

Using the over-the-air bootloader with STM32W108 devices

1 Introduction

This document describes the over-the-air bootloader provided for STM32W108 devices. The over-the-air (OTA) bootloader is a modified version of the USART-based bootloader specified in application note AN3155 in order to deal with an 802.15.4 wireless communication channel rather than a USART cable.

For more information, please refer to application note AN3155 *USART protocol used in the STM32 bootloader* available from www.st.com/stm32w.

This document applies to the following STM32W108xx kits:

- STM32W108xx starter kit (part number: STM32W-SK)
- STM32W108xx extension kit (part number: STM32W-EXT)
- STM32W108xx low-cost RF control kit (part number: STM32W-RFCKIT).

Overview

The purpose of the OTA bootloader application is to enable any node to receive a firmware image over the air using the 802.15.4 interface and write it in Flash memory. In this context, nodes willing to update their Flash contents with the new image are referred as bootloader device nodes, while those in charge of transmitting the image over the air will be called bootloader host nodes.

Figure 1. Memory layout

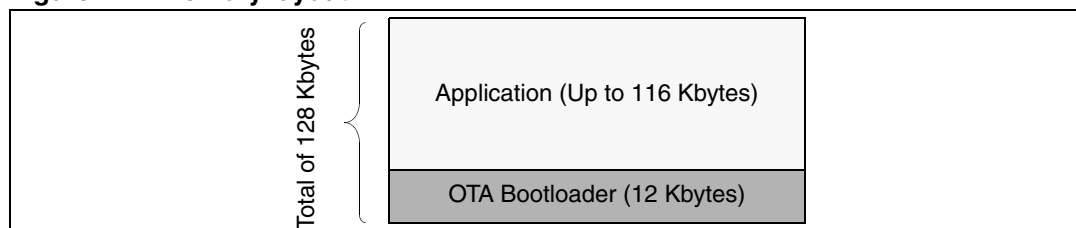


Figure 1 shows the memory layout of a bootloader device node; in order to be defined as such it needs an OTA bootloader application image loaded right from the beginning at the base of the STM32W Flash area (0x08000000) and any user application to run on the node will have to sit on the top of the OTA bootloader. The bootloader takes 12 Kbytes leaving up to 116 Kbytes free for user applications. At chip reset, control is passed to the bootloader which in turn jumps to the application if present in Flash memory, or else it will just remain in its main loop waiting for valid image packets sent by a host from the 802.15.4 RF interface. It is also possible to override the default 'jump to application' behavior by forcing a bootloader startup using a user-defined action (for example, a button press after reset). The bootloader can eventually be started up from the application as well, but it depends on the application; details related to bootloader activation criteria are out of the scope of the bootloader code.

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2 Communication protocol

A bootloading session consists of exchanges of commands codes and related data between bootloader device (target) and host (transmitter) nodes. The protocol chosen for this purpose is the same one as specified in application note AN3155 for STM32 USART bootloader; its commands are a subset of those specified. The command set is further described in the next section. The replacement of USART (universal synchronous/asynchronous receiver/transmitter) with the 802.15.4 standard for point-to-point transmission of bits over the air, implies the deployment of all the well-known features to cope with lossy channels such as CRC check, MAC level ACK detection and packet retries in addition to all the functions that the (higher level) protocol provides to improve the reliability of communication as described in the next section.

Commands and data are sent in the 802.15.4 payload which is variable in size according to the specific information to be sent. 802.15.4 packets can be sent unicast and broadcast. Broadcast packet are supported by a subset of commands and they are useful to discover nodes in bootloader mode.

Figure 2 shows the selected format for a unicast 802.15.4 packet.

Figure 2. 802.15.4 packet format for unicast packet transmission

Frame Control (2 bytes)	Sequence Number (1 byte)	Destination Pan ID (2 bytes)	Destination EUI64 (8 bytes)	Source EUI64 (8 bytes)	Payload (variable)	FCS (2 bytes)
0x61 0xCC						

Figure 3 shows the selected format for a broadcast 802.15.4 packet.

Figure 3. 802.15.4 packet format for broadcast packet transmission

Frame Control (2 bytes)	Sequence Number (1 byte)	Destination Pan ID (2 bytes)	Destination Short Address (2 bytes)	Source EUI64 (8 bytes)	Payload (variable)	FCS (2 bytes)
0x01 0xC8		0xFFFF	0xFFFF			

The communication channel (between channels 11 and 26) and the PAN ID can be freely chosen by the application before it launches the bootloader. In the case, where the bootloader is not started by the application, it will run on a default channel (15) and default bootloader PAN ID 0xB00B.

3 Bootloader command set

Table 1 lists commands supported by the OTA bootloader. A detailed command-by-command protocol description follows.

Table 1. OTA bootloader commands

Command	Command code	Command description
GET ⁽¹⁾	0x00	Gets version number and list of commands allowed.
GET VERSION ⁽¹⁾	0x01	Gets bootloader version and Read Protection status of the Flash memory.
GET ID ⁽¹⁾	0x02	Gets chip ID of device.
ERASE	0x43	Erases memory pages of selected device.
WRITE MEMORY	0x31	Writes up to 96 bytes in memory of selected device.
WRITE INCREMENTAL MEMORY ⁽²⁾	0x36	Writes up to 96 bytes in memory of selected device incrementing next write address on device automatically.
READ MEMORY	0x11	Reads up to 96 bytes of memory starting from a user-specified address.
GO	0x21	Starts the code at a given location for a given device.

1. This command is supported by unicast and broadcast packets, while all the other are unicast only.
2. The WRITE INCREMENTAL MEMORY command is the only one not included in the original USART bootloader command set.

Communication safety

All communications from the Host to the device are verified by:

- Checksum: received blocks of data bytes are XORed. A byte containing the computed XOR of all previous bytes is added to the end of each communication (checksum byte). By XORing all received bytes, data + checksum, the result at the end of the packet must be 0x00.
- For each command, the host sends a byte and its complement (XOR = 0x00).

Each packet is either accepted (ACK) or discarded (NACK):

- ACK = 0x79
- NACK = 0x1F

3.1 GET command

The GET command is used to determine the version of the bootloader and the supported commands. When the bootloader receives the GET command, it transmits the bootloader version and the supported command codes to the host as shown in the figures below.

Figure 4. GET command (host side)

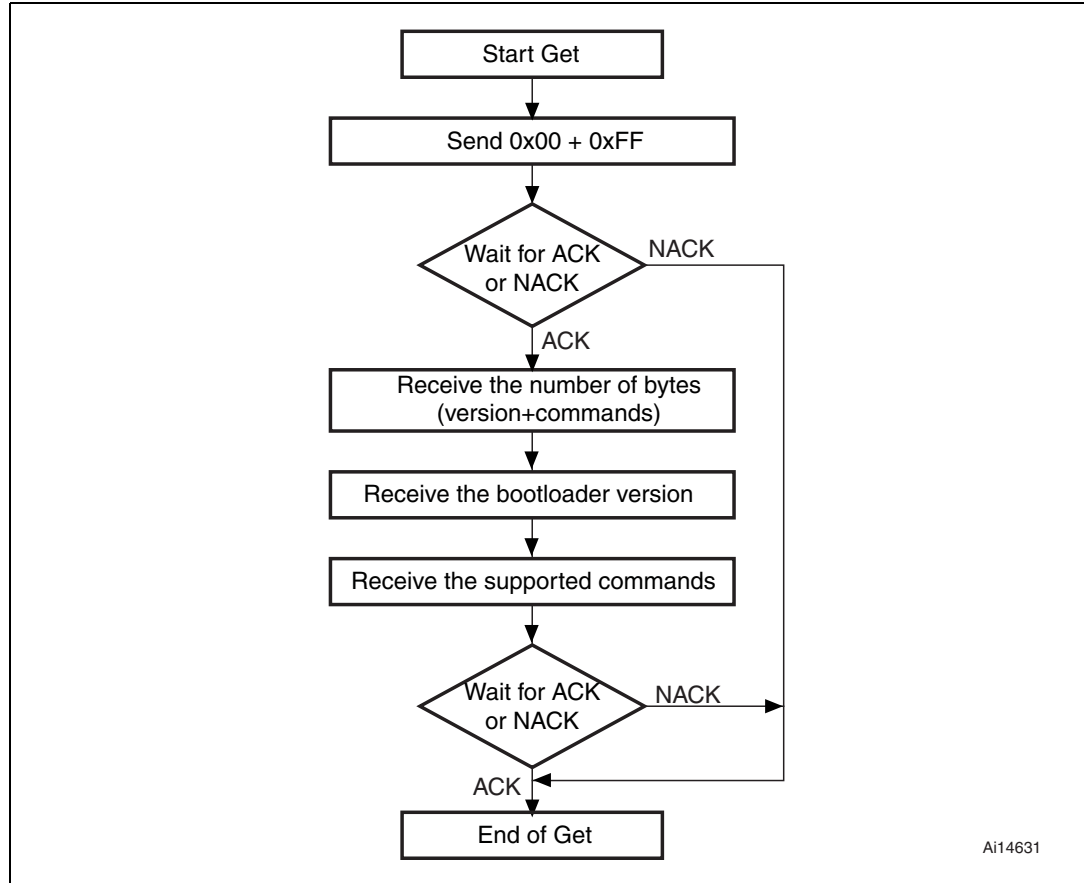
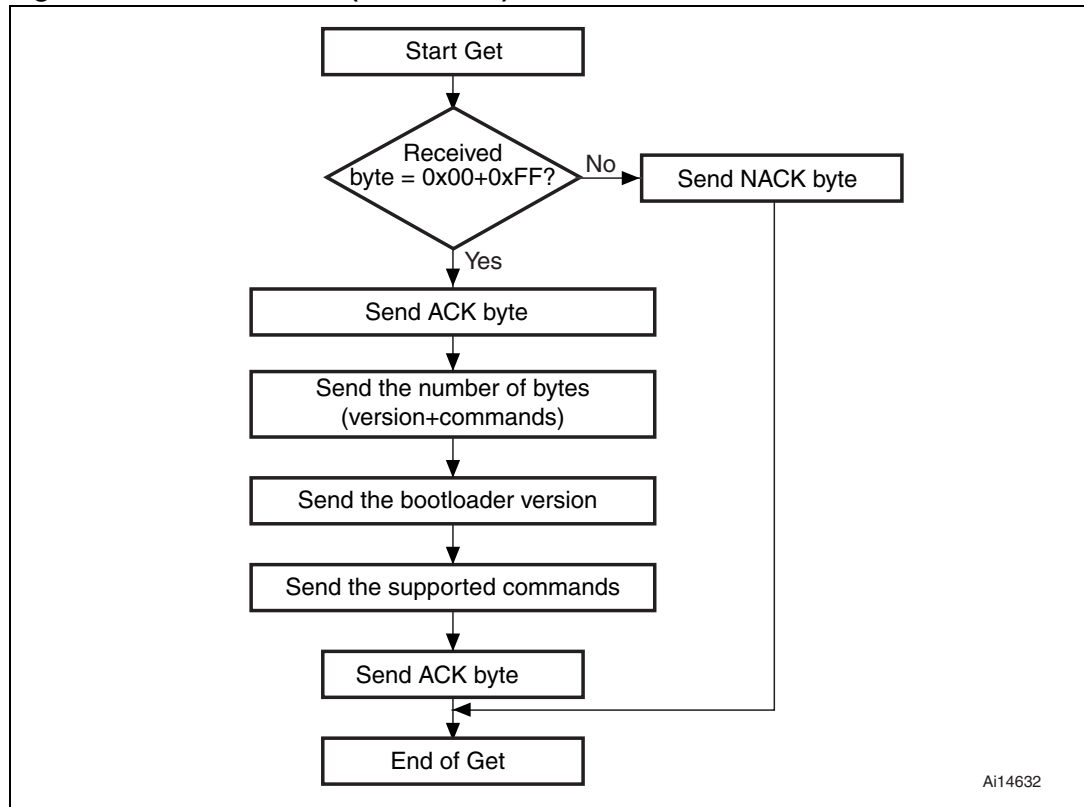


