

1 Introduction

The K32L2B is highly-integrated, market leading ultra low-power 32-bit microcontroller based on the enhanced Cortex-M0+ (CM0+) core platform. The family derivatives contain the following features:

- Core platform clock up to 48 MHz, bus clock up to 24 MHz.
- Memory option is up to 256 KB flash and 32 KB RAM.
- Two SPI modules.
- Two inter-integrated circuit (I2C) modules.
- One FlexIO module.

Over-The-Air (OTA) is a procedure to update the firmware without the use of physical wires, so it can be a solution for the current **Bluetooth LE Audio System**. When a product is ready and released in the field, OTA can be used to upload new firmware that brings new features.

- From the point view of a customer, OTA is convenient because the Headset does not need to be connected to a PC.
- From the point view of a manufacturer, OTA reduces the BOM cost as no USB hardware needs to be present.

This document provides **OTA Operation Steps** to support users who would like to use the [NXH3670_SDK_Gaming_G3.0](#) tool to update firmware in memory of K32L2B easily.

For more specific OTA introductions, including HAPI and Concept, refer to **HAPI OTA** of KL27.

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2 Concepts

2.1 OTA update process

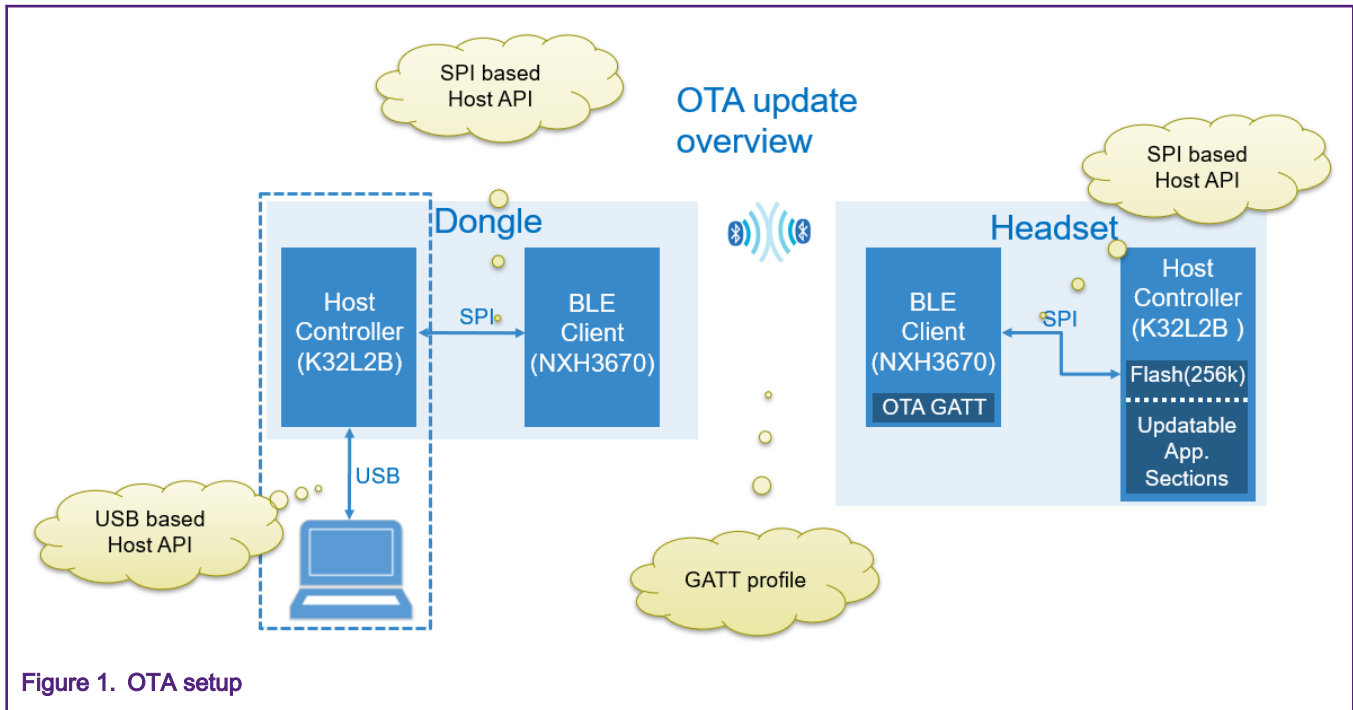


Figure 1. OTA setup

The setup requires a Dongle, Headset, PC and a USB cable connecting the Dongle and PC.

