PORSCHE

BBridge: System Architecture, Interface and Protocol Description

PEG-GX

Porsche Engineering

driving technologies

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Version History

Date	Version	Change	Author / Role
02.12.2015	0.1	Created first draft	Armando Perico
07.12.2015	0.2	Corrected tables from section 2.3	Armando Perico
08.12.2015	0.3	Added “addWhiteListItem” function / Updated unclear topics section	Armando Perico
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22.03.2016	1.1	Description updated for 4.2.4 and added Table 6	Janni Duerr
31.03.2016	1.2	Description updated for SPI Ready Line, Table 2	Janni Duerr

Open points in this document

Open Point	Section	Tbd by

Review

Role	Name	Department	Date	Version	Signature

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1 Introduction

1.1 Purpose of this document

The purpose of this document is to provide an overview of the system architecture for the Bbridge project and describe how to operate the hardware and software interfaces.

1.2 Referenced Documents

Document	Description // URL
3EGM401000-5431_TI_COM_TRD_3.6kW_Update_2015-10-12	First set of requirements provided by Bombardier.
Bluetooth Smart (Low Energy)	https://developer.bluetooth.org/TechnologyOverview/Pages/BLE.aspx
AN118 for Flash Programming of CC2540	http://www.ti.com/lit/an/swra410/swra410.pdf
B_Sample_Schematics_Bluetooth.pdf	Part of the Bombardier Panther hardware schematics containing the Bluetooth chipset. Provided by Bombardier.
PINNING_Bluetooth_CC2540_B0undB.pdf	Pinning overview of the Panther hardware provided by Bombardier.
CC2592RGVT	https://store.ti.com/CC2592RGVT.aspx
CC2540	http://www.ti.com/product/CC2540
BBridge_Transport_Layer_Protocol.pdf	Description of the BBridge Transport Layer Protocol used for the SPI communication. PES document.

Table 1 – Referenced Documents

1.3 Definitions, Acronyms and Abbreviations

Definition, Acronym, Abbreviaton	Desciption
Panther	µController host system that uses the BBridge software for networking
BBridge	Application that manages the networking over Bluetooth LE
Bluetooth LE	Bluetooth Low Energy , low range wireless personal area network technology
CC2540	µController subsystem for Bluetooth LE
BT	Bombardier Transportation GmbH
PES	Porsche Engineering Services GmbH
BLE	Bluetooth Low Energy / Bluetooth Smart
SPP	Serial Port Profile
TI	Texas instruments
SPI	Serial Peripheral Interface

Table 2: Definitions, Acronyms and Abbreviations

2 System Architecture

This section provides detailed information about the system architecture of the BBridge.

2.1 Panther System Overview

The application goal of this architecture aims to make it possible for two Panther devices to communicate transparently with each other over Bluetooth LE. The BBridge application encapsulates the Bluetooth mechanisms and provides a simple public API for external usage. Figure 1 shows how two Panther devices can communicate using a Bluetooth channel over an SPP (Serial Port Profile) approach.

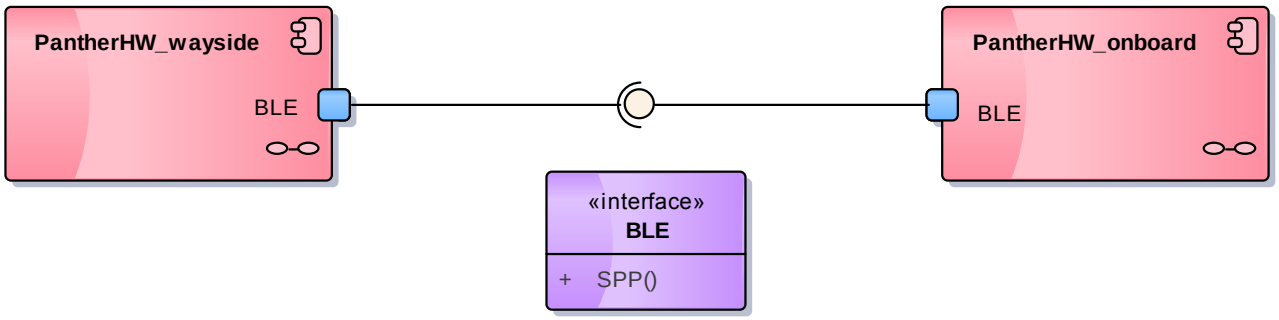

Figure 1 – System Architecture Overview

2.2 BBridge Interface Overview

This section gives an overview of the interfaces of the BBridge device. As shown in Figure 2, the Panther HW has four different Interfaces to the BBridge (SPI, Debug, WakeUP/Control and RF FrontEnd).

