments
D09r00	2012-03-28	Initial Draft, based on Running Speed and Cadence Profile. Incorporated feedback from WG.
D09r01	2012-03-28	Accepted all changes.
D09r02	2012-04-03	Incorporated feedback from the WG and added the multiple bikes considerations in section 5. Accepted all the changes. Added DIS requirement. Improved flexibility for setting of cumulative wheel event counter.
D09r03	2012-04-10	Accepted all changes. Prepared for BARB review. Incorporated feedback from Huanchun and Joe.
D09r04	2012-04-11	Accepted all changes. Resubmitted to BARB. Incorporated further BARB feedback.
D09r05	2012-05-02	Accepted all changes. Submitted for BARB vote. Added DIS requirements. Incorporated relevant BARB feedback from CSCP reviews. Version used at IOP with changes attributed to “Author”.
D09r06	2012-05-02	Accepted all changes. Resubmitted to BARB.
D10r00	2012-06-05	Changed revision to draft 1.0. Incorporated SF WG and BARB feedback.
D10r01	2012-06-28	Accepted all changes. Resubmitted to BARB. Incorporated further BARB feedback.
D10r02	2012-06-28	Accepted all changes. Resubmitted to BARB for final review.
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The Bluetooth SIG has adopted Section 13.1 of the IEEE Standards Style Manual, which dictates use of the words ``shall'', ``should'', ``may'', and ``can'' in the development of documentation, as follows:

The word *shall* is used to indicate mandatory requirements strictly to be followed in order to conform to the standard and from which no deviation is permitted (*shall* equals *is required to*).

The use of the word *must* is deprecated and shall not be used when stating mandatory requirements; *must* is used only to describe unavoidable situations.

The use of the word *will* is deprecated and shall not be used when stating mandatory requirements; *will* is only used in statements of fact.

The word *should* is used to indicate that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others; or that a certain course of action is preferred but not necessarily required; or that (in the negative form) a certain course of action is deprecated but not prohibited (*should* equals *is recommended that*).

The word *may* is used to indicate a course of action permissible within the limits of the standard (*may* equals *is permitted*).

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The term *Reserved for Future Use (RFU)* is used to indicate Bluetooth SIG assigned values that are reserved by the Bluetooth SIG and are not otherwise available for use by implementations.

Table of Contents

1 Introduction

The Cycling Speed and Cadence Profile is used to enable a data collection device to obtain data from a Cycling Speed and Cadence Sensor (CSC Sensor) that exposes the Cycling Speed and Cadence Service [1].

1.1 Profile Dependencies

This profile requires the Generic Attribute Profile (GATT).

1.2 Conformance

If conformance to this profile is claimed, all capabilities indicated as mandatory for this profile shall be supported in the specified manner (process-mandatory). This also applies for all optional and conditional capabilities for which support is indicated. All mandatory capabilities, and optional and conditional capabilities for which support is indicated, are subject to verification as part of the *Bluetooth* qualification program.

1.3 Bluetooth Specification Release Compatibility

This specification is compatible with any *Bluetooth* Core Specification [2] that includes the Generic Attribute Profile (GATT).

2 Configuration

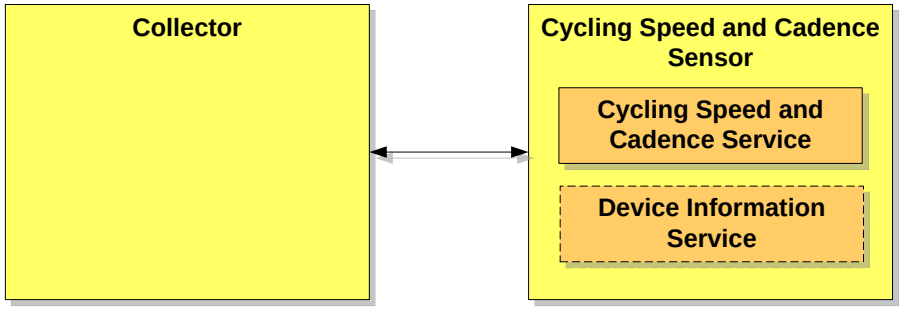
2.1 Roles

The profile defines two roles: CSC Sensor and Collector. The CSC Sensor is the device that reports wheel revolution data and/or crank revolution data and the Collector is the device that receives the data from a CSC Sensor. Cycling speed and cadence is calculated from this data at the Collector.

- The CSC Sensor shall be a GATT Server.
- The Collector shall be a GATT Client.

2.2 Role/Service Relationships

The following diagram shows the relationships between service and profile roles.



Notes: Profile roles are represented by yellow boxes and services are represented by orange boxes.

Items with dashed boxes are optional.

A CSC Sensor instantiates the Cycling Speed and Cadence Service [1] and optionally the Device Information Service [4].

2.3 Concurrency Limitations and Restrictions

There are no concurrency limitations or restrictions for the Collector and CSC Sensor roles imposed by this profile.

While there are scenarios to connect a Sensor to multiple Collectors not at the same time, support for multiple bonds in the Sensor is possible, but is outside the scope of this document.

2.4 Topology Limitations and Restrictions

2.4.1 Topology Restrictions for Low Energy

This section describes topology limitations and restrictions when the profile is to be used over Low Energy transport.

The CSC Sensor shall use the GAP Peripheral role.

The Collector shall use the GAP Central role.

2.4.2 Topology Limitations and Restrictions for BR/EDR

This section describes topology limitations and restrictions when the profile is to be used over BR/EDR transport.

There are no fixed master or slave roles in the profile.

2.5 Transport Dependencies

There are no transport restrictions imposed by this profile specification.

Where the term BR/EDR is used throughout this document, this also includes the use of AMP.