A typical scenario based on **K32L2B + NxH3670** is described as below:

1. Dongle and Headset are initially programmed over the USB interface.
2. Dongle and Headset are paired.
 - Pairing Data (PD) of Headset is independent on the PD of Dongle.

Once booted up, the Headset retrieves PD from its own Memory written in advance and will not store extra PD.
 - PD of Dongle is dependent on the PD of Headset.

Once booted up, the Dongle retrieves PD and pair with Headset, and then stores the Headset device information in Dongle's PD section (eg. Partition3: Device Info & Bonding Data).
3. Dongle is re-flashed with the `OTA_Dongle` application, which is the start of the OTA process.
 - `OTA_Dongle` can be used as VCOM to transfer data between PC and K32L2B through the USB.
 - Before re-flashing operation, make sure that PD is not erased. (Dongle is responsible for getting Headset's device information and `OTA_Dongle` is not). Two NXH devices are paired firstly and then connected, so they can't be connected if the user has erased PD data stored in Dongle's Flash.
 - In the Debug mode, the code takes up much space. The Headset board does not have enough spaces to store the binary data of Headset and `OTA_Headset` at the same time. So users can re-flash the Headset board with the `OTA_Headset` application to test the OTA function. User may need choose **Release mode** to make sure Flash has enough spaces to store firmware.
4. OTA process is triggered by PC application.
5. OTA finishes, firmware of Headset is updated.
6. Re-flash the Dongle with Gaming application.

2.2 Second Storage Bootloader (SSB)

The SSB is automatically bootstrapped by the (ROM) first stage bootloader.

You can store multiple firmware in flash according to your requirements and inform SSB which firmware to boot.

For example, considering Headset board has no USB port in the **K32L2B Bluetooth LE Audio System**, developers store at least three firmware in advance, including:

- **SSB**: To decide which firmware to boot.
- **OTA firmware**: To receive new firmware.
- **Application firmware**: An actual application, including specific Headset functions.

Taking the current demos as an example, SSB functions include:

1. Set the VTOR to the application vector table address.
2. Set stack pointers to the application stack pointer.
3. Jump to the application (PC now point to application).

NOTE

The current design uses NXH3670 to transfer data over the air and program K32L2B via the SPI interface assisted by the SSB code.

2.3 Partition table

The **Dongle**, **OTA_Dongle**, **Headset** and **OTA_Headset** applications and their locations are required to be mapped in Flash. This mapping is present in the Partition Table stored at a fixed offset in the Flash memory of the Host controller. For more information, refer to HAPI OTA.

[Figure 2](#) shows the partitions and offsets.