Note: The input and output signals described in this section are from the Bbridge perspective.

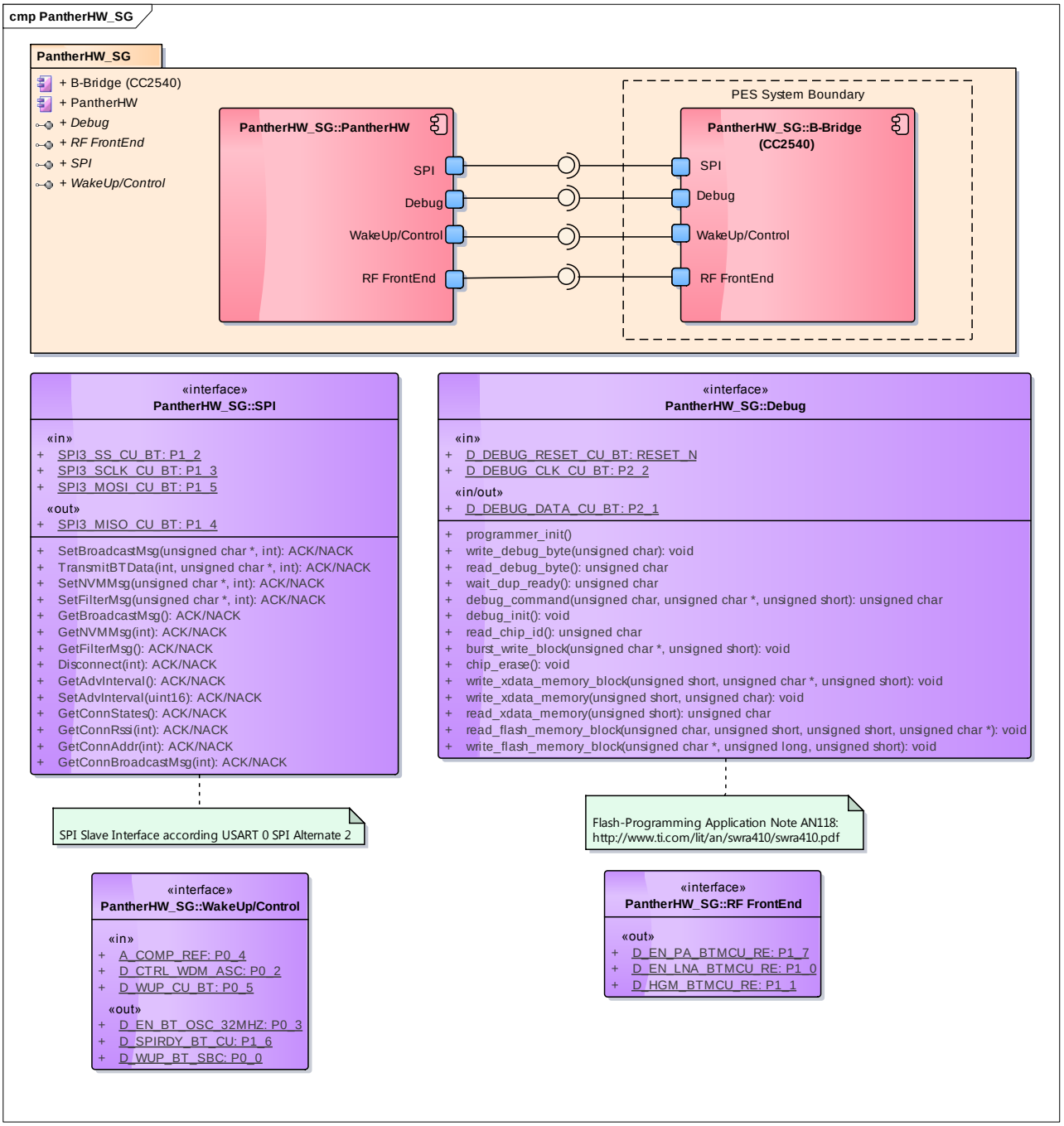

Figure 2 – Hardware Interfaces

2.2.1 SPI

The SPI interface is used by the Panther device (as master) to access and control the software functionalities available in the Bbridge application (as slave).

Parameter	Value
Clock Polarity (CPOL)	1
Clock Phase (CPHA)	1
Chip Select active state	active low
Data Order	MSB first
Theoretical max. Clock frequency using 32MHz Crystal	4MHz

Table 3: SPI hardware parameters

2.2.2 Debug

This interface allows the Panther application to directly “flash” data on the BBridge microcontroller (CC2540). Detailed information on how to use this interface is available in the application note 118 from Texas Instruments (AN118 – http://www.ti.com/lit/an/swra410/swra410.pdf).

2.2.3 WakeUp/Control

This interface allows the BBridge to inform the Panther HW of certain events. Since the Panther HW is the master on the SPI communication this interface enables the BBridge to trigger the Panther to retrieve data from the BBridge.

2.2.3.1 Wakeup Line

With the Wakeup Line (D_WUP_BT_SBC) the BBridge is capable of waking up the Panther HW. Whenever the BBridge establishes a validated connection to another device, the BBridge drives the pin high, and keeps it high. Connecting to further devices does not change the state of this signal. When there is no more validated connection the signal pin will be driven low again.

2.2.3.2 SPI Ready Line

With the SPI Ready Line (D_SPIRDY_BT_CU) the BBridge tells the Panther that it wants to send data to the Panther. This signal is active low. Meaning a low state of the signal implies the BBridge cannot accept SPI commands by the Panther and the Panther should start a read operation on the SPI interface.

2.2.3.3 Input Signals

The input signals (D_CTRL_WDM_ASC, D_WUP_CU_BT, A_COMP_REF) are not used for any purposes.

2.2.4 Radio frequency (RF) FrontEnd

This interface allows for controlling the “mode of operation” of the RF Frontend CC2592.

2.3 BBridge Hardware Perspective

Figure 3 shows a block diagram of the BBridge Device (CC2540) embedded in the Panther HW.