3 CSC Sensor Role Requirements

The CSC Sensor shall instantiate one and only one Cycling Speed and Cadence Service [1].

The Cycling Speed and Cadence Service shall be instantiated as a «Primary Service».

The CSC Sensor should instantiate the Device Information Service [4]. See specific recommendations in Section 3.2.

Service	CSC Sensor
Cycling Speed and Cadence Service	M
Device Information Service	O

Table 3.1: Cycling Speed and Cadence Service Requirements for the CSC Profile.

Other than the CSC Sensor requirements in this section refer to Sections 5.1 and 6.1 for additional CSC Sensor requirements for the LE Transport and Sections 5.3 and 6.3 for the BR/EDR transport.

3.1 Incremental Cycling Speed and Cadence Service Requirements

3.1.1 Additional Requirements for Low Energy Transport

This section describes additional CSC Sensor requirements beyond those defined in the Cycling Speed and Cadence Service when using this profile over Low Energy transport.

3.1.1.1 Service UUIDs AD Type

While in a GAP Discoverable Mode for initial connection to a Collector, the CSC Sensor should include the Cycling Speed and Cadence Service UUID defined in [3] in the Service UUIDs AD type field of the advertising data. This enhances the user experience as a CSC Sensor may be identified by the Collector before initiating a connection.

3.1.1.2 Local Name AD Type

For enhanced user experience a CSC Sensor should include the Local Name (containing either the complete or shortened value of the Device Name characteristic as defined in [2]) in its Advertising Data or Scan Response Data.

3.1.1.3 Writable GAP Device Name characteristic

The CSC Sensor may support the write property for the Device Name characteristic in order to allow a Collector to write a device name to the CSC Sensor.

3.1.1.4 Appearance AD Type

For enhanced user experience a CSC Sensor should include the value of the Appearance characteristic defined in [3] in its Advertising data or Scan Response data.

3.2 Incremental Device Information Service Requirements

In order to allow the user to log the type of equipment used in a training session, the CSC Sensor should instantiate the Manufacturer Name String and the Model Number String in the Device Information Service [4].

Device Information Service Characteristic	Requirement
Manufacturer Name String	O
Model Number String	O

Table 3.2: Device Information Service Requirements

4 Collector Role Requirements

The Collector shall support the Cycling Speed and Cadence Service [1].

The Collector may support the Device Information Service [4].

Service	Collector
Cycling Speed and Cadence Service	M
Device Information Service	O

Table 4.1: Collector Service Requirements

This section describes the profile procedure requirements for a Collector.

Profile Requirement	Section	Support in Collector
Service Discovery	4.2	M
Cycling Speed and Cadence Service Discovery	4.2.1	M
Device Information Service Discovery	4.2.2	O
Characteristic Discovery	4.3	M
Cycling Speed and Cadence Service Characteristic Discovery	4.3.1	M
Device Information Service Characteristic Discovery	4.3.2	O
CSC Measurement	4.4	M
CSC Feature	4.5	M
Sensor Location	4.6	O
SC Control Point	4.7	C.1

Table 4.2: Collector Requirements

C.1: Mandatory if at least one SC Control Point procedure is supported, otherwise excluded.

4.1 GATT Sub-Procedure Requirements

Requirements in this section represent a minimum set of requirements for a Collector. Other GATT sub-procedures may be used if supported by both Client and Server.

The table below summarizes *additional* GATT sub-procedure requirements beyond those required by all GATT Clients.

GATT Sub-Procedure	Collector Requirements
Discover All Primary Services	C.1
Discover Primary Services by Service UUID	C.1
Discover All Characteristics of a Service	C.2
Discover Characteristics by UUID	C.2
Discover All Characteristic Descriptors	M
Read Characteristic Value	M
Write Characteristic Value	C.3
Notification	M
Read Characteristic Descriptors	M
Write Characteristic Descriptors	M

Table 4.3: Additional GATT Sub-Procedure Requirements

C.1: Mandatory to support at least one of these Service Discovery sub-procedures when using the LE transport. Excluded when using the BR/EDR transport since SDP must be used in this case.

C.2: Mandatory to support at least one of these Characteristic Discovery sub-procedures.

C.3: Mandatory if at least one SC Control Point procedure is supported.

4.2 Service Discovery

When using the Low Energy transport, the Collector shall perform primary service discovery using either the GATT *Discover All Primary Services* sub-procedure or the GATT *Discover Primary Services by Service UUID* sub-procedure. Recommended fast connection parameters and procedures for connection establishment are defined in Section 5.2.4.

When using the BR/EDR transport, the Collector shall perform service discovery by retrieving the SDP record of the Cycling Speed and Cadence Service [1]. The SDP record can be found in Section 4 of [1].

4.2.1 Cycling Speed and Cadence Service Discovery

The Collector shall discover the Cycling Speed and Cadence Service.

4.2.2 Device Information Service Discovery

The Collector may discover the Device Information Service.

4.3 Characteristic Discovery

As required by GATT, the Collector must be tolerant of additional optional characteristics in the service records of services used with this profile.

4.3.1 Cycling Speed and Cadence Service Characteristic Discovery

The Collector shall use either the GATT *Discover All Characteristics of a Service* sub-procedure or the GATT *Discover Characteristics by UUID* sub-procedure to discover the characteristics of the service.

The Collector shall use the GATT *Discover All Characteristic Descriptors* sub-procedure to discover the characteristic descriptors described in the following sections.

4.3.1.1 CSC Measurement Characteristic

The Collector shall discover the CSC Measurement characteristic.

The Collector shall discover the *Client Characteristic Configuration* descriptor of the CSC Measurement characteristic.