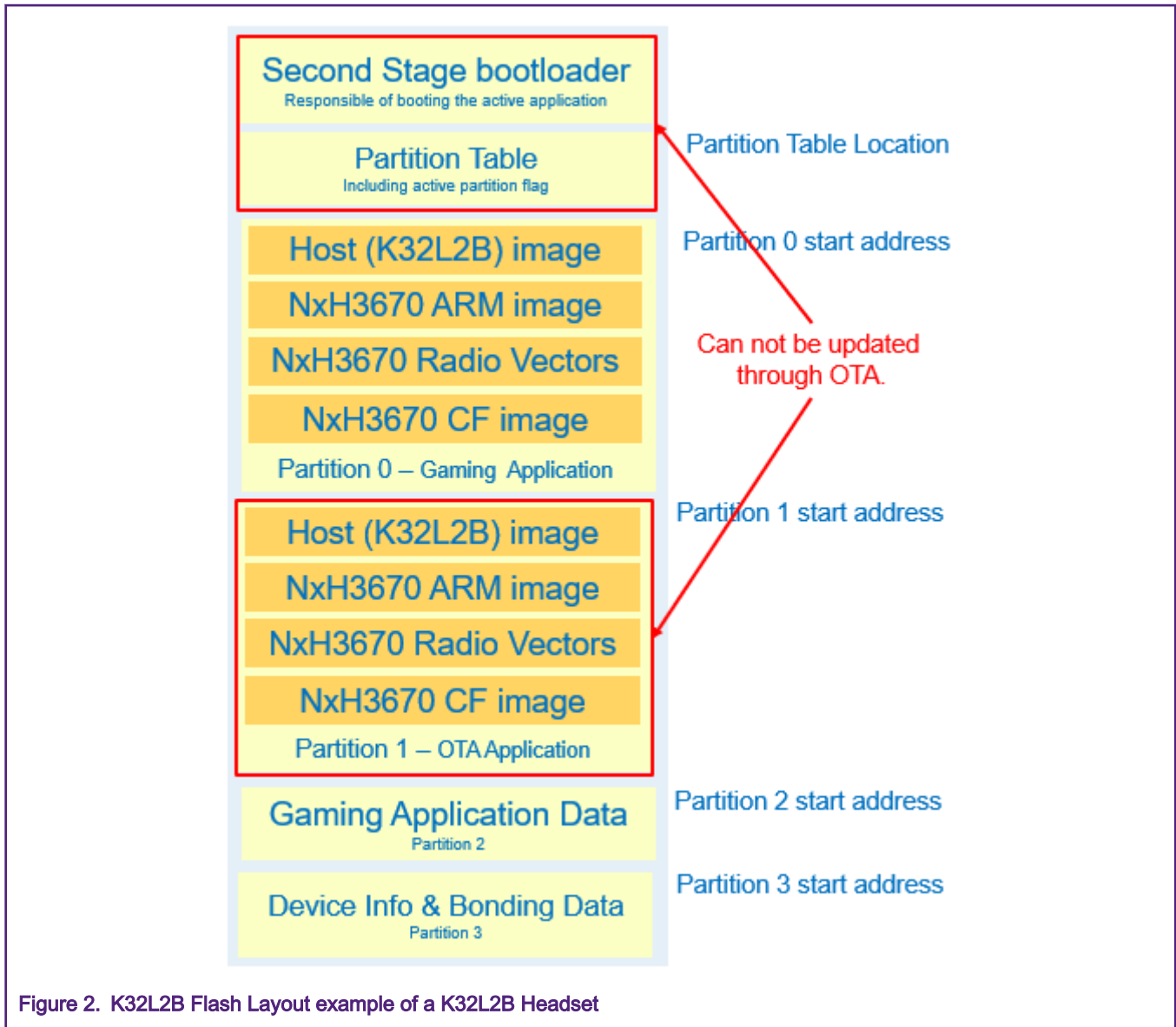


Figure 2. K32L2B Flash Layout example of a K32L2B Headset

- **Partition 0** is the Gaming Application. It contains the firmware for the K32L2B Host Controller firmware, the NxH3670 ARM image, the NxH3670 Audio Radio Vectors, and NxH3670 CoolFlux image.
- **Partition 1** is the OTA application. It contains the Host Controller (K32L2B) firmware and NxH3670 ARM Image. For OTA_Dongle, user only need to Flash `ota_app` and `NxH_Binary (ARM.phOtaDongle.ihex.eep)`.
 - `rfmac (rfmac.eep)` is added already in to `Nxh` image,
 - `CF (phStereoInterleavedAsrcTx.eep)` is not required/used.
- **Partition 2** contains Application data. As general-purpose data storage for the Gaming application, it is currently unused.
- **Partition 3** contains the Device info and Bonding data. Device information contains Bluetooth LE specific attributes that need to be present for the air interface to work. Bonding data makes sure that Dongle and Headset automatically reconnect. Bonding data is only relevant for the Dongle.

3 Using Flashtool

This document lists the operation steps of how to use .BAT to update firmware easily and quickly. For more information of Flashtool, refer to the HAPI OTA and tools sections in NXH3670_SDK_Gaming_G3.0.