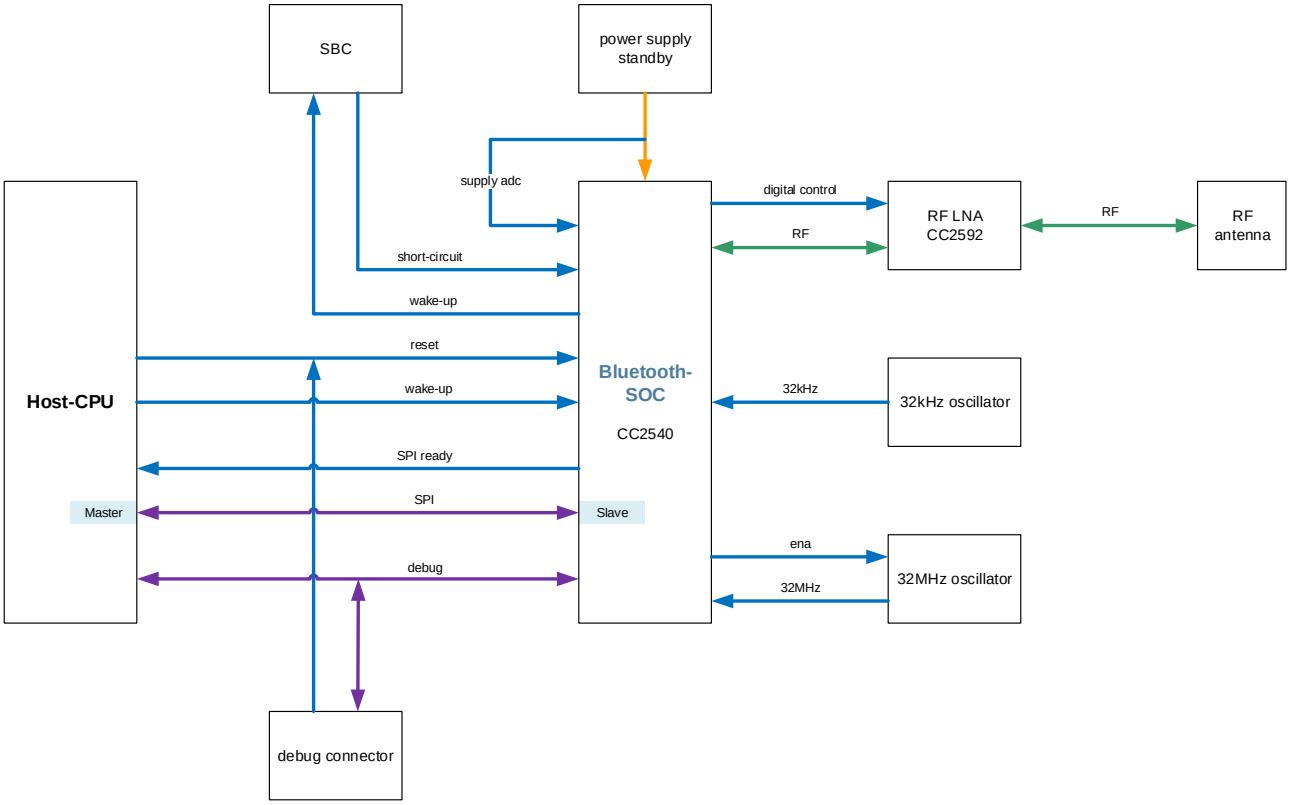

Figure 3 – Hardware block diagram

3 BBridge Communication Protocol

This section describes the BBridge Communication Protocol which is used for communication between the BBridge and the Panther HW. Handling of the SPI and SPI Ready Line is done by the Transport Layer Protocol. The software stack for the transport layer for both sides BBridge and Panther is provided by PES.Thus the Panther application needs to take care of the data payload only **. The Transport Layer Protocol is described in the document BBridge Transport Layer Protocol. Figure 4 shows the Communication and Transport Layers.