4.3.1.2 CSC Feature Characteristic

The Collector shall discover the CSC Feature characteristic.

4.3.1.3 Sensor Location Characteristic

The Collector may discover the Sensor Location characteristic.

4.3.1.4 SC Control Point Characteristic

The Collector may discover the SC Control Point characteristic.

If the Collector discovers the SC Control Point characteristic, it shall also discover the *Client Characteristic Configuration* descriptor of the SC Control Point characteristic.

4.3.2 Device Information Service Characteristic Discovery

The Collector may discover the characteristics of the Device Information Service.

In order for the Collector to discover the characteristics of the Device Information Service, it shall use either the GATT *Discover All Characteristics of a Service* sub-procedure or the GATT *Discover Characteristics by UUID* sub-procedure to discover all characteristics of the service.

4.4 CSC Measurement

The Collector shall control the configuration of notifications (i.e., via the *Client Characteristic Configuration* descriptor) of the CSC Measurement characteristic.

The Collector shall be able to receive multiple notifications of the CSC Measurement characteristic from the CSC Sensor at regular intervals.

When a Collector requires a connection to a CSC Sensor to receive speed and cadence measurements it shall follow the connection procedures described in Section 5.

The Collector shall determine the contents of the CSC Measurement characteristic structure based on the content of the Flags field. This allows the Collector to determine whether or not the following fields are present: Cumulative Wheel Revolutions, Last Wheel Event Time, Cumulative Crank Revolutions and Last Crank Event Time.

The Collector shall support the calculation of instantaneous speed and instantaneous cadence. The Collector should support the calculation of average speed and average cadence.

Calculation of speed at the Collector can be derived from the wheel circumference and data in two successive measurements. The Collector calculation can be performed as shown below:

> Speed = (Difference in two successive Cumulative Wheel Revolution values * Wheel Circumference) / (Difference in two successive Last Wheel Event Time values)

Calculation of cadence at the Collector can be derived from data in two successive measurements. The Collector calculation can be performed as shown below:

> Cadence = (Difference in two successive Cumulative Crank Revolution values) / (Difference in two successive Last Crank Event Time values)

While the Cumulative Wheel Revolution value cannot practically roll over during the life of the Sensor, the Cumulative Crank Revolution value will occasionally roll over (i.e. as frequently as every 12 hours if ridden at 80 rpm). As such, the Collector shall take into account that the Cumulative Crank Revolution value can roll over during a ride. See Section 4.7.2.1 for information on how to set this value.

The Collector shall be tolerant of the fact that the Cumulative Wheel Revolutions value may decrement for some implementations (e.g. if the bicycle is rolled in reverse).

The Collector shall take into account that the Wheel Event Time and the Last Crank Event Time can roll over during a ride.

The Collector shall determine the features supported by the CSC Sensor by reading the CSC Feature characteristic (see Section 4.5).

If the Collector has a display, it should alert the user when data required for calculation of instantaneous speed or instantaneous cadence is no longer being received (e.g. due to link loss or sensor misalignment). This can be done by displaying “--" (i.e. 2 dashes) or by other means. Once the data is again received (e.g. the link is restored or sensor position readjusted), the display should return to normal. In addition, if the user is coasting (i.e., not rotating the crank), the instantaneous cadence may also be represented on the display as “--" (i.e., 2 dashes).

As a result of a link loss situation during a ride, the Collector should take this loss into account when calculating the average.

If the Collector receives a CSC Measurement characteristic with Reserved for Future Use (RFU) bits of the Flags field that are non-zero, it shall ignore those bits and continue to process the CSC Measurement characteristic in the same way as if all the RFU bits had been zero.

When the implementation receives a CSC Measurement characteristic with additional, unrecognized, octets, the Collector behavior shall be identical to the Collector behavior when only recognized octets are received. This is to enable compatibility with future Cycling Speed and Cadence Service updates for the case where available octets in the characteristic are specified for optional use. What the Collector does with the additional, unrecognized, octets is left to the implementation.

4.5 CSC Feature

The Collector shall read the CSC Feature characteristic to determine the supported features of the CSC Sensor in order to understand the capabilities of the CSC Sensor. In many cases, this will allow the Collector to operate more efficiently. For example, if the Wheel Revolution Data Supported bit is set to 0 (meaning this feature is not supported), then it is unnecessary for the Collector to check the value of the Wheel Revolutions Data Present bit with each CSC Measurement characteristic.

If the Wheel Revolution Data Supported bit is set to 0 (False), the Collector should ignore the Wheel Revolution Present bit of the Flags field of the CSC Measurement characteristic.

If the Crank Revolution Data Supported bit is set to 0 (False), the Collector should ignore the Crank Revolution Data Present bit of the Flags field of the CSC Measurement characteristic.

If the Multiple Sensor Locations Supported bit is set to 0 (False), the Collector shall assume that the CSC Sensor doesn’t support the configuration of multiple sensor locations. Otherwise, the Collector may request a list of supported sensor locations (see Section 4.7.2.3) and configure the CSC Sensor as described in Section 4.7.2.2 with the appropriate sensor location.

Whether a bit is defined as static during the lifetime of the device (i.e. static permanently or until Service Changed is indicated) or static during a connection, is defined on a bit by bit basis in Table 3.2 of [1] (Static Requirements for CSC Feature Bits).

If the Collector reads CSC Feature characteristic bits that are set and yet are designated as Reserved for Future Use (RFU) in [3] it shall ignore those bits and behave as if all the RFU bits had been zero. The Collector may nevertheless preserve the state of the RFU bits when storing the data and/or providing the data for use by the implementation. What a Collector does with the received RFU information is left to the implementation.