3.1 Modification introduction

1. ota_update_headset.bat

```

20 if [%1] == [] (
21     choice /C AS /N /M "Updating an ADK[A] or SDK[S] board for headset?"
22     if ERRORLEVEL 2 (
23         set FLASHLIST=%APP_DIR%script\flashlist_release_sdk.yml
24         set LAYOUT=%APP_DIR%script\layout_release_sdk.yml
25         goto USB_CONFIG_U
43 if [%1] == [sdk] (
44     set FLASHLIST=%APP_DIR%script\flashlist_release_sdk.yml
45     set LAYOUT=%APP_DIR%script\layout_release_sdk.yml
46     goto USB_CONFIG_C

```

User need replace 'flashlist_release_adk_headset.yml' with their own 'flashlist_xxx.yml'
User need replace 'layout_release_adk_headset.yml' with their own layout_xxx.yml

```

74 call %FLASHTOOL% --dev %USBPORT% --connection ota --flash-list %FLASHLIST%
--layout %LAYOUT% --partition 0 --activate 0 --flash-only nxh_app,rfmac,cf,kl_app -v

```

User need choose update which Partition over the air (Partition x)
User need choose activate which Partition after over the air update(Active x)
User can choose which images to update

Figure 3. ota_update_headset.bat modification introduction

With JLink, perform the following steps to convert .yml of Partition table to .BIN that will be downloaded to Flash.

- a. Open a command line interface
- b. Go to your NXH3670_SDK_Gaming_G3.0 folder
- c. Run `flash_scripts\flashtool.cmd -> dev table.bin -> connection export -> layout`
`kinetis_democode\apps\kl_dongle\script\layout_debug_sdk.yml`

```

C:\k127\NXH3670_SDK_Gaming_G3.0>flash_scripts\flashtool.cmd --dev table.bin --connection export
--layout kinetis_democode\apps\kl_dongle\script\layout_debug_sdk.yml
##### creating partition table layout ...
+++ reading layout file (kinetis_democode\apps\kl_dongle\script\layout_debug_sdk.yml) ...
+++ flashing the layout ...

```

table.bin	BIN File	2019/5/13 16:51	3 KB
-----------	----------	-----------------	------

Figure 4. Convert .yml to bin

However, first 2560 (0xA00) bytes of this table.bin are all 0x00. This document introduces two methods to handle it.

- Make sure that table.bin is flashed before flashing the SSB located in 0x00. Otherwise, the table.bin will overwrite the SSB. So for OTA, user have to port the kl_ssb application or flash SSB file as well.
- Or, you can delete 2560 (0xA00) bytes of this table.bin and then download the changed table.bin to Partition table address.(In our software, we put it to 0x3f400).

2. flashlist_release_sdk.yml

```

1 ▾ binaries:
2 ▾   - name: ssb
3     files:
4       - kinetis_democode/apps/kl_ssb/sdk/release/kl_ssb_sdk.bin
5     address: 0x0
6 ▾   - name: kl_app
7     files:
8       - kinetis_democode/apps/kl_headset/sdk/release/kl_headset_sdk.bin.eep
9     offset_index: 0
10    partition: { name: "app", type: firmware }
11    headroom: -1,

```

kl_ssb_sdk.bin
kinetis_democode/apps/kl_headset/sdk/release/kl_headset_sdk.bin.eep

User can replace 'kl_ssb_sdk.bin' with their own SSB.bin
User can replace this location with their own location for firmware
User can replace 'kl_headset_sdk.bin.eep' with their own '.EEP' bin

Figure 5. flashlist_release_sdk.yml modification introduction

flashlist_release_sdk.yml (kl_headset) lists the binaries and offset_index of Partition to be used to operate OTA. In this example, the user want update 'kl_headset_sdk.bin.eep' to offset_index_0 of the current Partition.

3. layout_release_sdk.yml

```

7  # partition_id 0
8  - name: "app"
9  type: firmware
10 base address: 0xbf0
11 size: 0x2a000 # 168 KB
12 offsets:
13 - 0x0 # kl_app | 52 KB (21 KB free)
14 - 0xd010 # nxh_app | 65 KB (4 KB free)
15 - 0x1d410 # rfmac | 18 KB (2 KB free)
16 - 0x21c10 # cf | 32 KB (2 KB free)
17 # partition_id 1
18 - name: "ota"
19 type: firmware
20 base address: 0x2abf0
21 size: 0x14c00 # 83 KB
22 offsets:
23 - 0x0 # kl_ota_app | 24 KB
24 - 0x6010 # nxh_ota_app | 58 KB
    
```

- ▢ If user want put OTA related code in Partition0, they can replace 'app' with 'ota'
- ▢ Partition0's base_address
- ▢ The offsets of Images in Partition0 is based on base_address.
- ▢ Partition1's base_address should be equal to or bigger than the sum of Partition0's address and size.