Figure 5. GET command (device side)



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All information sent by the device starting from the first ACK/NACK to the last ACK/NACK is contained inside a single 802.15.4 packet as shown in [Figure 6](#).

The STM32 sends the following bytes:

- Byte 1: ACK
- Byte 2: N = 09 (the number of bytes to follow – 1)
(Does not include the current byte and ACKs.)
- Byte 3: Bootloader version (0 < Version < 255)
- Byte 4: 0x00 GET command
- Byte 5: 0x01 GET VERSION; and
READ PROTECTION STATUS
- Byte 6: 0x02 GET ID
- Byte 7: 0x11 READ MEMORY command
- Byte 8: 0x21 GO command
- Byte 9: 0x31 WRITE MEMORY command
- Byte 10: 0x43 ERASE command
- Byte 11: 0x36 WRITE MEMORY INCREMENTAL command
- Last byte (15): ACK

Figure 6. GET packet example (unicast)

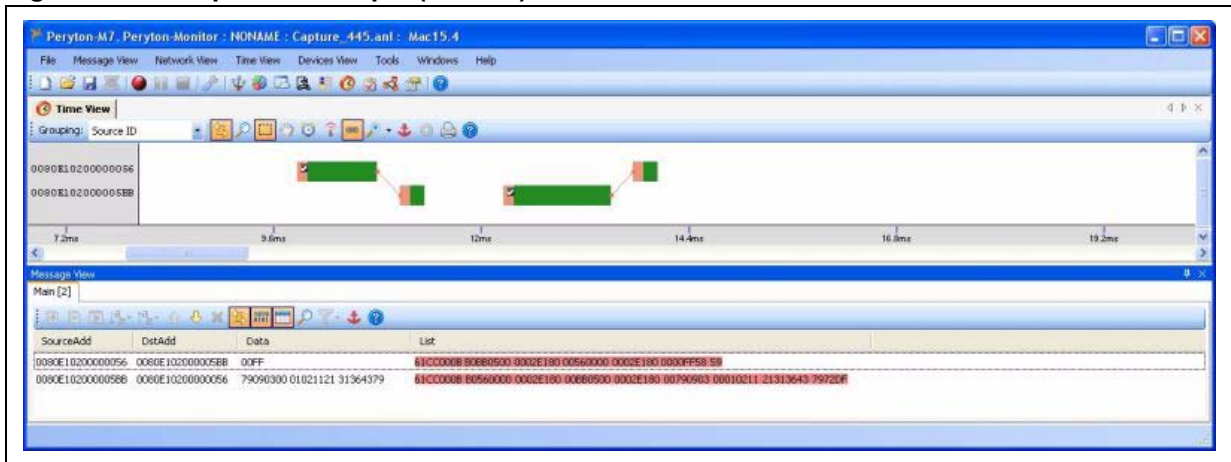
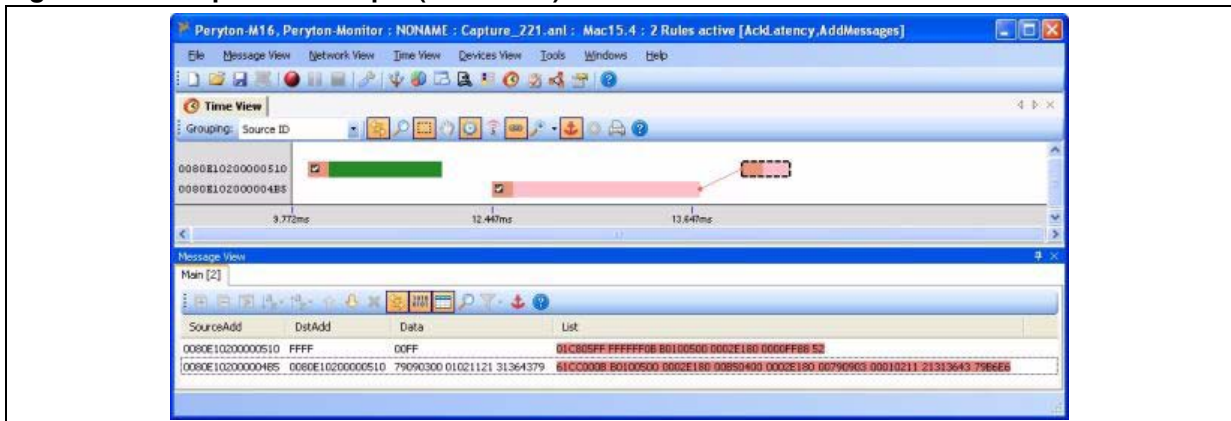


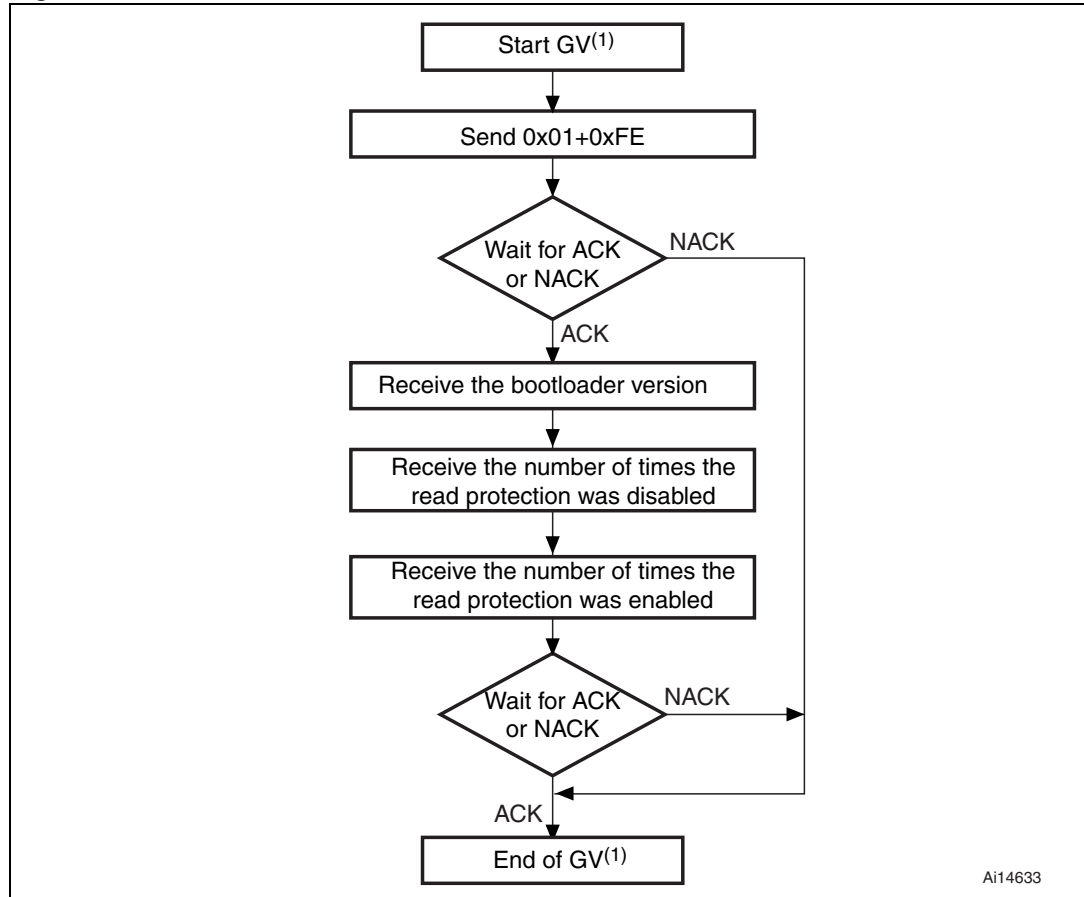
Figure 7. GET packet example (broadcast)



3.2 GET VERSION & READ PROTECTION STATUS command

The GET VERSION & READ PROTECTION STATUS command is used to get the bootloader version and the read protection status. When the bootloader receives the command, it transmits the information described below (version, read protection: number of times it was enabled and disabled) to the host.