4.6 Sensor Location

The Sensor Location characteristic describes the location where the device is intended to be installed. If the CSC Sensor supports the Multiple Sensor Locations feature, the value of the Sensor Location characteristic may change while in a connection; otherwise, if the Sensor Location characteristic is present and the Multiple Sensor Locations feature is not supported, the value of the Sensor Location characteristic is static for the lifetime of the CSC Sensor.

If the CSC Sensor supports the Multiple Sensor Locations Feature, the Collector should read the value of the Sensor Location characteristic each time the connection is established to determine if the CSC Sensor is properly configured. This should be done in case the Sensor Location characteristic value was altered by another Collector or in case the CSC Sensor is unable to cache the value. See Section 4.7.3 for information relating to the caching of the Sensor Location characteristic.

If the Collector reads a Sensor Location value that is designated as Reserved for Future Use (RFU), it shall either ignore the value or substitute it with the value for ‘Other’ (0x00).

4.7 SC Control Point

Before performing a SC Control Point procedure, the Collector shall configure the SC Control Point characteristic for indications (i.e. via the *Client Characteristic Configuration* descriptor).

The Collector may perform a write to the SC Control Point to request a desired procedure. A procedure begins when the Collector writes the SC Control Point to perform some desired action and ends when a *Response Code* SC Control Point indication is sent by the CSC Sensor.

When a Collector requires a connection to a CSC Sensor, it shall follow the connection procedures described in Section 5.

4.7.1 SC Control Point Procedure Requirements

Table 4.4 shows the requirements for the SC Control Point procedures (Op Codes) in the context of this profile:

Procedure (Op Code)	Requirement
Set Cumulative Value	O
Update Sensor Location	C.1
Request Supported Sensor Locations	C.1

Table 4.4: SC Control Point Procedure Requirements

C.1: If one of Update Sensor Location feature or Request Supported Sensor Locations feature is supported, both are required.

4.7.2 SC Control Point Behavioral Description

The Collector shall write to the SC Control Point characteristic using one of the supported Op Codes in Table 4.4 to request a CSC Sensor to perform a procedure. This may include a Parameter that is valid within the context of that Op Code as defined in [1].

4.7.2.1 Set Cumulative Value Procedure

If the Wheel Revolution Data Supported bit of the CSC Feature characteristic is set to 1, then this procedure is supported by the CSC Sensor.

To request a specific setting of the Cumulative Wheel Revolutions value within the CSC Sensor, the Collector shall write the *Set Cumulative Value* Op Code followed by a UINT32 parameter. For example, writing a parameter of 0x00000000 will set the Cumulative Wheel Revolutions value to 0 within the Sensor.

In some cases it may be desirable for a user to transfer the distance value (i.e. Cumulative Wheel Revolutions Value in the Sensor) from their old sensor onto their new sensor (e.g. if they desire to keep track of the total distance they have put on their bike).

In one scenario, a Collector that knows the Cumulative Wheel Revolutions value that was reached with the old CSC Sensor (or can calculate it from the total distance recorded) uses the Set Cumulative Value Procedure to set the Cumulative Wheel Revolutions value within the new CSC Sensor to the same value.

In a second scenario, both the Collector and the CSC Sensor are being replaced at the same time. The user interface of the new Collector allows the user to set the wheel circumference for the bike and the total distance value that he or she desires to transfer from the old CSC Sensor. The Collector is able to calculate the Cumulative Wheel Revolutions value from these two values and can use the Set Cumulative Value Procedure to set the Cumulative Wheel Revolutions value within the new CSC Sensor to the same value as it had reached in the old CSC Sensor.

The Collector shall wait for the *Response Code* SC Control Point Indication with the Response Value set to *Success* indicating successful operation as per the request or an error response value as described in section 4.7.3 or for the procedure to time out according to the procedure time out operation described in Section 4.7.4.

See Section 4.7.3 for general error handling procedures.

4.7.2.2 Update Sensor Location Procedure

If the Multiple Sensor Locations Supported bit of the CSC Feature characteristic is set to 1, then this procedure is supported by the CSC Sensor.

To update the sensor location within the CSC Sensor, the Collector shall write the *Update Sensor Location* Op Code with a Parameter that represents a supported location. A list of supported sensor locations, for a particular CSC Sensor, is determined through the use of the Request Supported Sensor Locations procedure described in Section 4.7.2.3. The possible sensor location values are defined in the Sensor Location characteristic description in [3].

The Collector shall wait for the *Response Code* SC Control Point Indication with the Response Value set to *Success* indicating success of the operation as per the request or an error response value as described in section 4.7.3 or for the procedure to time out according to the procedure time out operation described in Section 4.7.4.

See Section 4.7.3 for general error handling procedures.

4.7.2.3 Request Supported Sensor Locations Procedure

If the Multiple Sensor Locations Supported bit of the CSC Feature characteristic is set to 1, then this procedure is supported by the CSC Sensor.

To request the list of the sensor locations supported by the CSC Sensor, the Collector shall use the *Request Supported Sensor Locations* procedure.

The Collector shall wait for the *Response Code* SC Control Point Indication with the Response Value set to *Success* indicating successful of operation as per the request with the list of supported locations or an error response value as described in Section 4.7.3 or for the procedure to time out according to the procedure time out operation described in Section 4.7.4. The possible sensor location values are defined in the Sensor Location characteristic description in [3].

Since the list of supported locations is static for the lifetime of the device as defined in the Cycling Speed and Cadence Service, the Collector should cache the list of supported values.

See Section 4.7.3 for general error handling procedures including information relating to the caching of the Sensor Location characteristic.