Figure 6. layout_release_sdk.yml modification introduction

You can design your own layout_release_sdk.yml to meet the use of Flash. In the software design, MCU reads NXH_Binaries from specified location and then transfer data to NXH3670 through the SPI interface. Make sure the design of Flash layout is correct.

Perform the following step to convert .BIN to .EEP that will be used in OTA process.

- Use ...tools\to_eep.cmd by inputting -i XXX.bin -o XXX.bin.eep

The screenshot shows a Windows command prompt window with the following command entered: `to_eep.cmd -i XXX.bin -o XXX.bin.eep address=0x0 length=111`. Below the command prompt, a file explorer window shows the directory `NXH3670_SDK_Gaming_G3.0 > tools`. The file explorer displays a list of files: `to_eep.cmd` (Windows Command), `XXX.bin` (BIN File), `XXX.bin.eep` (EEP File), and `XXX.bin.eep.hex` (HEX File).

Figure 7. Converting .BIN to .EEP

3.2 Test process

When users change `ota_update_headset.bat`, `flashlist_release_sdk.yml` and `layout_release_sdk.yml` correctly, OTA can work.

Assuming that **Dongle** and **Headset** have already paired successfully, follow the steps as below.

1. Download `OTA_Dongle` and make sure that the PC can recognize it as a **USB Serial Device**.

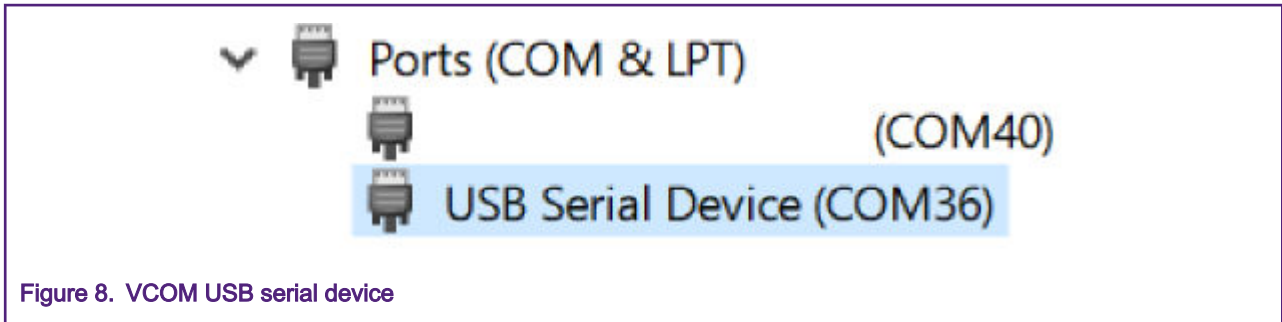


Figure 8. VCOM USB serial device

As shown in [Figure 8](#), PC recognize it as **COM36**.

2. This document list two cases:
 - a. **Case 1:** Users are running `app` instead of `ota_app`.
 - In the **Release mode**, `Active_flag` of `APP_Partition` is **0** (Partition 0 – Gaming Application) currently, which indicates that users need send command to switch `Active_Partition` from **0** to **1** (Partition 1 – OTA Application).

```
##### flashing binaries ...
+++ reading flash list file ...
+++ checking flash list file ...
+++ connecting to the remote device ...
+++ switching remote active partition to OTA partition ...
+++ rebooting remote to UIA partition ...
+++ connecting to the remote device ...
+++ getting remote table version ...
```

Figure 9. Need Switch operation

- If users use `phOtaHeadset.ihex.eep` instead of `phGamingRx.ihex.eep` in the **app** case, it means they have boot and start `NXH3670` as OTA function (users can use OTA-related tool to communicate with Dongle board with firmware `phOtaHeadset.ihex.eep`) and do not need switch remote `Active_Partition` actually. However, the `hci_table` of **app** do not have OTA related code, so it cannot be used to operate OTA .
- b. **Case 2:** Users are running `ota_app` and `NXH_Binary` is `phOtaHeadset.ihex.eep`.
 - In the **Debug mode**, `Active_flag` of `OTA_Partition` is **1** (Partition 1 – OTA Application) currently, which indicates that the code is ready for OTA process and do not need switch remote `Active_Partition`.