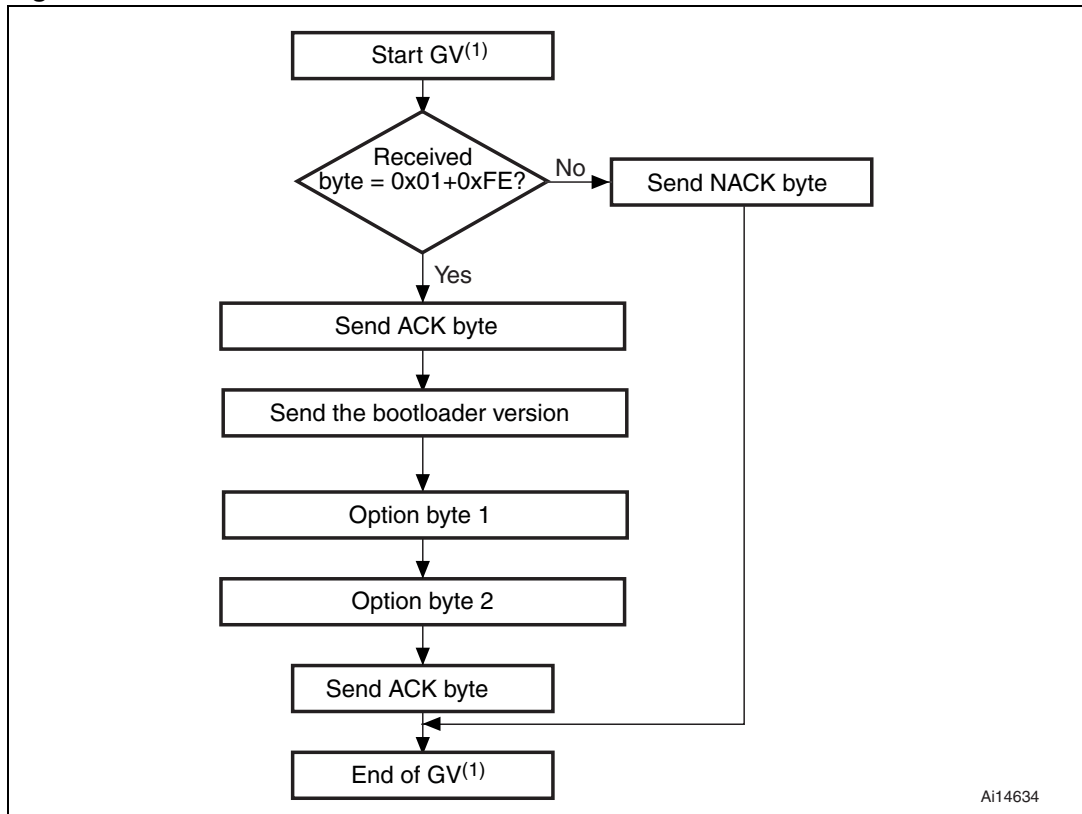
Figure 8. Get Version & Read Protection Status command: host side



1. GV = Get Version & Read Protection Status.

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Figure 9. Get Version & Read Protection Status command: device side



1. GV = Get Version & Read Protection Status.

The STM32 device sends the following bytes:

- Byte 1: ACK
- Byte 2: Bootloader version ($0 < \text{Version} \leq 255$)
- Byte 3: Option byte 1: 0x00 to keep the compatibility with generic bootloader protocol
- Byte 4: Option byte 2: 0x00 to keep the compatibility with generic bootloader protocol
- Byte 5: ACK

Figure 10. GET VERSION packet example (unicast)

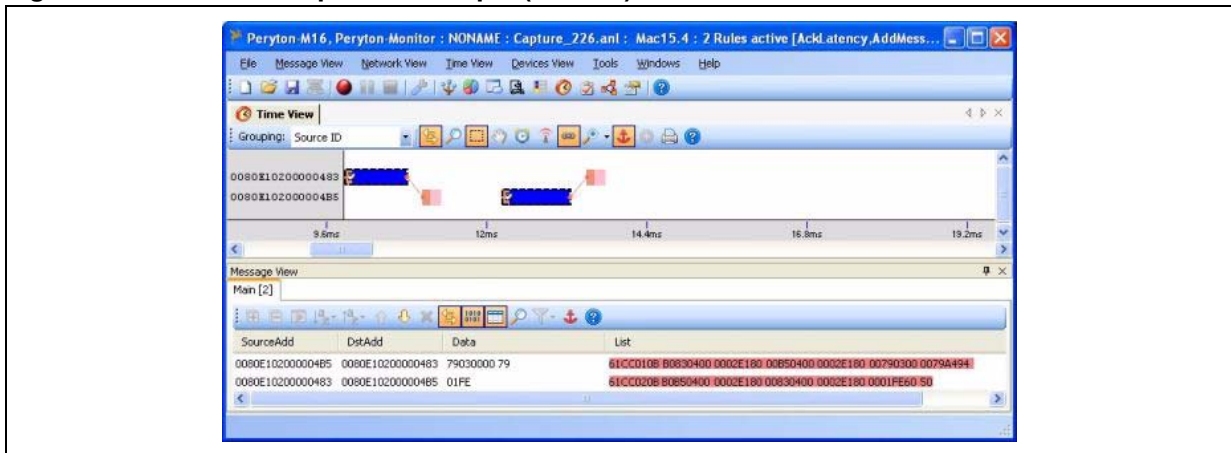
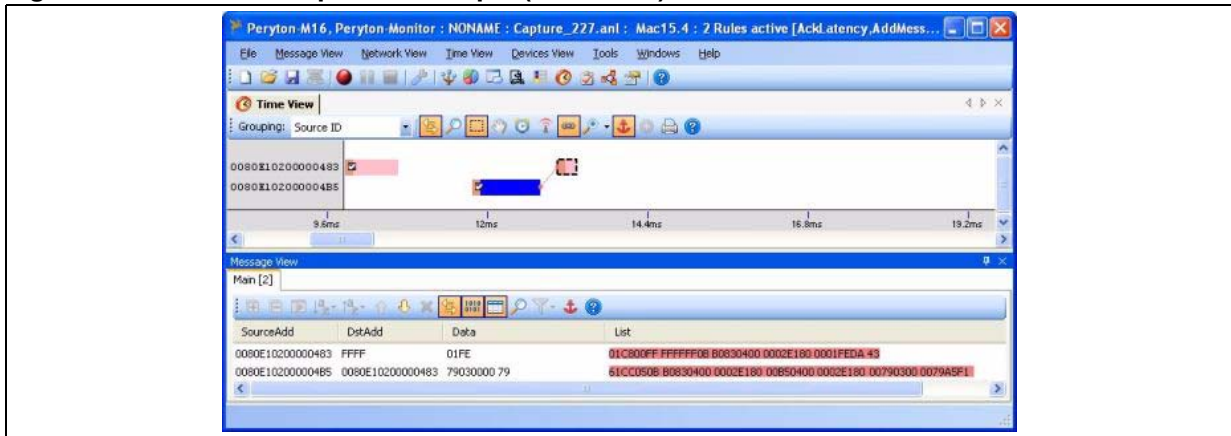


Figure 11. GET VERSION packet example (broadcast)



3.3 GET ID command

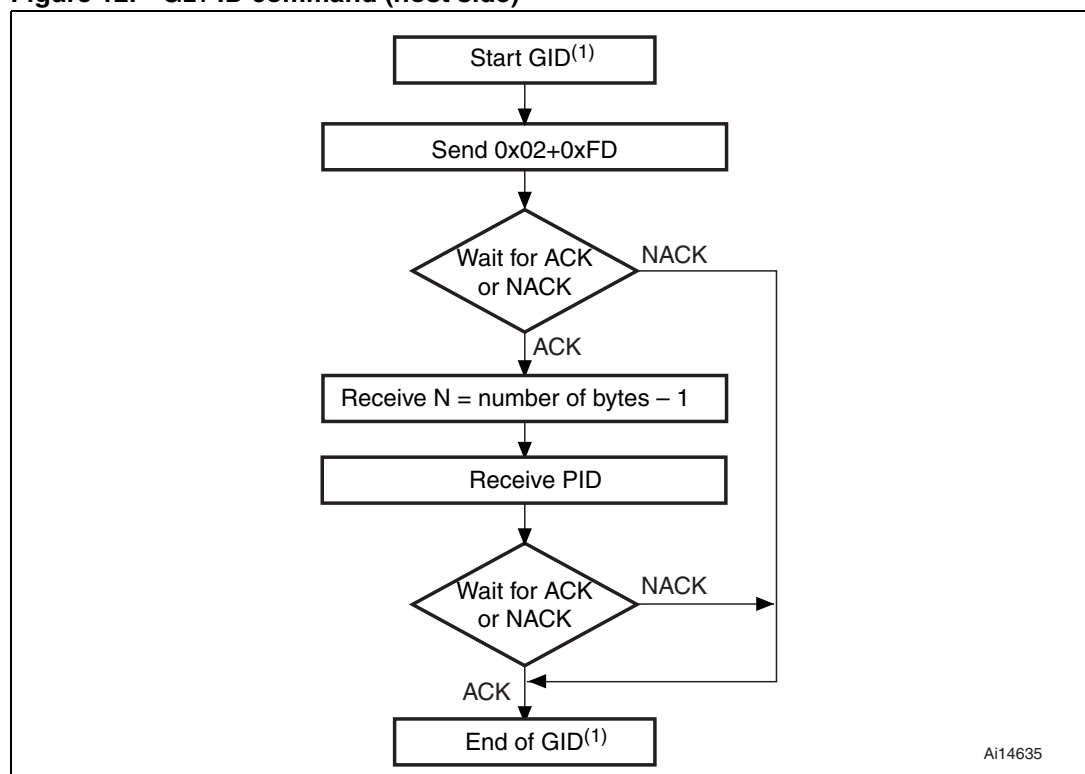
The GET ID command is used to get the version of the chip ID (identification). When the bootloader receives the command, it transmits the device ID to the host.