4.7.3 General Error Handling

Other than error handling procedures that are specific to certain Op Codes, the following apply:

If the Collector writes an Op Code to the SC Control Point characteristic that is unsupported by the CSC Sensor, the CSC Sensor will respond with a *Response Code* SC Control Point indication with the *Response Value* set to *Op Code not supported*.

If the Collector writes a Parameter to the SC Control Point characteristic that is invalid (e.g. the Collector writes the *Update Sensor Location* Op Code with a sensor location that is not valid in the context of the CSC Sensor), it will receive a *Response Code* SC Control Point indication with the *Response Value* set to *Invalid Parameter*.

If the Collector writes an Op Code to the SC Control Point characteristic which results in an operation failure (e.g. the CSC Sensor cannot perform the procedure for any reason), it will receive a *Response Code* SC Control Point indication with the *Response Value* set to *Operation Failed*.

If the Collector writes an Op Code to the SC Control Point while the Sensor is performing a previously triggered SC Control Point operation (i.e. resulting from an invalid behavior of the Collector) and receives an ATT Error Response with the Application error code set to *Procedure Already In Progress*, the Collector shall wait until the current SC Control Point procedure completes before starting a new procedure.

If the Collector writes an Op Code to the SC Control Point while the SC Control Point characteristic is not configured for indication (i.e. via the *Client Characteristic Configuration* descriptor), it will receive an ATT Error Response with the Application error code set to *Client Characteristic Configuration Descriptor Improperly Configured*.

If a Service Changed indication is received from the CSC Sensor, this indicates not only that the Collector shall re-perform Service and Characteristic discovery (as defined in GATT), but also that the cached values for characteristics (e.g. the Sensor Location characteristic) may no longer be valid and Collectors that use the Sensor Location feature are required to re-perform the Request Supported Sensor Locations procedure to acquire a list of supported locations.

4.7.4 Procedure Timeout

In the context of the SC Control Point characteristic, a procedure is started when the CSC Sensor sends the response to the Collector's Write request for the SC Control Point characteristic. The procedure is considered to be complete when the SC Control Point characteristic is indicated with the Op Code set to *Response Code*.

In the context of the SC Control Point characteristic, a procedure is not considered started and not queued in the CSC Sensor when a write to the SC Control Point results in an ATT Error Response defined in Section 1.6 of the Cycling Speed and Cadence Service [1].

A procedure is considered to have timed out if an SC Control Point indication is not received within the ATT transaction timeout, defined as 30 seconds in Volume 2 Part F Section 3.3.3 of [2], from the start of the procedure.

If the link is lost while a SC Control Point procedure is in progress then the procedure shall be considered to have timed out. See Section 4.7.4.1 for handling this condition.

Thus a Collector shall start a timer, with the value set to the ATT transaction timeout, after the write response is received from the CSC Sensor. The timer shall be stopped

when a SC Control Point indication is received and the Op Code is set to *Response Code*. If the timer expires then the procedure shall be considered to have failed.

4.7.4.1 SC Control Point Procedure Timeout Handling

If an SC Control Point procedure times out (see Section 4.7.4 for details of how this may occur) then no new SC Control Point procedure shall be started by the Collector until a new link is established with the CSC Sensor.

4.8 Device Information Service Characteristics

The Collector may read the value of Device Information Service characteristics.

5 Connection Establishment Procedures

This section describes the connection establishment and connection termination procedures used by a CSC Sensor and Collector in certain scenarios.

The following scenario description is informative for Low Energy Transport:

> Once configured by the Collector, a CSC Sensor will typically remain powered off between uses and will only advertise and allow a Collector to connect when it detects user activity and has data to send. In this scenario, the CSC Sensor will enter a GAP Connectable Mode and start advertising when it has data to send to a Collector. The Collector will typically execute a GAP connection establishment procedure such that it is scanning for a CSC Sensor. When a connection is established and the CSC Sensor is configured for notifications and indications by the Collector, the CSC Sensor sends notifications to the Collector at regular intervals. When the training session is ended on the Collector, the Collector typically terminates the connection. When the CSC Sensor is inactive for a certain period of time, the CSC Sensor typically terminates the connection.

5.1 CSC Sensor Connection Establishment for Low Energy Transport

This section describes connection procedures to address the following scenarios:

- Section 5.1.1 describes the connection procedure when the CSC Sensor does not support bonding or if the CSC Sensor supports bonding but, is not bonded with any Collectors.
- Section 5.1.2 describes the connection procedure when the CSC Sensor is bonded with one or more Collectors.
- Section 5.1.3 is used when the established connection is broken after a link loss.

5.1.1 Connection Procedure for Unbonded Devices

This procedure is used for connection establishment when the CSC Sensor is not bonded with any Collectors and ready for connection (e.g. when the CSC Sensor detects some activity or when commanded by the user).

The CSC Sensor should use the GAP General Discoverable Mode with connectable undirected advertising events when establishing a connection.

It is recommended that the CSC Sensor advertises using the parameters in Table 5.1. The interval values in the first row are designed to attempt fast connection to devices during the first 30 seconds; however, if a connection is not established within that time, the interval values in the second row are designed to reduce power consumption for devices that continue to advertise.

Advertising Duration	Parameter	Value
First 30 seconds (fast connection)	Advertising Interval	30 ms to 60 ms
After 30 seconds (reduced power)	Advertising Interval	1 s to 1.2 s

Table 5.1: Recommended Advertising Interval Values

The advertising interval and time to perform advertising should be configured with consideration for user expectations of connection establishment time.

The CSC Sensor shall accept any valid values for connection interval and connection latency set by the Collector until service discovery, bonding and encryption (if required) are complete. Only after that should the CSC Sensor request to change to the preferred connection parameters that best suit its use case.