The following example assumes that user is using [Case 1](#).

Open a command line interface and go to the `flash_scripts` folder. Input:

- `ota_demo_sdk.bat` (Users may change it and rename it)
- `board` (this document uses the SDK board to test, so input **S**)
- USB port name (**COM36**).


```

C:\k127\NXH3670_SDK_Gaming_G3.0\flash_scripts\ota_update_headset_ADZ96_20190511.bat
Updating an ADK[A] or SDK[S] board for headset? S
Enter USB port name of dongle: COM36
The USB port is COM36
Serial port COM36 opened
+++ reading layout file (C:\k127\NXH3670_SDK_Gaming_G3.0\flash_scripts\..\kinetis_democode\apps\k1_headset\script\layout
.release.sdk.ADZ96_20190511.yml)...
##### flashing binaries ...
+++ reading flash list file ...
+++ checking flash list file ...
+++ connecting to the remote device ...
+++ getting remote table version ...
version: 48
--- skipping ssb image
+++ flashing k1_app @ index 0 ...
+++ calculating local fingerprint for index 0 ...
local fingerprint: 3517288705
+++ getting remote fingerprint for index 0 ...
remote fingerprint: 1995252804
@ [1]0 0x0 -> kinetis_democode/apps/k1_headset/sdk/release/4_1_led_blinky_2ABF0_eep.eep
[#####] 100%
--- skipping pairing_data image
--- skipping k1_ota_app image
--- skipping nxh_ota_app image
+++ changing remote active partition (1) ...
+++ rebooting remote to active partition ...
    
```

ota_update_headset_ADZ96_20190511.bat
S
COM36
layout
.release.sdk.ADZ96_20190511.yml

[#####]

ota_update_headset_ADZ96_20190511.bat
S
COM36
layout
.release.sdk.ADZ96_20190511.yml

[#####]

- ota_update_headset_ADZ96_20190511.bat The new changed '.bat', 'yml' and 'eep' files according user's design
- S The character that need user input.
- [#####] Command send from 'OTA_Dongle' to 'Headset' and event received from 'Headset' to 'OTA_Dongle'.(Flashtool will do this according user's '.bat' file)

Figure 10. CMD of OTA process

As shown in Figure 10, [#####] 100% indicates the update progress.

3. LOG information

To view OTA progress better, users can download OTA_Headset_Debug_mode code that can provide the LOG information.

```

k1_headset] WriteToPartition event (20 bytes @ id: 1 | offset: 0x11a8
k1_headset] WriteToPartition event (20 bytes @ id: 1 | offset: 0x11bc
k1_headset] WriteToPartition event (20 bytes @ id: 1 | offset: 0x11d0
k1_headset] WriteToPartition event (20 bytes @ id: 1 | offset: 0x11e4
k1_headset] WriteToPartition event (20 bytes @ id: 1 | offset: 0x11f8
k1_headset] WriteToPartition event (20 bytes @ id: 1 | offset: 0x120c
k1_headset] WriteToPartition event (20 bytes @ id: 1 | offset: 0x1220
k1_headset] WriteToPartition event (20 bytes @ id: 1 | offset: 0x1234
    
```

Figure 11. OTA_Headset WriteToPartition event

4 Software design

In order to describe the software design clearly, some programs are attached for user as reference.