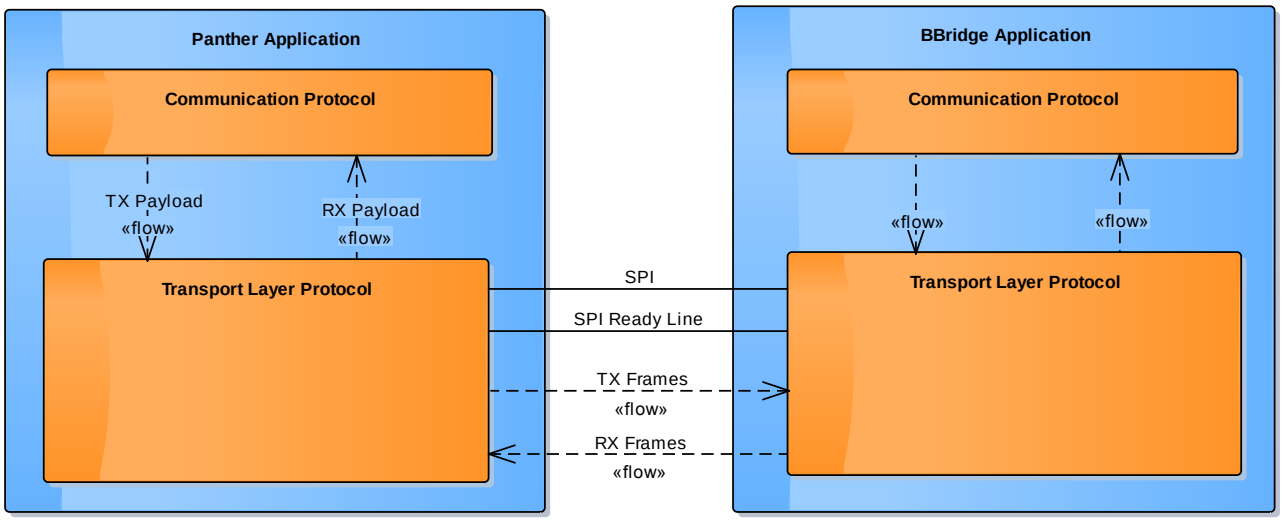

Figure 4: Communication and Transport Layer

** Note: Hardware dependent low-level SPI functionality (Sending/Receiving) is not part of the Transport Layer Protocol.

3.1 Communication Sequences

There are three communication sequences that cover the possible data exchange between Panther and BBridge. An important part of the communication protocol is the acknowledging of all commands by the BBridge. Meaning every command sent by the Panther is acknowledged either with an positive response (ACK) or a negative response (NACK).