The STM32 device sends the following bytes:

- Byte 1: ACK
- Byte 2: N = the number of bytes - 1
(N = 1 for STM32), except for current byte and ACKs.
- Bytes 3-4: PID (Byte 3 = 0x09, Byte 4 = 0xA8)
- Byte 5: ACK

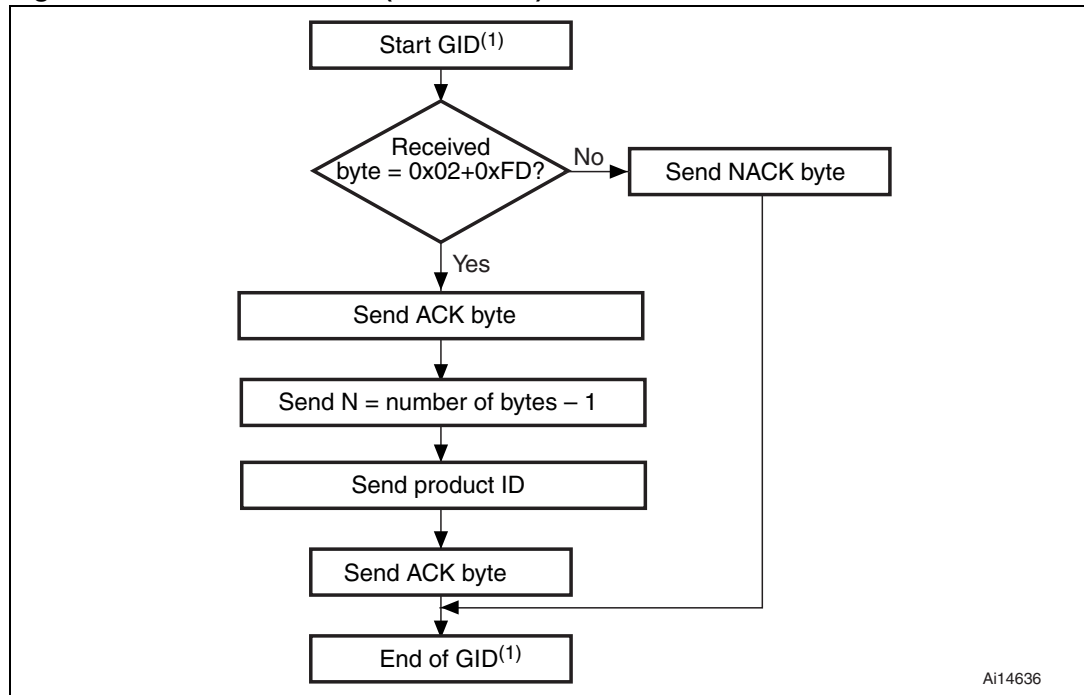
All information sent by the device starting from the first ACK/NACK to the last ACK/NACK is contained inside a single 802.15.4 packet as shown in [Figure 14](#).

Figure 12. GET ID command (host side)



1. GID = Get ID command.

Figure 13. GET ID command (device side)



1. GID = Get ID command.

Figure 14. GET ID packet example (unicast)

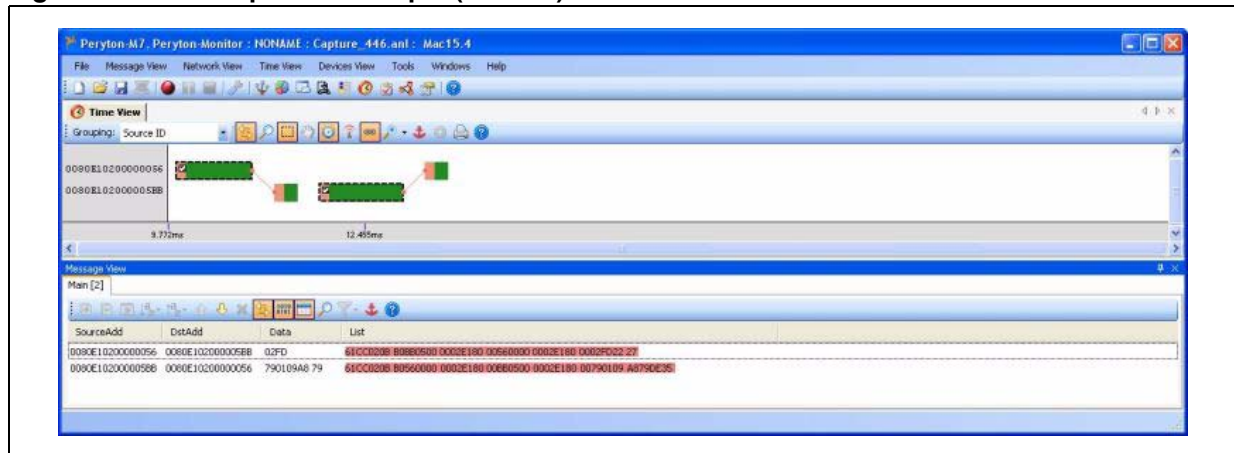
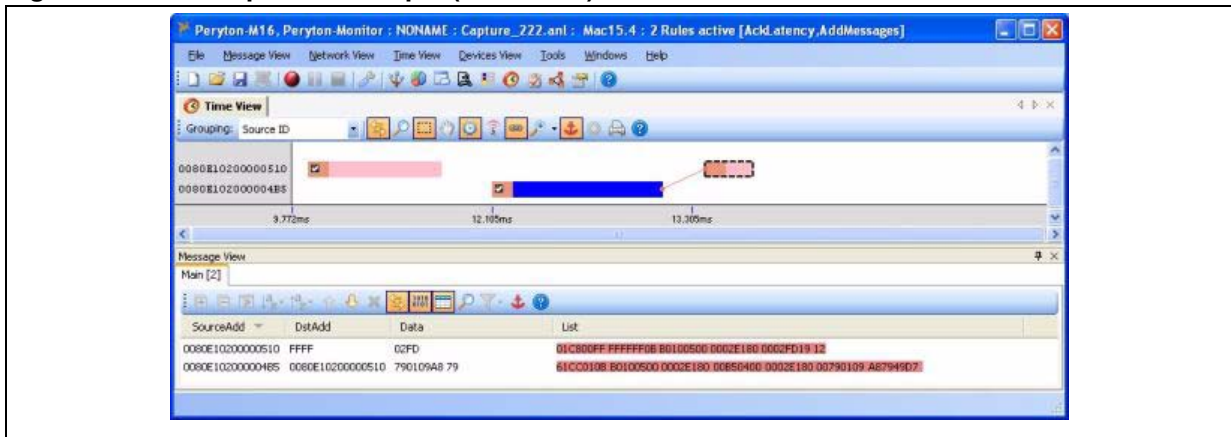


Figure 15. GET ID packet example (broadcast)



3.4 READ MEMORY command

The READ MEMORY command reads data from any valid memory address in RAM, Flash memory and the information block (System memory or option byte areas).

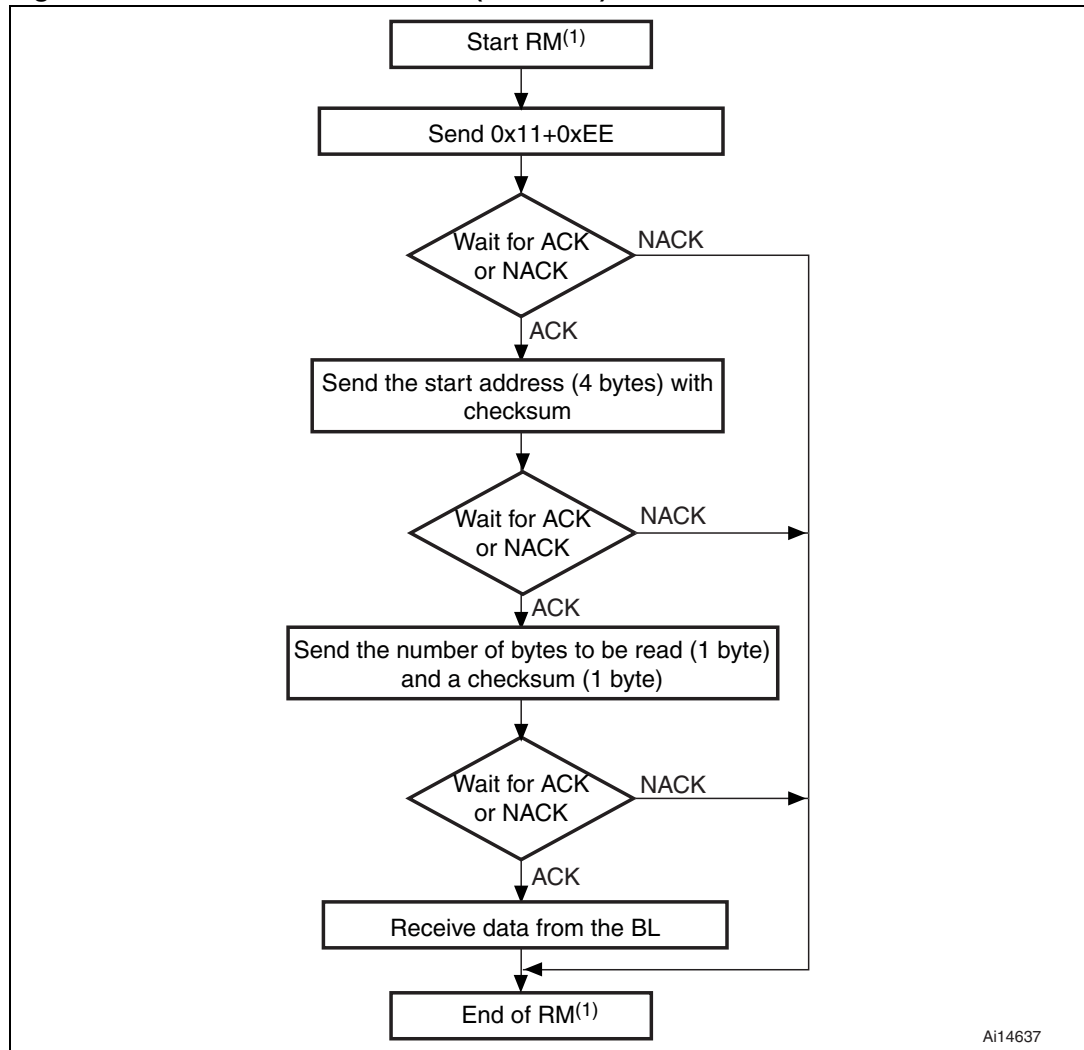
When the bootloader receives the READ MEMORY command, it transmits the ACK byte to the application. After sending the ACK byte, the bootloader waits for an address (4 bytes, where Byte 1 is the address MSB and Byte 4 is the LSB) and a checksum byte. Then it checks the received address. If the address is valid and the checksum is correct, the bootloader transmits an ACK byte, otherwise it transmits a NACK byte and aborts the command.

When the address is valid and the checksum is correct, the bootloader waits for the number of bytes to be transmitted – 1 (N bytes) and for its complemented byte (checksum). If the checksum is correct, it then transmits the needed data ((N + 1) bytes) to the application, starting from the received address. If the checksum is not correct, it sends a NACK before aborting the command.