If a connection is not established within a time limit defined by the CSC Sensor, the CSC Sensor may exit the GAP Connectable Mode.

The CSC Sensor should be in a bondable mode during this procedure to optimize the future connections to the Collector (e.g., a Watch or a Phone) using the procedure described in Section 5.1.2.

If a bond is created, the CSC Sensor should write the Bluetooth device address of the Collector in the CSC Sensor controller's White List.

When the CSC Sensor no longer detects user activity for several seconds (e.g., 10 to 20 seconds), the CSC Sensor should perform the GAP *Terminate Connection* procedure.

When the CSC Sensor is disconnected by the Collector and it is ready for connection (e.g., when the CSC Sensor detects some activity or when commanded by the user), the CSC Sensor should initiate the Connection Procedure for Bonded Devices described in Section 5.1.2. This will enable reconnection with bonded Collectors.

5.1.2 Connection Procedure for Bonded Devices

This procedure is used after the CSC Sensor is bonded with one or more Collectors using the connection procedure in Section 5.1.1 and ready for connection (e.g., when the CSC Sensor detects some activity or when commanded by the user).

The CSC Sensor should use the GAP General Discoverable Mode with connectable undirected advertising events when establishing a connection. For the first 10 seconds a White List containing addresses of only bonded devices should be used to allow only active bonded Collectors to establish a connection. In order to allow connection with additional Collectors, a white list should not be used after the ten second period has expired.

It is recommended that the CSC Sensor advertises using the parameters in Table 5.1. The interval values in the first row are designed to attempt fast connection to devices during the first 30 seconds; however, if a connection is not established within that time, the interval values in the second row are designed to reduce power consumption for devices that continue to advertise.

The advertising interval and time to perform advertising should be configured with consideration for user expectations of connection establishment time.

The CSC Sensor shall accept any valid values for connection interval and connection latency set by the Collector until service discovery, bonding and encryption (if required) are complete. Only after that should the CSC Sensor request to change to the preferred connection parameters that best suit its use case.

If a connection is not established within a time limit defined by the CSC Sensor, the CSC Sensor may exit the GAP Connectable Mode.

When the CSC Sensor no longer detects user activity for several seconds (e.g., 10 to 20 seconds), the CSC Sensor should perform the GAP *Terminate Connection* procedure.

5.1.3 Link Loss Reconnection Procedure

When a connection is terminated due to link loss, a CSC Sensor should attempt to reconnect to the Collector by entering a GAP Connectable Mode using the recommended advertising interval values shown in Table 5.1.

5.2 Collector Connection Establishment for Low Energy Transport

This section describes connection procedures to address the following scenarios:

- Section 5.2.1 describes the connection procedure if the Collector needs to initiate a connection to an unbonded CSC Sensor.
- Section 5.2.2 describes the connection procedure when the Collector needs to initiate a connection with a bonded CSC Sensor.
- Section 5.2.3 is used when the established connection is broken after a link loss.

5.2.1 Connection Procedure for Unbonded Devices

This procedure is used for connection establishment when the Collector connects to a CSC Sensor to which it is not bonded. A Collector will typically execute a connection establishment procedure at the start of a training session such that it scans for a connectable CSC Sensor in the background or when commanded by the user.

The Collector should use the GAP *General Discovery* procedure to discover a CSC Sensor.

A Collector may use one of the following GAP connection procedures based on its connectivity requirements:

- *General Connection Establishment* procedure. The Collector may use this procedure when it requires measurements from one or more CSC Sensors. This procedure allows a Collector to connect to a CSC Sensor discovered during a scan without using the White List.
- *Direct Connection Establishment* procedure. The Collector may use this procedure when it requires measurements from a single CSC Sensor.

A Collector should use the recommended scan interval values shown in Table 5.2. For the first 30 seconds, the Collector should use the first scan window / scan interval pair to attempt fast connection. However, if a connection is not established within that time, the Collector should switch to one of the other scan window / scan interval options as defined below to reduce power consumption.

Scan Duration	Parameter	Value
First 30 seconds (fast connection)	Scan Interval	30 ms to 60 ms*
	Scan Window	30 ms

Scan Duration	Parameter	Value
After 30 seconds (reduced power) - Option 1	Scan Interval	1.28 s
	Scan Window	11.25 ms
After 30 seconds (reduced power) - Option 2	Scan Interval	2.56 s
	Scan Window	22.5 ms

Table 5.2: Recommended Scan Interval and Scan Window Values

* A scan interval of 60 ms is recommended when the Collector is supporting other operations to provide a 50% scan duty cycle versus 100% scan duty cycle.

Option 1 in Table 5.2 uses the same background scanning interval used in BR/EDR so the power consumption for LE will be similar to the power consumption used for background scanning on BR/EDR. Option 2 uses a larger background scanning interval (i.e. twice as long) than used in BR/EDR so the power consumption for LE will be less than the power consumption used for background scanning on BR/EDR. Connection times during background scanning will be longer with Option 2.

The Collector should use a scan window and scan interval suitable to its power and connection time requirements. Increasing the scan window increases the power consumption, but decreases the connection time.

The scan interval and scan window should be configured with consideration for user expectations of connection establishment time.

When the connection is established, the Collector should bond with the CSC Sensor during this procedure to optimize the future connections to the device using the procedure described in Section 5.2.2.

If a bond is created, the Collector should write the *Bluetooth* device address of the CSC Sensor in the Collector controller's White List and set the Collector controller's initiator filter policy to 'process connectable advertisement packets'.

Once connected, the Collector shall configure the CSC Measurement characteristic for notification.

The Collector should terminate the connection when the measurement session is terminated at the Collector by the user. The CSC Sensor will typically terminate the connection if the CSC Sensor no longer detects user activity for several seconds (e.g. 10 to 20 seconds).