3.1.1 Set Value

A Set Value sequence describes communication which was initiated by the Panther in order to set a value on the BBridge device.

Note: This can be any command which does not expect the BBridge to send data in return.

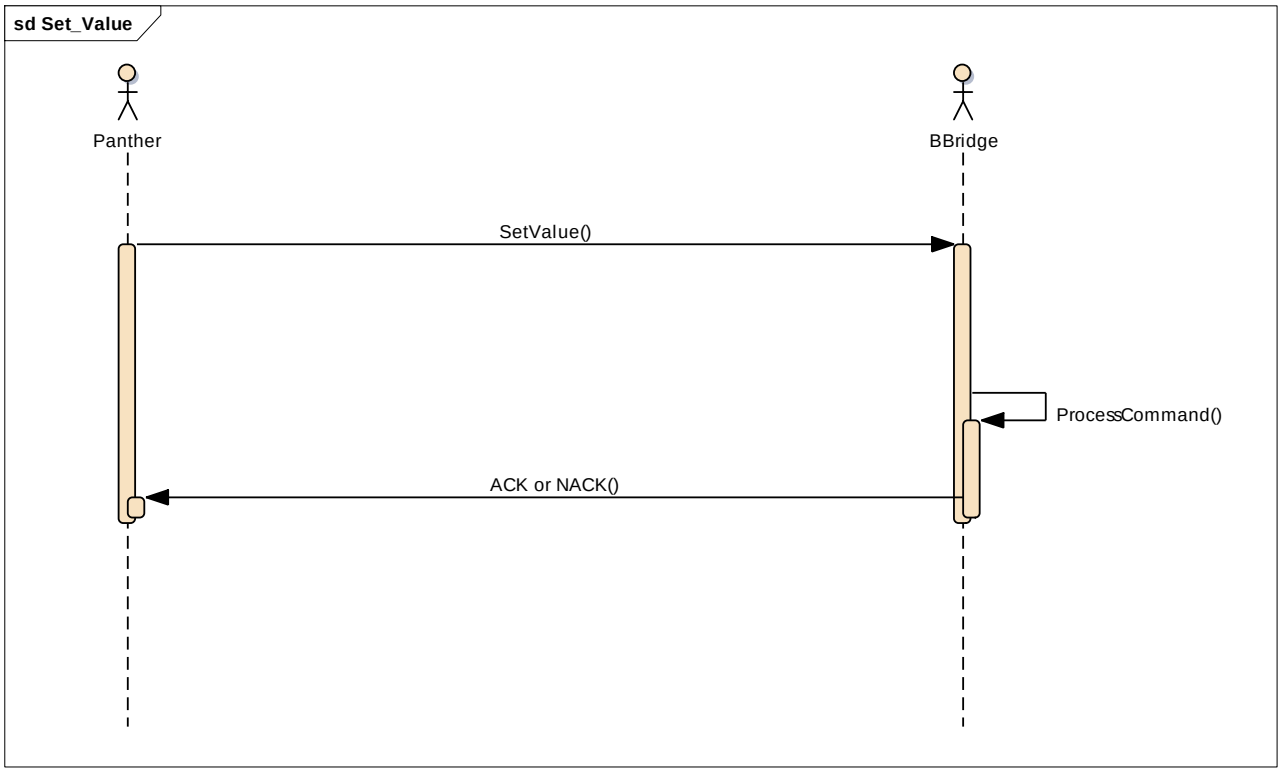

Figure 5: Set Value Sequence Diagram

3.1.2 Get Value

A Get Value sequence describes communication which was initiated by the Panther in order to read a value from the BBridge device.