4.1 Code of SSB

```

enum _vector_table_entries { kInitialSP = 0,kInitialPC };

uint32_t *appVectorTable = NULL;
uint32_t applicationAddress = 0;
uint32_t stackPointer = 0;

appVectorTable = (uint32_t *) (entry.startAddress + entry.imageOffsets[0] +
NVMMGR_EEP_INITIAL_HEADER_SIZE);
applicationAddress = appVectorTable[kInitialPC];
stackPointer = appVectorTable[kInitialSP];
    
```

```
JumpToApplication(applicationAddress, stackPointer);
```

```
void JumpToApplication(uint32_t applicationAddress, uint32_t stackPointer)
{
    /* Static variables are needed as we need to ensure the values we are using are not stored on the
    previous stack */
    static uint32_t s_stackPointer = 0;
    s_stackPointer = stackPointer;
    static void (*farewellBootloader)(void) = 0;
    farewellBootloader = (void (*)(void))applicationAddress;

    /* Set the VTOR to the application vector table address */
    SCB->VTOR = applicationAddress;

    /* Set stack pointers to the application stack pointer */
    __set_MSP(s_stackPointer);
    __set_PSP(s_stackPointer);

    /* Jump to the application */
    farewellBootloader();
}
```

```
bootValidApp    PROC
                EXPORT  bootValidApp
    LDR    r1, [r0, #0]    ; Get app stack pointer
    MOV    sp,r1          ;
    LDR    r1, [r0, #4]    ; Get app reset vector
    BX    r1              ; PC now point to App_Firmware
    ENDP
```

4.2 Code of OTA receive

To let users understand the OTA receive process easily, this section provides an **event handler** in the `OTA_Headset` code: `HCI_VS_WRITE_TO_PARTITION_SUB_EVENT`, to introduce how to write firmware to Flash.

Assuming Dongle board is running the **OTA_Dongle** demo and Headset board is running **OTA_Headset** demo, the NXH3670 of Headset can receive event from Dongle and transmit event to Host Controller (K32L2B) through the SPI interface.

1. The NXH3670 of Headset receive `HCI_VS_WRITE_TO_PARTITION_SUB_EVENT (0Xe1)` sent from the NXH3670 of Dongle, then will run `HCI_EvtWriteToPartitionHandler`.

```
{
    .evtCode = HCI_VS_EVENT_CODE,
    .subEvtCode = HCI_VS_WRITE_TO_PARTITION_SUB_EVENT,
    .evtHandler = HCI_EvtWriteToPartitionHandler,
    .evtParamsLen = HCI_UNDEFINED_PARAMETER_LENGTH,
},
```

2. Write the data to the requested partition with offset. This document lists some APIs as below:
 - Users need to write outside of the current cached sector, so all data need to be copied in the current sector.

```
ReadFromFlash(s_Context.cacheBuf, SECTOR_SIZE_IN_BYTES, s_Context.cachedSectorAddr)
```

- Users can modify Cache with the data sent from NXH3670 of Dongle board.

```
memcpy(&s_Context.cacheBuf[cacheOffset], data, cpyLen);
```

- When the data of one packet is copied to `cacheBuf`, users can program Sector by using Flash write API.

```
ProgramSector(s_Context.cacheBuf, SECTOR_SIZE_IN_BYTES, s_Context.cachedSectorAddr);
```

3. The operation is successful to NXH3670 with a command as below:

```
HCI_CmdDataWrittenToPartition(&req);
HCI_SendCmdBlocking(&req)
```

4.3 Code of OTA send

To let user understand the OTA send process easily, this section uses Pseudo code to introduce how **OTA_Dongle** sends firmware to **OTA_Headset**.

```
void UsbVcomDataReceived_Cb(uint32_t length, uint8_t *data)
{
    switch (opcode) {
        case HCI_CMD_VS_CONNECT_OPCODE: {
            ...
            HCI_CmdPrepareConnect(&hciReq, &connectParams);
            ...
            break;}

        default: {
            ...
            HCI_CmdPrepareHostGenericCmd(&hciReq, data, length);
            ...
            break;}
    }
}
```

NOTE

- **Case** `HCI_CMD_VS_CONNECT_OPCODE`
This CMD means that the **OTA_Dongle** wants to connect **OTA_Headset**.
- **Default** CMD
OTA_Dongle will send any other CMD to **OTA_Headset** by using NXH3670. Actually, the MCU of **OTA_Headset** is responsible for writing these data to Flash.

5 Conclusion

Users can implement program update by using the Flashtool and files in `NXH3670_SDK_Gaming_G3.0`. Changes may be required on design needs. The firmware update speed via OTA is about 1 KB per second.

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Date of release: 01/2020

Document identifier: AN12649