When the Collector is disconnected, the Collector may initiate the Connection Procedure for Bonded Devices described in Section 5.2.2. This will enable reconnection with bonded CSC Sensors.

For Collectors that may be used with one or more bikes, refer to section 5.4.

5.2.2 Connection Procedure for Bonded Devices

This procedure is used for connection establishment with a bonded CSC Sensor. A Collector will typically execute a connection establishment procedure at the start of a training session such that it scans for a bonded connectable CSC Sensor in the background or when commanded by the user.

The Collector should use the GAP *General Discovery* procedure to discover a CSC Sensor.

A Collector may use one of the following GAP connection procedures based on its connectivity requirements:

- *General Connection Establishment* procedure. The Collector may use this procedure when it requires measurements from one or more CSC Sensors. This procedure allows a Collector to connect to a CSC Sensor discovered during a scan without using the White List.
- *Direct Connection Establishment* procedure. The Collector may use this procedure when it requires measurements from a single CSC Sensor.
- *Auto Connection Establishment* procedure. The Collector may use this procedure when it requires measurements from one or more CSC Sensors. This procedure will automatically connect to a CSC Sensor in the White List.
- *Selective Connection Establishment* procedure. The Collector may use this procedure when it requires measurements from one or more CSC Sensors. This procedure allows a Collector to connect to a CSC Sensor discovered during a scan while using the White List.

A Collector should use the recommended scan interval values shown in Table 5.2. For the first 30 seconds, the Collector should use the first scan window / scan interval pair to attempt fast connection. However, if a connection is not established within that time, the Collector should switch to one of the other scan window / scan interval options as defined in Table 5.2 to reduce power consumption.

The Collector should use a scan window and scan interval suitable to its power and connection time requirements. Increasing the scan window increases the power consumption, but decreases the connection time.

The scan interval and scan window should be configured with consideration for user expectations of connection establishment time.

The Collector shall start encryption after each connection creation to verify the status of the bond. If encryption fails upon connection establishment (i.e. the bond no longer exists), the Collector must, after user interaction, re-bond, perform service discovery (unless the Collector had previously determined that the CSC Sensor did not have the <<Service Changed>> characteristic), and configure the CSC Sensor *Client Characteristic Configuration* descriptors again before using any of the services referenced by this profile in case the configuration was altered or lost.

The Collector should terminate the connection when the measurement session is terminated at the Collector by the user. The CSC Sensor will typically terminate the connection if it no longer detects user activity for several seconds (e.g., 10 to 20 seconds).

When the Collector is disconnected the Collector may reinitiate the Connection Procedure for Bonded Devices described in Section 5.2.2.

For Collectors that may be used with one or more bikes, refer to section 5.4.

5.2.3 Link Loss Reconnection Procedure

When a connection is terminated due to link loss, a Collector should attempt to reconnect to the CSC Sensor using any of the GAP connection procedures with the parameters in Table 5.2.

5.2.4 Fast Connection Interval

To avoid very long service discovery and encryption times, the Collector should use the connection intervals defined in Table 5.3 in the connection request.

Parameter	Value
Minimum Connection Interval	50 ms
Maximum Connection Interval	70 ms

Table 5.3: Recommended Fast Connection Interval Values

At any time a low latency is required, for example to perform key refresh or encryption setup, this should be preceded with a connection parameter update to the minimum and maximum connection interval values defined in Table 5.3 and a connection latency of zero. This fast connection interval should be maintained as long as low latency is required. After that, it should switch to the preferred connection parameters as decided by the CSC Sensor using the GAP *Connection Parameter Update* procedure.

5.3 Connection Establishment for BR/EDR

This section describes the connection establishment and connection termination procedures used by a CSC Sensor and Collector using a BR/EDR transport. Unlike the LE Connection procedures, which describe specific connection parameters, BR/EDR connection establishment does not state requirements beyond those described in GAP based on potential interactions with other BR/EDR profiles operating concurrently on the CSC Sensor and/or Collector. Therefore, power consumption may not be optimized for the BR/EDR transport as compared to an LE transport when no other profiles are operating over the BR/EDR transport.

When using BR/EDR, devices can utilize sniff mode to reduce power consumption; however no particular parameters are recommended and the requirements of other profiles may need to be considered.

5.3.1 Connection Procedure

The procedures for establishing a connection between a CSC Sensor and Collector that do not have an existing bond and for re-establishing a connection between bonded devices use the inquiry, discovery, paging, pairing and security procedures described in Generic Access Profile of the Core Specification [2] and any additional GAP requirements enumerated in Sections 6 and 7.

5.3.1.1 Connection Procedure for Unbonded Devices

The CSC Sensor shall use the GAP General Discoverable Mode when it is not bonded with any Collectors and is ready for a connection (e.g. when the CSC Sensor detects some activity or when commanded by the user).

The Collector should use the GAP *General Discovery* procedure to discover a CSC Sensor to establish a connection to a CSC Sensor to which it is not bonded.

Either the CSC Sensor or the Collector can establish a BR/EDR link to a remote peer device.

Once a link is established, the Collector shall discover the Cycling Speed and Cadence Service using SDP procedures prior to establishing a GATT connection.

Once the Cycling Speed and Cadence Service is discovered and a GATT connection is established, the Collector shall discover the Cycling Speed and Cadence Service characteristics exposed by this service using GATT Discovery procedures.

Once connected and the Cycling Speed and Cadence Service is discovered, the Collector shall configure the SC Measurement characteristic for notification.

The Collector should initiate bonding between the two devices. If a bond is created, the Collector should cache the SDP Service Record for the Cycling Speed and Cadence Service.