Note: This can be any command after which the Panther expects the BBridge to send data to the Panther containing the value the Panther requested.

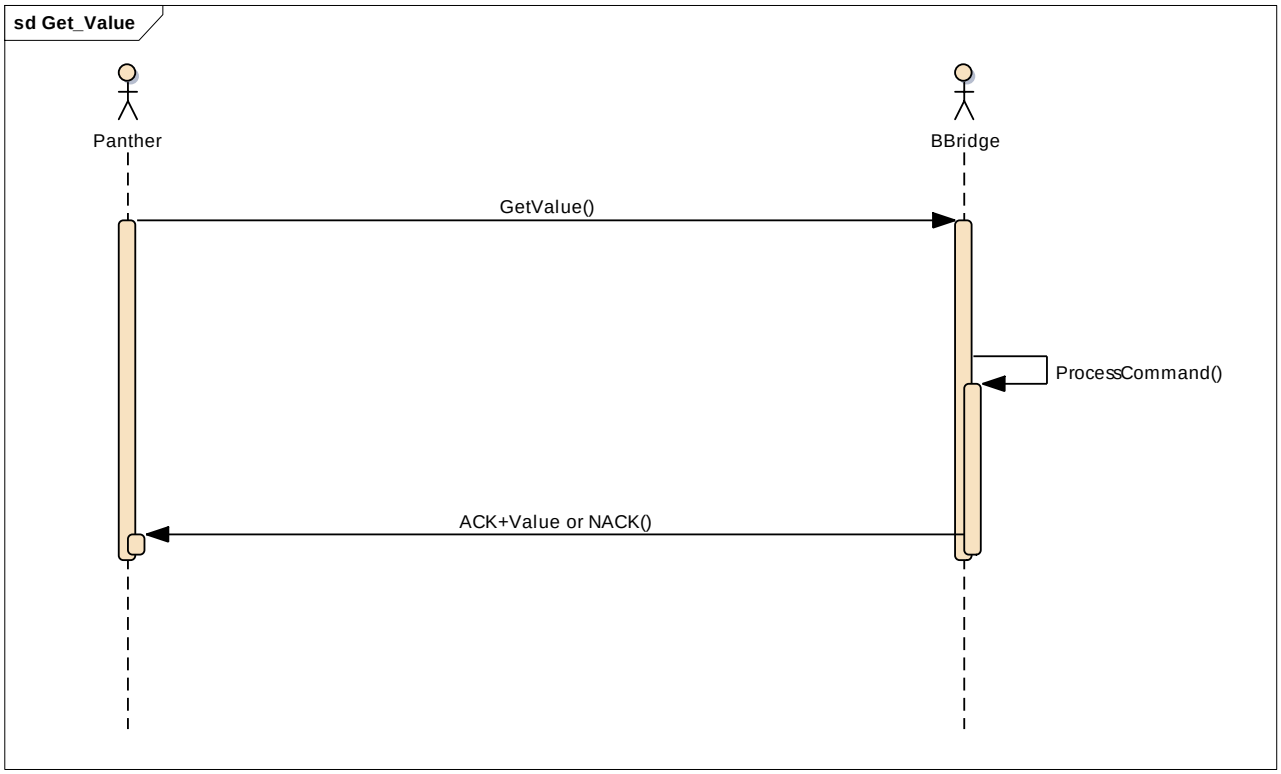

Figure 6: Get Value Sequence Diagram

3.1.3 BBridge Event

A BBridge Event sequence describes communication which was initiated by the BBridge. The data may contain received Bluetooth data or information on connections that were established/lost.