The host sends bytes to the STM32 as follows:

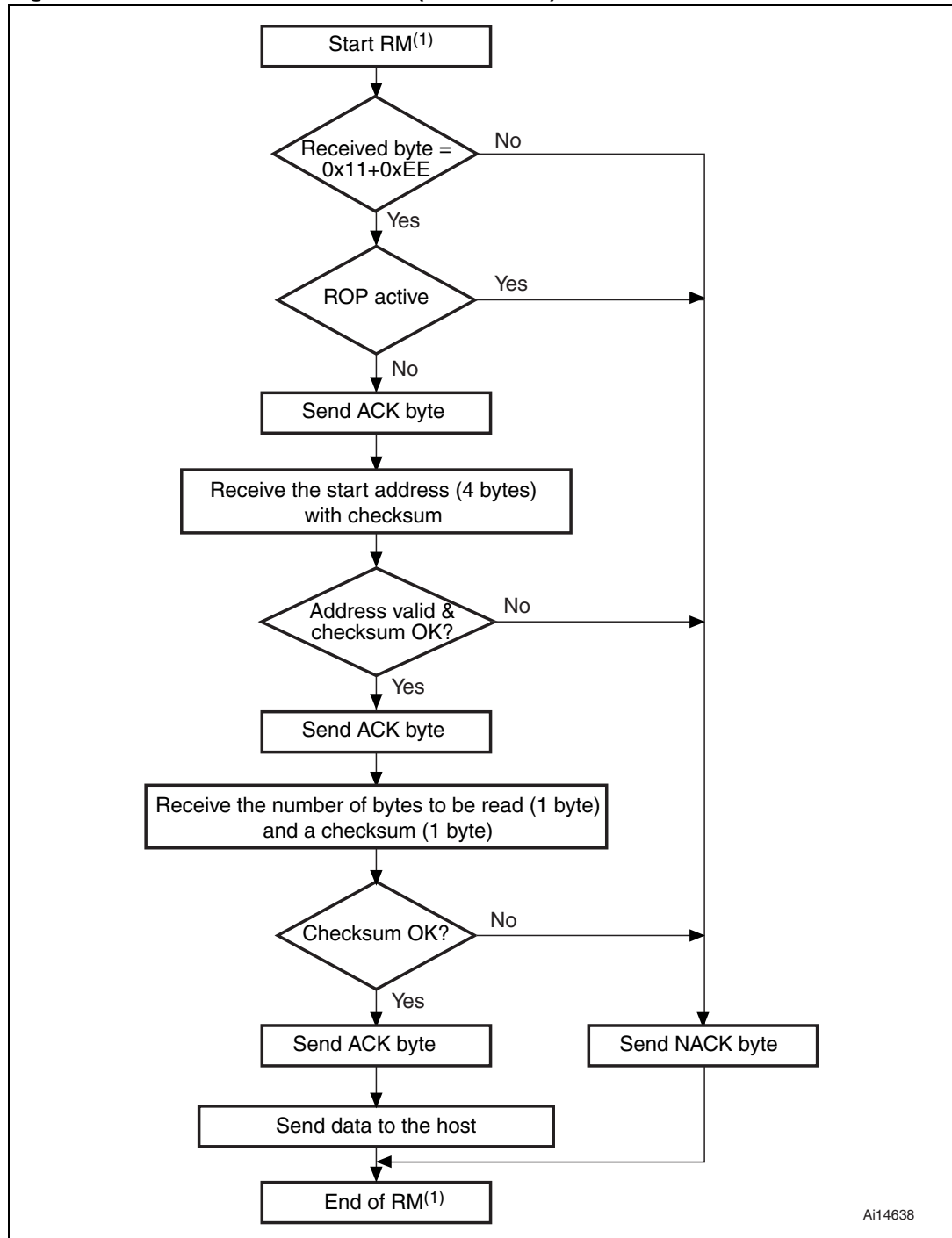
- Bytes 1-2: 0x11+0xEE
- Wait for ACK*
- Bytes 3 to 6: Start address (Byte 3 is MSB and Byte 6 is LSB)
- Byte 7: Checksum (XOR value of Bytes 3 to 6)
- Wait for ACK*
- Byte 8: The number of bytes to be read – 1 ($0 < N \leq 95$);
- Byte 9: Checksum (XOR value (complement) of Byte 8)

Figure 16. READ MEMORY command (host side)



1. RM = READ MEMORY command.

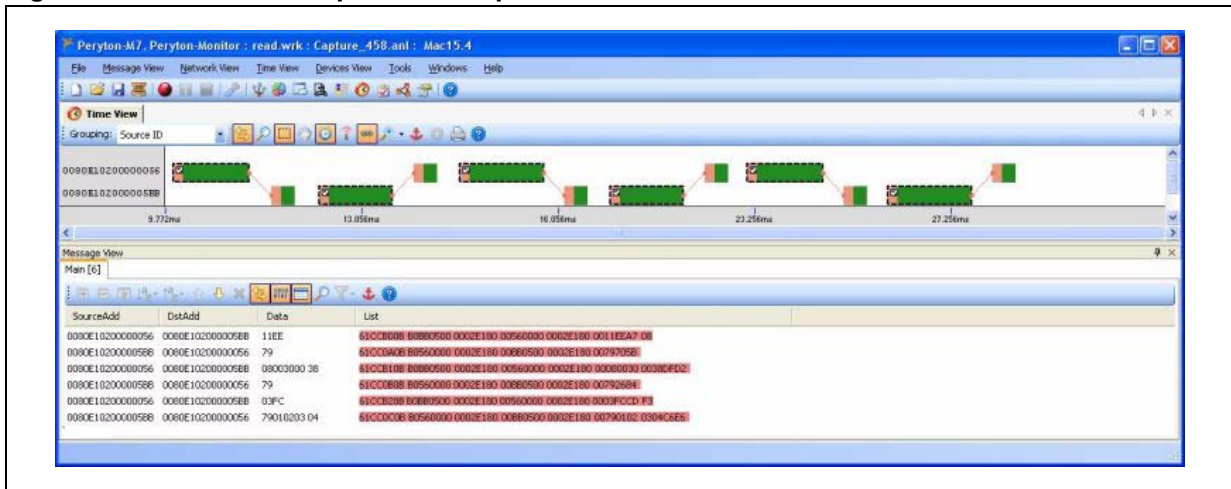
Figure 17. READ MEMORY command (device side)



1. RM = READ MEMORY command.

The last ACK/NACK is sent before the data block to be read within the same 802.15.4 packet payload (while other ACK/NACKs are sent in independent packets).

Figure 18. READ MEMORY packet example



3.5 Go command

The GO command is used to execute the downloaded code or any other code by branching to an address specified by the application. When the bootloader receives the GO command, it transmits the ACK byte to the application. After sending the ACK byte, the bootloader waits for an address (4 bytes, where Byte 1 is the address MSB and Byte 4 is LSB) and a checksum byte, then it checks the received address. If the address is valid and the checksum is correct, the bootloader transmits an ACK byte; otherwise, it transmits a NACK byte and aborts the command.

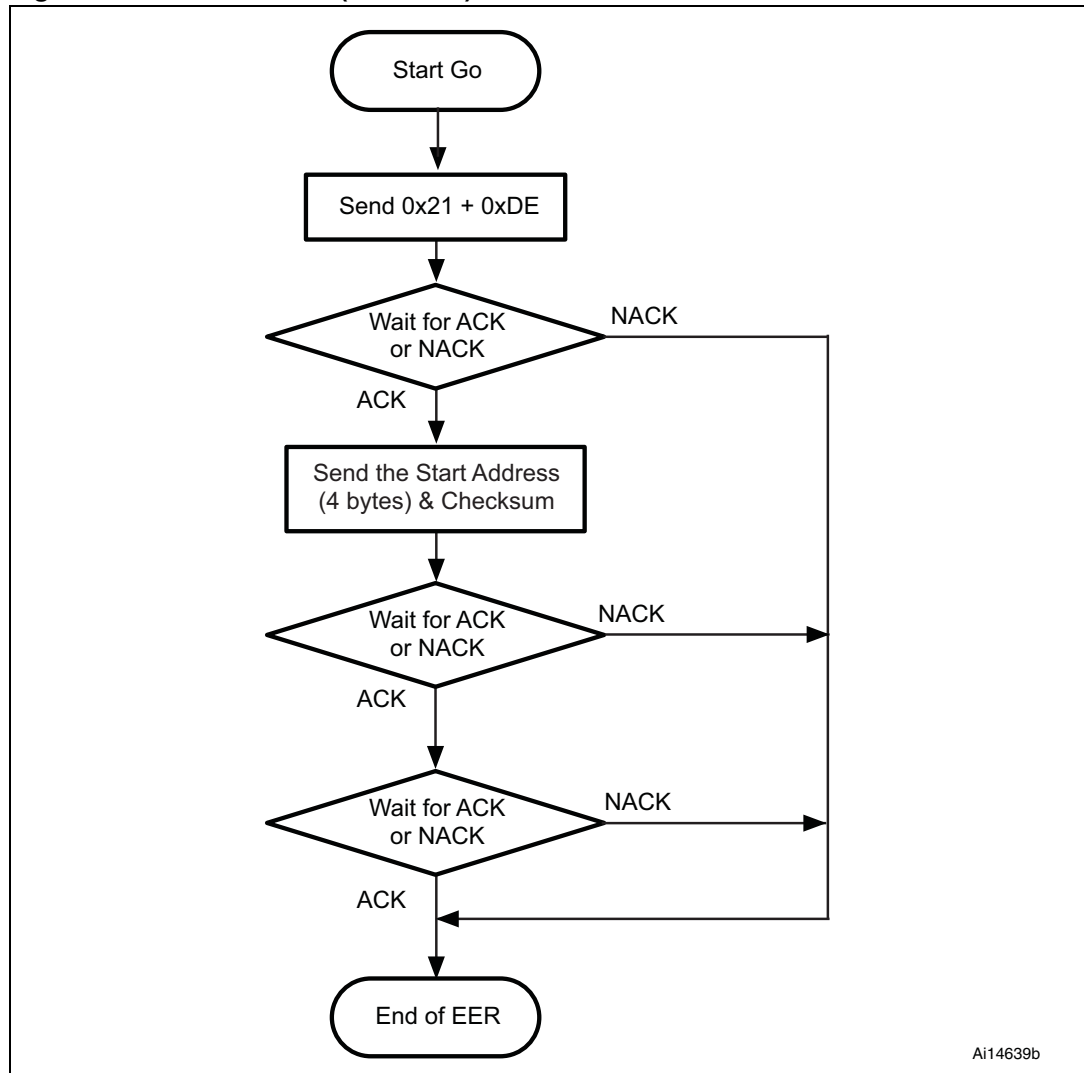
When the address is valid and the checksum is correct, the bootloader firmware performs the following:

- It initializes the registers of the peripherals used by the bootloader to their default reset values.
- It initializes the user application's main stack pointer.
- It jumps to the memory location programmed in the received 'address + 4' (which corresponds to the address of the application's reset handler).