When the CSC Sensor no longer detects user activity for several seconds (e.g., 10 to 20 seconds), the CSC Sensor may disconnect the link, depending on the use cases of the devices and other profiles connected on either device.

For Collectors that may be used with one or more bikes each with its own independent set of sensors, refer to Section 5.4.

5.3.1.2 Connection Procedure for Bonded Devices

The CSC Sensor shall use the GAP Link Establishment Procedure to connect to any bonded Collectors when it is ready for a connection (e.g. when the CSC Sensor detects some activity or when commanded by the user).

The Collector shall be Connectable to accept a connection from a CSC Sensor to which it is bonded.

Either the CSC Sensor or the Collector can establish a BR/EDR link to a remote peer device.

If a higher layer determines the bond no longer exists on the remote device, the local device must reconfigure the remote device after

- user interaction confirms that the user wants to re-pair with the remote device,
- re-bonding has been performed, and
- service discovery has been performed.

If the local device had previously determined that the remote device did not have the <<Service Changed>> characteristic then service discovery may be skipped.

When the CSC Sensor no longer detects user activity for several seconds (e.g., 10 to 20 seconds), the CSC Sensor may disconnect the link, depending on the use cases of the devices and other profiles connected on either device. When the CSC Sensor is disconnected and it is ready for reconnection (e.g., when the CSC Sensor detects some

activity or when commanded by the user), the CSC Sensor should initiate a connection with the Collector.

For Collectors that may be used with one or more bikes each with its own independent set of sensors, refer to Section 5.4.

5.3.2 Link Loss Reconnection Procedure

When a connection is terminated due to link loss, a CSC Sensor should reconnect to the Collector by attempting, for an implementation-specific time, to reestablish an ACL link between the two devices. The Collector should remain Connectable for an implementation-specific time so that a CSC Sensor can reestablish an ACL link.

5.4 Multiple Bike Considerations

In the context of this Profile, a Collector may be used with more than one bike, but not simultaneously. To enhance the user experience and because each bike may be equipped with its own set of Sensors (e.g. a Cycling Speed Sensor and a Cycling Cadence Sensor or even a Sensor supports both speed and cadence), it is recommended that the user interface on the Collector allows the user of the Collector to select the bike to be used among a list of the user's bikes. The list of Sensors associated to one specific bike may be used to populate the white list to avoid connection to a previously known Sensor installed on another of the user's nearby bikes.

The user interface on the Collector should also provide a mechanism to remove Sensors and to add new Sensors to a bike definition to enhance the user experience.

6 Security Considerations

This section describes the security considerations for a CSC Sensor and Collector.

6.1 CSC Sensor Security Considerations for Low Energy

This section describes the security requirements for the CSC Sensor for an LE transport.

All supported characteristics specified by the Cycling Speed and Cadence Service shall be set to LE Security Mode 1 and either Security Level 1, 2 or 3.

The CSC Sensor should bond with the Collector.

The CSC Sensor should use the SM *Slave Security Request* procedure.

If used, all characteristics exposed by the Device Information Service for use by this profile should be set to the same security mode and level as the characteristics in the Cycling Speed and Cadence Service.

6.2 Collector Security Considerations for Low Energy

This section describes the security requirements for the Collector for an LE transport.

The Collector should bond with the CSC Sensor.

The Collector shall accept any request by the CSC Sensor for LE Security Mode 1 and either Security Level 1, 2 or 3.

6.3 Security Considerations for BR/EDR

As required by GAP, Security Mode 4 shall be used for connections by CSC Sensor and Collector.

- The Collector and CSC Sensor should bond.
- Acceptance of Bonding should be supported by all CSC Sensors and Collectors.
- Initiation of Bonding should be supported by Collectors.

7 Generic Access Profile for BR/EDR

This section defines the support requirements for the capabilities as defined in the Generic Access Profile of the Core Specification [2] when BR/EDR is used.

7.1 Modes

The Mode Procedures as defined in GAP describe requirements for both CSC Sensor and Collectors involved. This profile further refines the requirements.

- General Discoverable mode shall be supported by CSC Sensors supporting BR/EDR.
- Bondable mode should be supported by CSC Sensors and Collectors

Table 7.1 shows the support status for GAP Modes in this profile.

Procedure	Support in CSC Sensor	Support in Collector
General Discoverable Mode	M	X

Table 7.1: Modes

7.2 Idle Mode Procedures

The Idle Mode Procedures as defined in GAP describe requirements for both CSC Sensor and Collectors involved. This profile further refines the requirements.

- General inquiry shall be supported by all Collectors.
- General bonding should be supported by all CSC Sensors and Collectors.

Table 7.2 shows the support status for Idle Mode procedures within this profile.

Procedure	Support in CSC Sensor	Support in Collector
General Inquiry	X	M

Table 7.2: Idle mode procedures

8 Acronyms and Abbreviations

Acronyms and Abbreviations	Meaning
ACL	Asynchronous Connection-oriented [logical transport]
AD	Advertising Data
AMP	Alternate MAC PHY
BR/EDR	Basic Rate / Enhanced Data Rate
CSC	Cycling Speed and Cadence
GAP	Generic Access Profile
GATT	Generic Attribute Profile
LE	Low Energy
RFU	Reserved for Future Use
SC	Speed and Cadence
SDP	Service Discovery Protocol
SM	Security Manager
UUID	Universally Unique Identifier

Table 8.1: Acronyms and Abbreviations

9 References

[1] Cycling Speed and Cadence Service
[2] Bluetooth Core Specification v4.0 or later
[3] Characteristic and Descriptor descriptions are accessible via the Bluetooth SIG Assigned Numbers.
[4] Device Information Service v1.1 or later