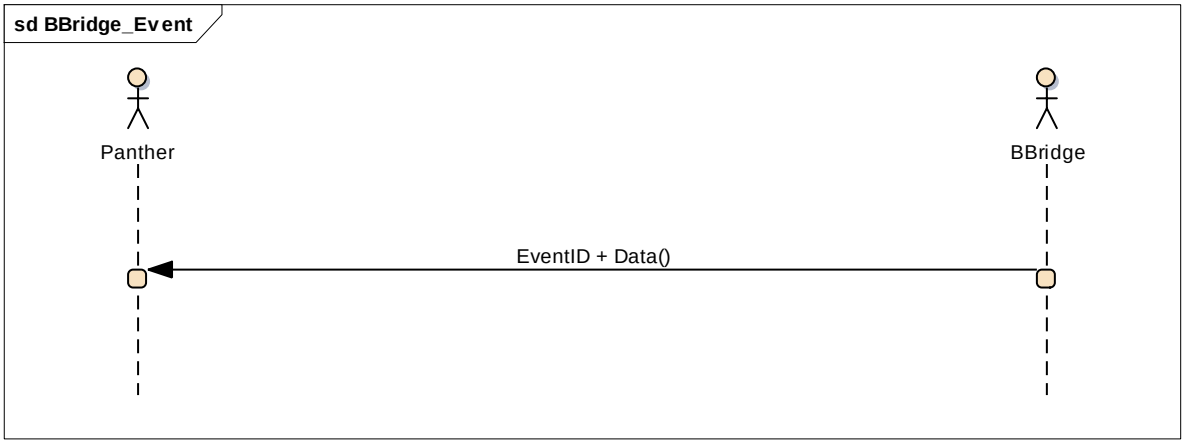

Figure 7: BBridge Event Sequence Diagram

4 BBridge Command Description

This section gives detailed information on the commands which are used for the BBridge Communication Protocol. It shows how the Payload is structured and which data it can contain.

4.1 Panther to BBridge

4.1.1 Payload Format

The payload sent from the Panther to the BBridge contains one command Byte (CMD_0) as well as a number Data Bytes. If the payload does not contain any data other than the command Byte, the payload has the size 1.

Byte0	Byte1	Byte2		Byte N+1
CMD_0	Data_0	Data_1	…	Data_N

4.1.2 Command list

This list shows the commands for the CMD_0 Byte and the following Data Bytes depending on the command. It also shows in which Operating Modes the functions are available.

Function	CMD_0	Data Bytes	IDLE Mode	Scan. Mode	Conn. Mode
Set Broadcast Message	0x00	Message (max. 21 Bytes)	Yes	No	No
Get Broadcast Message	0x01	None	Yes	No	No
Set Filter Message	0x02	Message (max. 21 Bytes)	Yes	Yes	No
Get Filter Message	0x03	None	Yes	Yes	No
Set Operating Mode	0x04	Operating Mode (1 Byte) See 4.1.2.1	Yes	Yes	Yes
Get Operating Mode	0x05	None	Yes	Yes	Yes
Disconnect From Device	0x06	Connection index [0-2] (1Byte) See 4.2.4	No	Yes	Yes
Set NVM Byte	0x07	Index [0-7] (1Byte) + NVM Byte (1 Byte)	Yes	No	No
Get NVM Byte	0x08	Index [0-7] (1Byte)	Yes	No	No
Send Data	0x09	Connection index [0-2] (1 Byte) + Data (max. 20 Bytes)	No	Yes	Yes
Set Advertise Interval	0x0A	[0ms – 65000ms] (2 Bytes)	Yes	No	No
Get Advertise Interval	0x0B	None	Yes	No	No
Get Connection States	0x0C	None	No	Yes	Yes
Get Connection RSSI	0x0D	Connection index [0-2] (1Byte) See 4.2.4	No	Yes	Yes
Get Connection Address	0x0E	Connection index (1 Byte) See 4.2.4	No	Yes	Yes
Get Connection Broadcasted Message	0x0F	Connection index (1 Byte) See 4.2.4	No	Yes	No

Table 4: Panther to BBridge command list

4.1.2.1 Operating Modes List

CMD	Operating Mode
0x00	None
0x01	IDLE
0x02	Scanner
0x03	Connectable

Table 5: List of Operating Modes

4.2 BBridge to Panther

4.2.1 Payload Format

The payload sent from the BBridge to the Panther contains two command Bytes (CMD_0, CMD_1) as well as a number Data Bytes. If the payload does not contain any data other than the command Bytes, the payload has the size 2.