For example, if the received address is 0x0800 0000, the bootloader will jump to the memory location programmed at address 0x0800 0004.

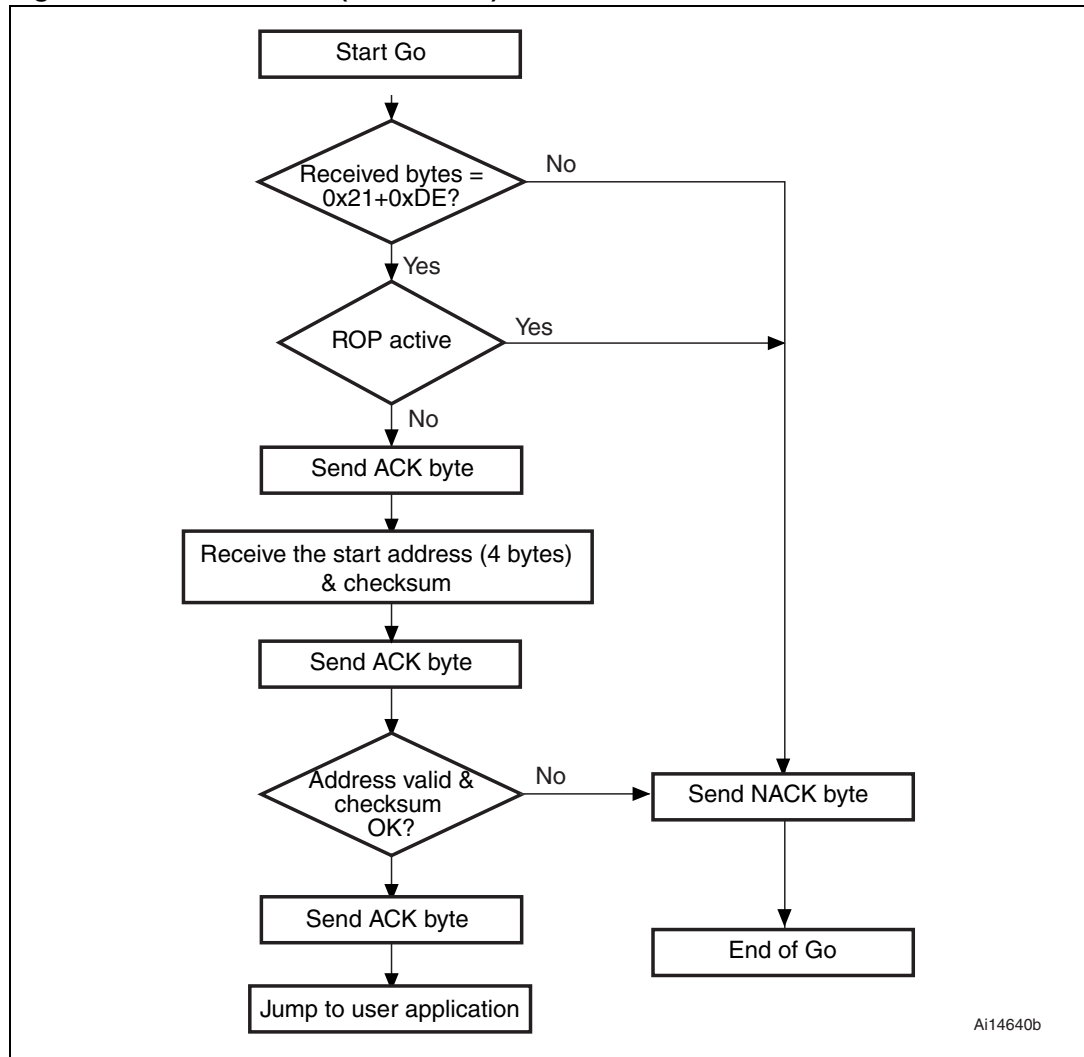
In general, the host should send the base address where the application to jump to is programmed.

Figure 19. Go command (host side)



- Note:
- 1 Valid addresses for the GO command are in RAM or Flash memory. All other addresses are considered not valid and are NACKed by the device.
 - 2 When an application is loaded into RAM and then a jump is made to it, the program must be configured to run with an offset to avoid overlapping with the first RAM memory used by the bootloader firmware.
 - 3 The jump to the application works only if the user application correctly sets the vector table to point to the application address.

Figure 20. Go command (device side)



The host sends the following bytes to the STM32 device:

Byte 1: 0x21

Byte 2: 0xDE

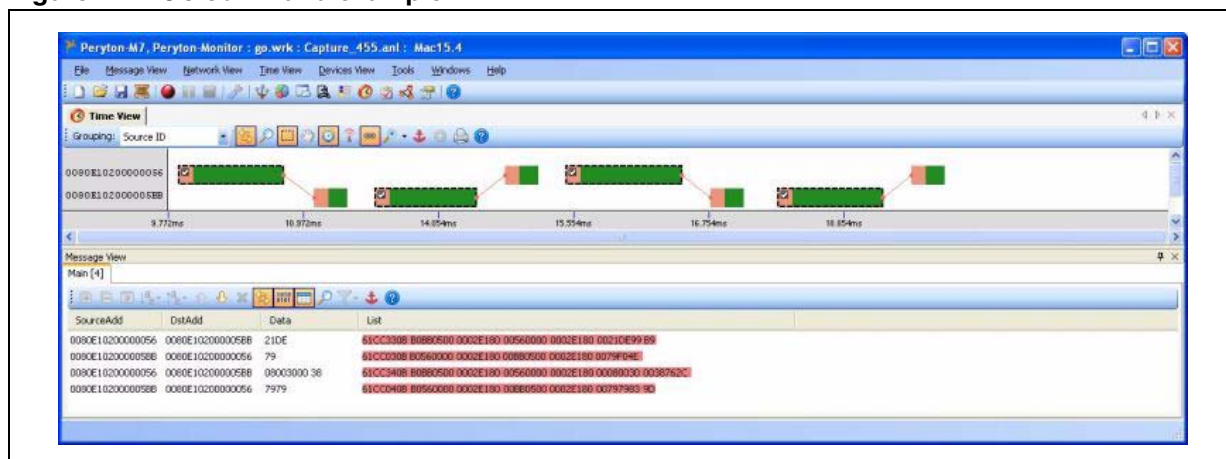
Wait for ACK

Bytes 3 to 6: Start address (Byte 3 is the MSB and Byte 6 is the LSB)

Byte 7: Checksum (XOR value of Bytes 3 to 6)

The second and third ACK/NACKs are sent by the device within the same 802.15.4 packet while the first is sent independently.

Figure 21. Go command example



3.6 WRITE MEMORY command

The WRITE MEMORY command writes data to any valid memory address (see note below) of RAM, Flash memory or Option byte area.

When the bootloader receives the WRITE MEMORY command, it transmits the ACK byte to the application. After sending the ACK byte, the bootloader waits for an address (4 bytes, where Byte 1 is the address MSB and Byte 4 is the LSB) and a checksum byte, it then checks the received address. For the Option byte area, the start address must be the base address of the Option byte area (see note) to prevent unwanted writing to this area.

Note: 1 Write operations to Flash memory/SRAM must be word (32-bit) aligned and data should be in multiples of four bytes. If less data are written, the remaining bytes should be filled by 0xFF.

If the received address is valid and the checksum is correct, the bootloader transmits an ACK byte; otherwise, it transmits a NACK byte and aborts the command. When the address is valid and the checksum is correct, the bootloader:

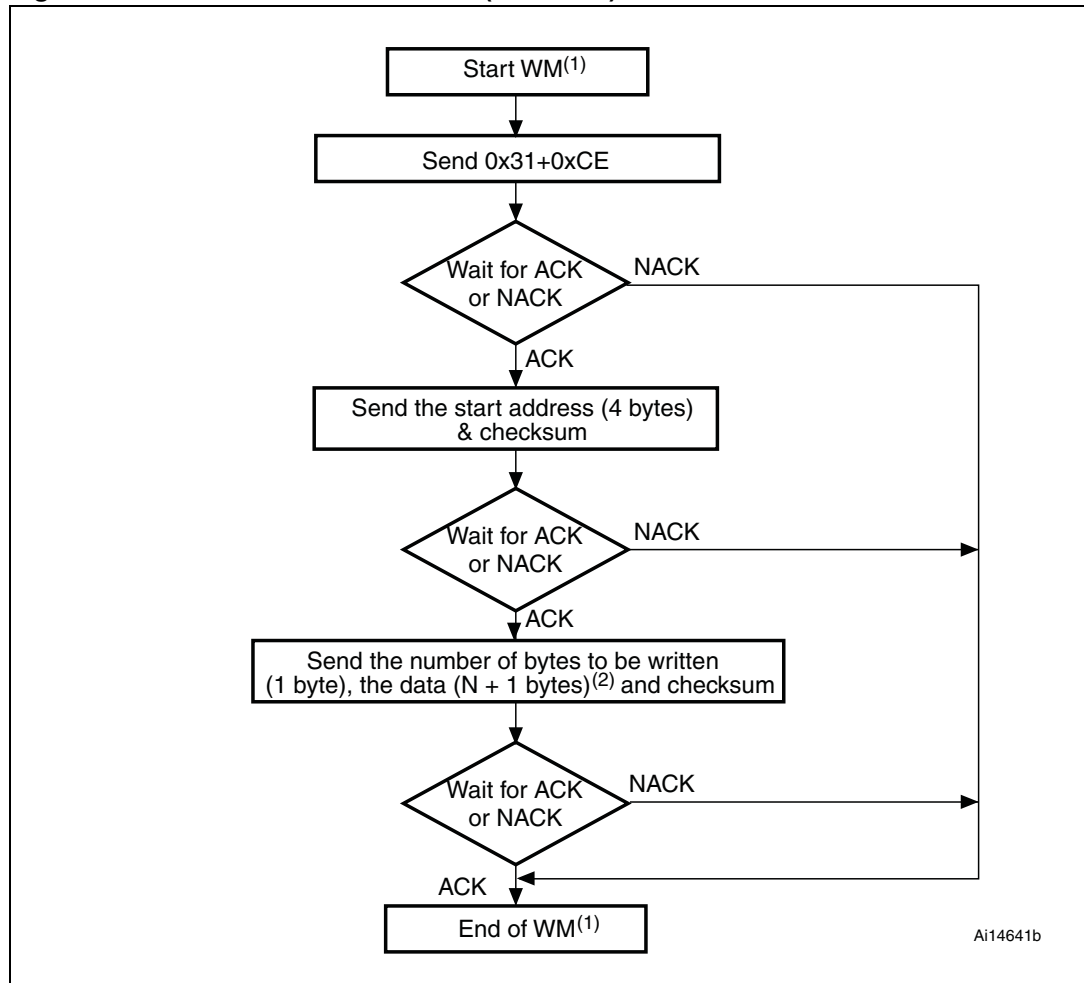
- receives a byte (N) containing the number of data bytes to be received,
- receives the user data ((N + 1) bytes) and the checksum (XOR of N and of all data bytes),
- programs the user data to memory starting from the received address,
- at the end of the command, if the write operation was successful, the bootloader transmits the ACK byte; otherwise it transmits a NACK byte to the application and aborts the command.

The maximum length of the block to be written for STM32W devices is 96 bytes.

If the WRITE MEMORY command is issued to the Option byte area, all options are erased before writing the new values.

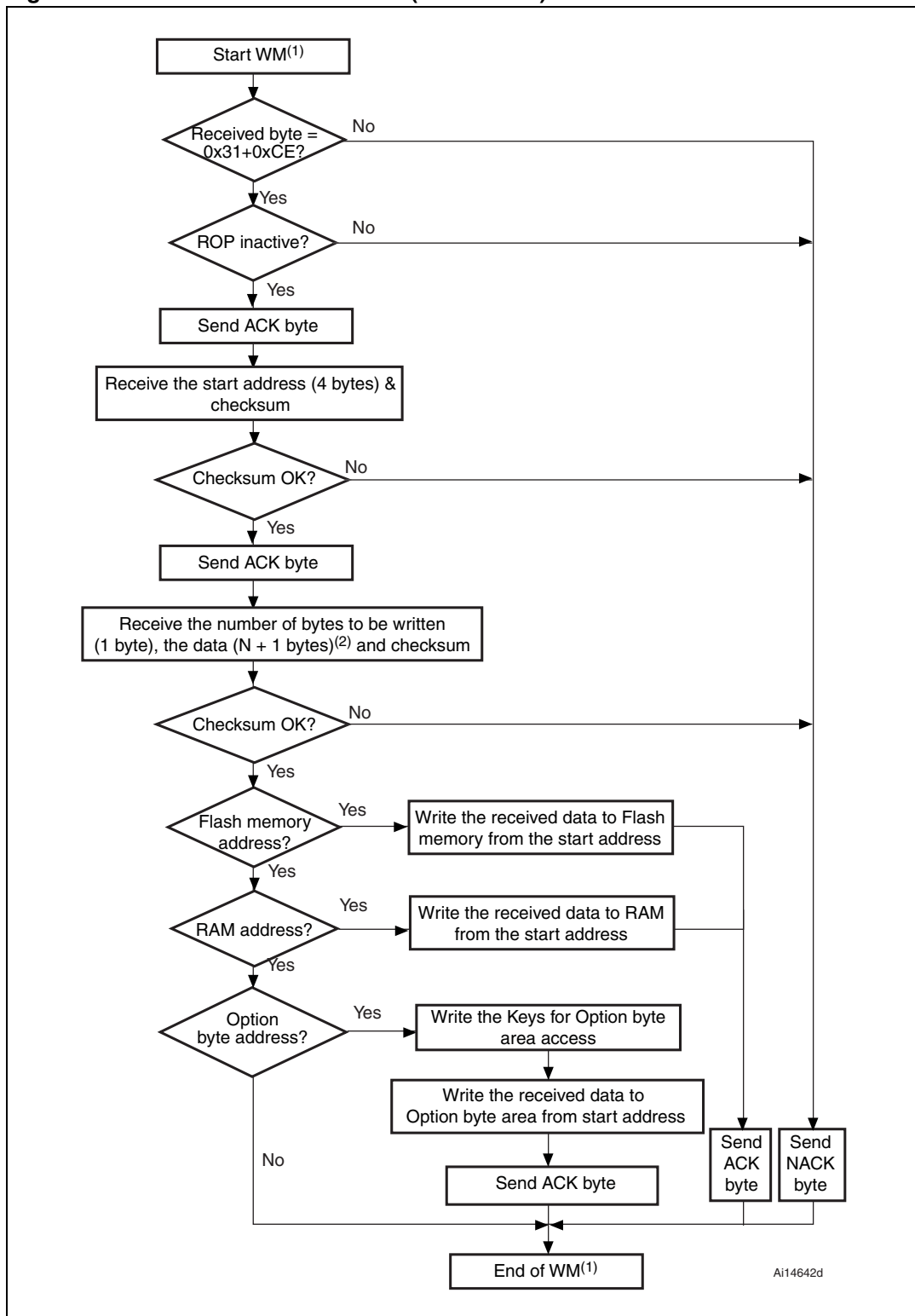
- Note:**
- 1 When writing to the RAM, you should take care not to overlap the first RAM memory used by the bootloader firmware.
 - 2 No error is returned when performing write operations on write-protected sectors.
 - 3 No error is returned when the start address is invalid.

Figure 22. WRITE MEMORY command (host side)



- 1. WM = WRITE MEMORY command.
- 2. N+1 should always be a multiple of 4.

Figure 23. WRITE MEMORY command (device side)

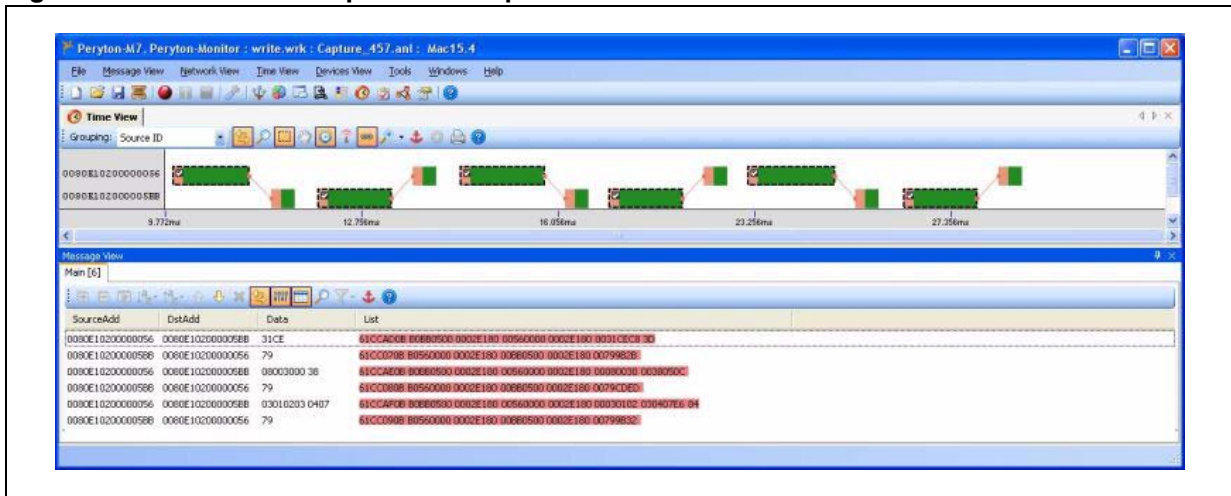


- 1. WM = WRITE MEMORY command.
- 2. N+1 should always be a multiple of 4.

The host sends the following bytes to the STM32W device:

- Byte 1: 0x31
- Byte 2: 0xCE
- Wait for ACK*
- Bytes 3 to 6: Start address (Byte 3 is the MSB and Byte 6 is the LSB)
- Byte 7: Checksum (XOR value of Bytes 3 to 6)
- Wait for ACK*
- Byte 8: Number of bytes to be received ($0 < N \leq 95$)
N + 1 data bytes (maximum of 96 bytes)
- Byte 9: Checksum (XOR value of N, N+1 data bytes)

Figure 24. WRITE MEMORY packet example



3.7 ERASE MEMORY command

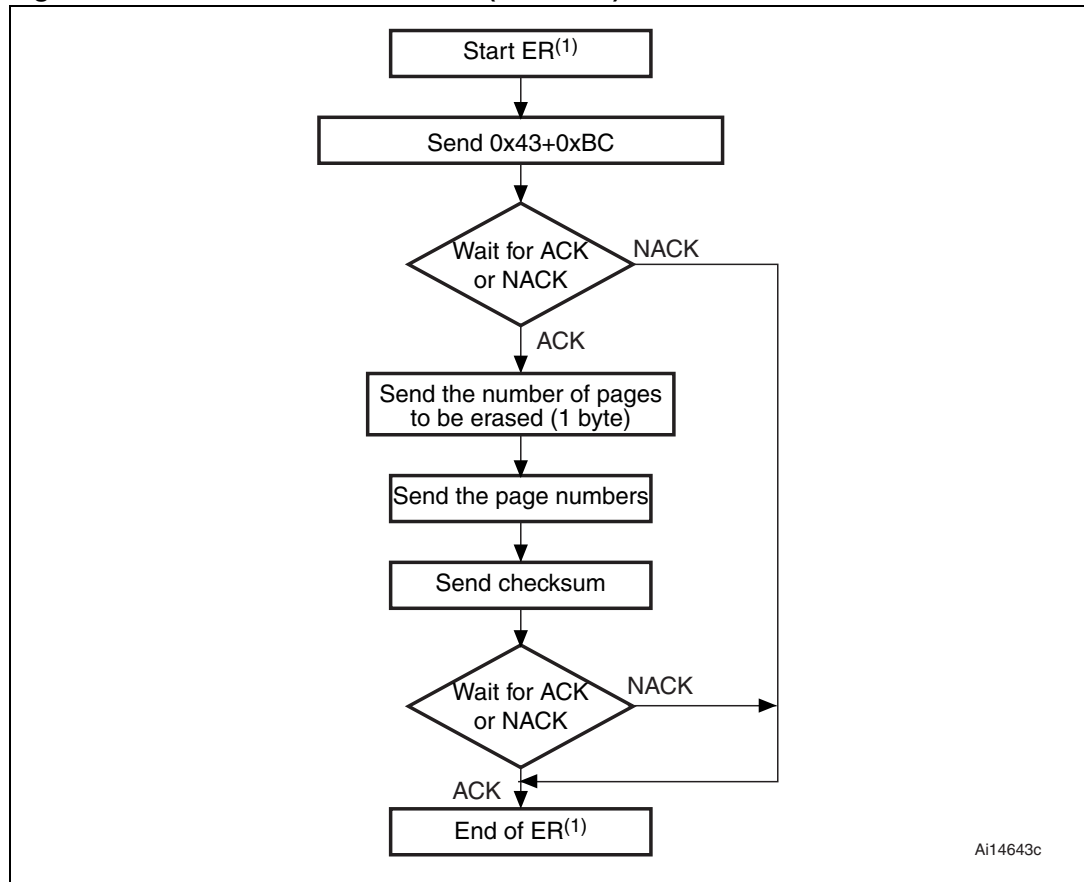
The ERASE MEMORY command enables the host to erase Flash memory pages. When the bootloader receives the ERASE MEMORY command, it transmits the ACK byte to the host. After sending the ACK byte, the bootloader receives one byte (the number of pages to be erased), the Flash memory page codes and a checksum byte. If the checksum is correct, the bootloader erases the memory and sends an ACK byte to the host; otherwise, it sends a NACK byte to the host and the command is aborted.