Byte0	Byte1	Byte2	Byte3		Byte N+2
CMD_0	CMD_1	Data_0	Data_1	…	Data_N

Table 6 shows the possible values for the CMD_0 byte.

Value	Description
0x00	ACK
0x01	NACK
0x02	EVENT

Table 6: Possible CMD_0 values

4.2.2 ACK response structure

An ACK command is the positive response to a command sent from the Panther to the BBridge. The CMD_0 Byte contains the ACK, the CMD_1 the repetition of the CMD_0 Byte sent by the Panther. If the command was an Set Value command, no data follows. If it was an Get Value command the Value follows in the corresponding amount of data bytes.

CMD_0	CMD_1	Data (X Bytes)
0x00	(Repeat Panther Cmd)	Data if Get Value, none if Set Value

4.2.2.1 Acknowledges to Get Value commands

When the Panther sends a Get Value command, the BBridge answers either with a NACK response or with an ACK response that contains the requested Value. The table below shows the corresponding ACK responses and the contained data.

Function	Data Bytes
Get Broadcast Message	Message (max. 21 Bytes)
Get Filter Message	Message (max. 21 Bytes)
Get Operating Mode	Operating Mode (1 Byte) See 4.1.2.1
Get Advertise Interval	[0ms – 65000ms] (2 Bytes)
Get Connections States	[0-1] [0-1] [0-1] (3 Bytes) **
Get Connection RSSI	RSSI Value [-127 - +127] (1 Byte)
Get Connection Address	Bluetooth Address [0x00 – 0xFFFFFFFFFFFF] (6 Bytes)
Get Connection Broadcasted Message	Broadcasted Message (max. 21 Bytes)
Get NVM Byte	NVM Byte (1 Byte)

Table 7: List of ACK to Get Value commands

** 0 meaning not connected, 1 meaning validated connection active. In case the BBridge Device is in Connectable Mode, the states of Connection[1] and Connection[2] are always zero, since only one connection is possible.

4.2.3 NACK response structure

A NACK command is the negative response to a command sent from the Panther to the BBridge. The CMD_0 Byte contains the NACK, the CMD_1 the repetition of the CMD_0 Byte sent by the Panther. One Data Byte follows containing the reason for the negative response.

CMD_0	CMD_1	Data_0
0x01	(Repeat Panther Cmd)	NACK reason

4.2.3.1 Possible NACK reasons

NACK	Description
0x00	Command unknown
0x01	BBridge busy
0x02	Not connected
0x03	Invalid request
0x04	Index out of range
0x05	Sending data has failed
0x06	Internal Error
0x07	Timeout

Table 8: Possible NACK reasons

4.2.4 BBridge Event command structure

A BBridge Event command is sent from the BBridge to the Panther on five different events, described below.

1) A validated connection to another BBridge device has been established

CMD_0	CMD_1	Data_0	Data_1	Data_2
0x02	0x00	Connection[0] State	Connection[1] State	Connection[2] State

In case the BBridge Device is in Connectable Mode, the states of Connection[1] and Connection[2] are always zero, since only one connection is possible.

2) A validated connection to another BBridge device has been lost

CMD_0	CMD_1	Data_0	Data_1	Data_2
0x02	0x01	Connection[0] State	Connection[1] State	Connection[2] State

3) The BBridge has received Bluetooth data from another BBridge device

CMD_0	CMD_1	Data_0	Data_1 to Data_N (X Bytes)
0x02	0x02	Connection Index	Data

4) The BBridge Device initialized correctly (sent once at power on only)

CMD_0	CMD_1	Data_0
0x02	0x03	Current Operating Mode

5) Internal Error

CMD_0	CMD_1	Data_0
0x02	0x04	Reserved