ERASE MEMORY command specifications:

- The bootloader receives one byte containing N, the number of pages to be erased – 1. (For $0 \leq N \leq 115$, N + 1 pages are erased.)
- The bootloader receives (N + 1) bytes, each byte containing a page number.

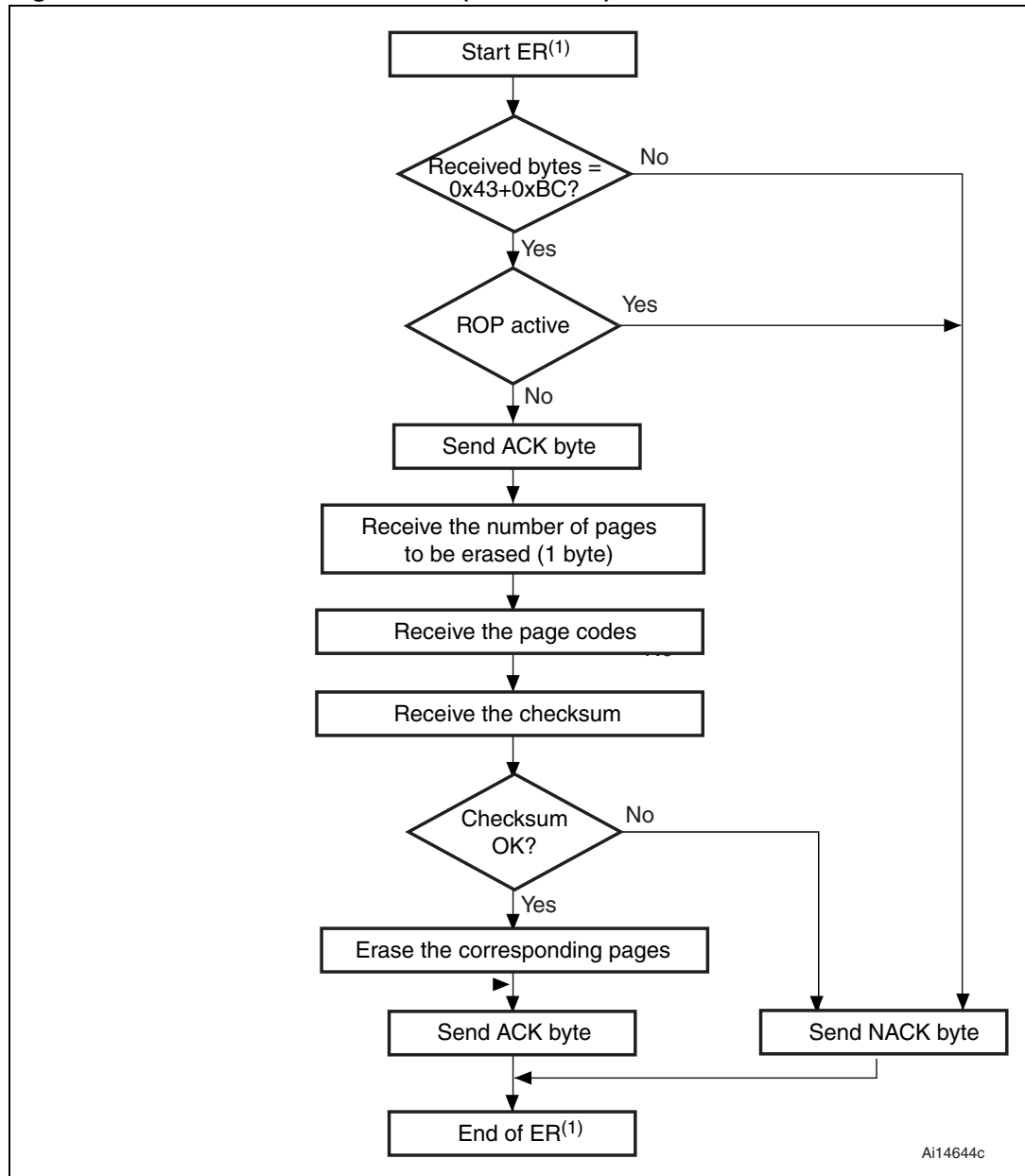
Note: No error is returned when performing erase operations on write-protected sectors.

Figure 25. ERASE MEMORY command (host side)



1. ER = ERASE MEMORY command.

Figure 26. ERASE MEMORY command (device side)



1. ER = ERASE MEMORY command.

The host sends bytes to the STM32 as follows:

Byte 1: 0x43

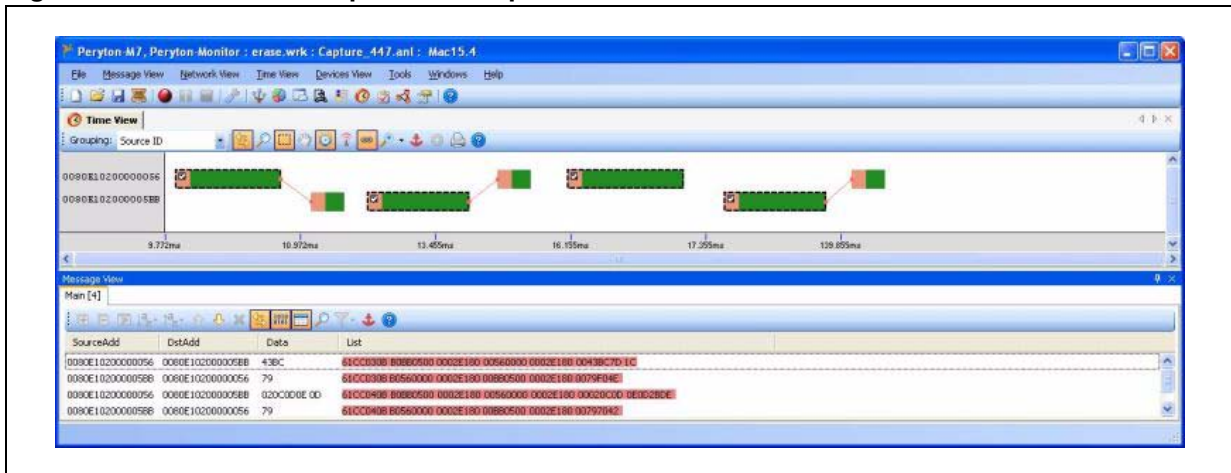
Byte 2: 0xBC

Wait for ACK

Byte 3: Number of pages to be erased – 1
($0 \leq N \leq$ maximum number of pages)

Byte 4: N + 1 bytes (page numbers)
and then checksum (XOR value of N, N+1 bytes)

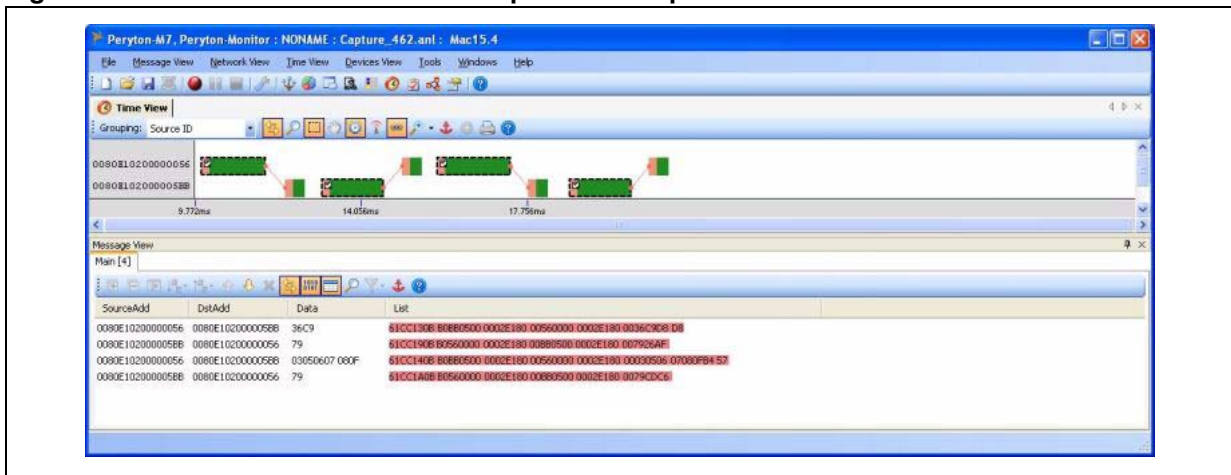
Figure 27. ERASE MEMORY packet example



3.8 WRITE INCREMENTAL MEMORY command

The WRITE INCREMENTAL MEMORY command has the same purpose of the WRITE MEMORY command but can be used to save some bandwidth by avoiding having to transmit the write address each time we wish to write a block. It only works when writing to consecutive memory blocks. The device has a write pointer as an initial memory address for incremental write operations. When the command is received, the device writes the command data in memory and then increments the pointer by an amount of bytes equal to the write data length. The write pointer update is also affected by the ordinary write command after which the new address offset is the sum of the write address (provided as command parameter) and the write data block length. The write pointer is initially set to the base of the application address (0x08003000).

Figure 28. WRITE INCREMENTAL MEMORY packet example



4 Revision history

Table 2. Document revision history

Date	Revision	Changes
23-Aug-2010	1	Initial release.
04-Mar-2011	2	Updated STM32W website URL and added support for STM32W108xx kits.

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